A Behavioural Lens on Transportation Systems:

The Psychology of Commuter Behaviour and Transportation Choices

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Table of Contents

List of Figures

List of Tables

Executive Summary

Transportation is a significant consideration for the Regional Municipality of York Region ("the Region") as York Region's population is expected to rise to 1.79 million by 2041. Given the expected growth, it is important for the Region to continue focusing on shifting travel behaviour from single occupant vehicle driving to transit usage and other forms of active transportation. This paper examines how the characteristics of a travel path and information can affect travel behaviour. It also examines how connected and autonomous vehicle technologies can influence driving and travel behaviour. Several broad themes arose from the literature review and observational studies conducted (refer to Appendix 4 for a summary of guidelines):

- The Region should further place priority on infrastructure that makes transit and active transportation seamless, convenient, and safe.
- Physical travel is goal-oriented activity and commuters should feel they are always making progress. Unexpected delays and general wait times should be managed by the expanded use of real-time information.
- To discourage single occupant vehicle driving, the Region should consider regulating the pricing and amount of parking available. The Region should consider further investing in commuter parking with access to HOV/bus-only lanes (when possible). The pricing strategy should incentivize residents to use transit and active transportation and could be a part of a larger rewards system.
- Driving behaviour is different with an automated, driverless vehicle and changes to the transportation infrastructure may be needed to accommodate varying types of automated vehicles.
- Connected and automated vehicle technologies could be used by the Region to shift travel and driver behaviour by better facilitating first and last mile travel for transit, and further improving road safety and traffic management.

1. Introduction

York Region is a significant part of the Greater Toronto Area (GTA) with 1.2 million people calling the area home in 2015 (Regional Municipality of York, 2016). Transportation is a significant consideration for the Regional Municipality of York ("the Region") as over 492,000 trips originate in York Region every morning, with the average work trip being 21 kilometres (Data Management Group: University of Toronto, 2011).

Public transit usage within York Region has risen from 8.9% (2001) to 12.5% (2011). Despite this growth, 86% of people drive to work, and only 1% cycle to the office (Regional Municipality of York, 2016). These numbers will gain more attention in the coming years as the population continues to grow, with the number of York Region inhabitants expected to rise to 1.79 million by 2041 and 900,000 jobs in the area. Given the expected population growth, it is important for the Region to continue its efforts in shifting the commuter's travel behaviour from single occupant vehicle driving to using public transit and active transportation modes.

With a population (and employment) density below 0.5 per square kilometre (50 per hectare) for most of York Region (Regional Municipality of York, 2016), it is understandable that there are limits to improving the service frequencies for the YRT/Viva public transit service. Yet there are interventions that can be implemented within the Region's infrastructure and present-day YRT/Viva transit service that can encourage commuters to shift their travel behaviour.

While shifting travel behaviour is important, automobiles will arguably, still be a significant part of the traffic ecosystem. As automakers implement connected and automated vehicle technologies into new vehicles, it is important to understand the implications of these emerging technologies on travel and driving behaviour. Much discussion in the media has focussed on the benefits of connected and autonomous vehicles on enhancing mobility and reducing accidents due to human error. Much less attention has been paid to the fact that consumer adoption of these vehicles will be gradual and the impact this will have on road users. According to an estimate by the Institute of Electrical and Electronics Engineers (IEEE), autonomous vehicles will account for 75% of the vehicles on the road by 2040 (IEEE, 2012). Changes to the transportation infrastructure will be needed to accommodate all forms of vehicles - traditional, connected, highly automated, and fully automated. Also, connected and automated vehicle technologies could be used by the Region to shift travel and driver behaviour and further improve road safety.

The paper is broadly divided into three sections, with the first two sections connecting several behavioural insights to specific features of public transit and active transportation. The first section covers the impact of various characteristics of a travel pathway on a commuter's travel decision. The second section focuses on the presentation of information regarding transportation choices and its influence on a commuter before or while travelling. The section details the benefits of providing the commuter with real-time information on possible choices and cites best practice examples where specific interventions have shown a quantifiable change to public transit usage. To do this, a small observational study was undertaken for this research report in order to identify firsthand some of the last mile frictions commuters experience while travelling on the YRT/Viva transit system and provide some direction for the literature review that was to be undertaken for this report. Four university students were recruited and asked to use the YRT/Viva system to make a round trip to and from a randomly chosen destination within York Region, and use the YRT/Viva trip planner to plan their travel route. Participants were then asked to document their experience and a focus group was conducted to further understand their travel experience. The students were regular users of transit within Toronto, and two students have used the YRT/Viva system in the past. The insights garnered from the observational study informed the direction of the literature review that was conducted for this report, which examined some of the work published in the research areas of transportation choices, human factors, and behavioural science.

The last section focuses on connected and autonomous vehicle technologies and their influence on driving and travel behaviour. The first portion of this section reviews some of the benefits connected technology and autonomous vehicle offers. The latter portion reviews insights from research from fields of human factors and behavioural science to understand how automated vehicles affect driver behaviour and interactions between road users. Guidelines are provided to inform future initiatives on using connected technologies to improve traffic management and integrating autonomous vehicles into the traffic system.

2. The Impact of Path Characteristics on Travel Choices

Physical travel is inherently a goal-oriented exercise where a person moves from starting point (A) to an ending point (B). Apart from obvious determinants such as cost, time (Lovelock, 1975), and reliability of the transport mode (Carrel, Halvorsen & Walker, 2013), travel choices are also impacted by "path characteristics" (Soman & Shi, 2003). The term "path characteristics" refers to the physical, perceptual, and time-related features associated with the door-to-door travel path including:

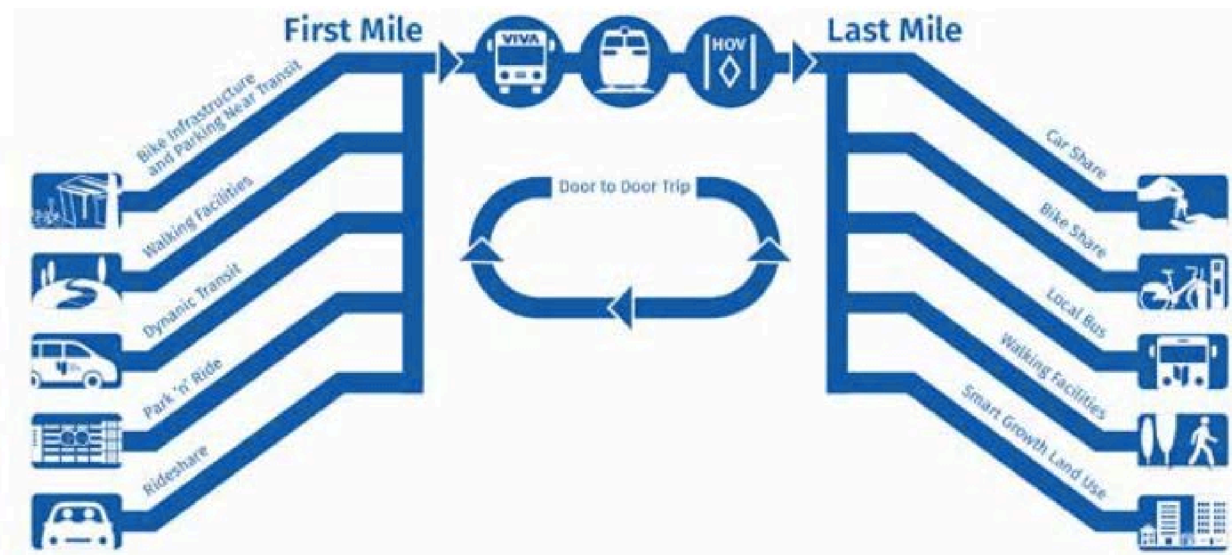
- The physical path (e.g. road/walking/bike paths) associated with the travel mode chosen.
- How time during the journey is spent. While total travel time is an important factor in travel choice, delays, wait times, and the position of those delays and wait times along the travel path can also influence travel choice.
- The physical environment surrounding the travel path.

To understand the role of these features, consider an individual who needs to travel to and from work in York Region. Several travel options are available to this person, with each option having different path characteristics. All of these travel modes succeed in bringing the individual from point A to point B while the path characteristics of each travel mode can be very different:

1) Driving - for most of the journey, an individual is travelling within the vehicle and the physical environment is defined by the vehicle interior. Idle times and delays due to traffic are generally experienced within the vehicle. Sidewalks and other walking facilities are used for a small amount of walking required to travel from the parking lot to the destination.
2) Using a ridesharing or taxi service– while it potentially shares many of the same path characteristics as driving, additional wait times may be associated with this travel mode. Commuters may experience long or short wait times depending how long it takes to hail a taxi service. For ridesharing or carpooling, the physical travel path may change (compared to driving alone) as other passengers may need to be picked up.
3) Cycling – while the cyclist and driver potentially share the same road, the physical environment is quite different. Unlike a driver, a cyclist's environment is not enclosed by a car interior and they are more exposed to the elements. Furthermore, cyclists may have to share the road with vehicles if they are using a multi-use road.
4) Walking – while the physical path may be similar to driving for short trips, pedestrians access a different part of the road infrastructure since they use the city's streets and boulevards.

5) A multi-modal approach – here, the commuter uses a variety of transportation modes such as walking or biking, and then taking public transit, to move from one place to another. A well - known issue that may arise with the multi-modal approach is the first and last mile problem. This refers to the situation where commuters may have difficulty accessing public transit hubs because it is physically too far to walk to a nearby transit station or parking infrastructure is not available. It can also refer to psychological or safety factors where commuters may view travelling to a public transit network too much of a hassle or unsafe.

Figure 1. Illustration of various door-to-door trip scenarios using multiple modes of transportation



(Source: The Regional Municipality of York Transportation Master Plan, 2016)

Research has shown that several elements in the travel path can affect a commuter's experience and influence travel choice. The following focuses on some of these factors and its influence on the commuter's travel experience. Focus is placed on the transition from one mode of transport to another (or transferring between vehicles if it is within the same travel mode) as it is an important factor in transportation choice.

Specifically, the challenges discussed in this section are:

- *Hassle factors:* issues that can increase/decrease the mental effort required from a commuter. For example, an intuitive, easily understood navigation system can help the commuter easily plan their journey and transfer between public transit networks or various buses within the network.
- *Perceived progress towards a destination*: when a commuter's perception or movement towards their destination is lowered by the amount of idle time present.

- *Physical characteristics of the travel path:* the physical environment can influence perceptions of personal safety and comfort and can be hampered by a lack of infrastructure, such as a lack of well-lit transit stops or physical protection for cyclists.

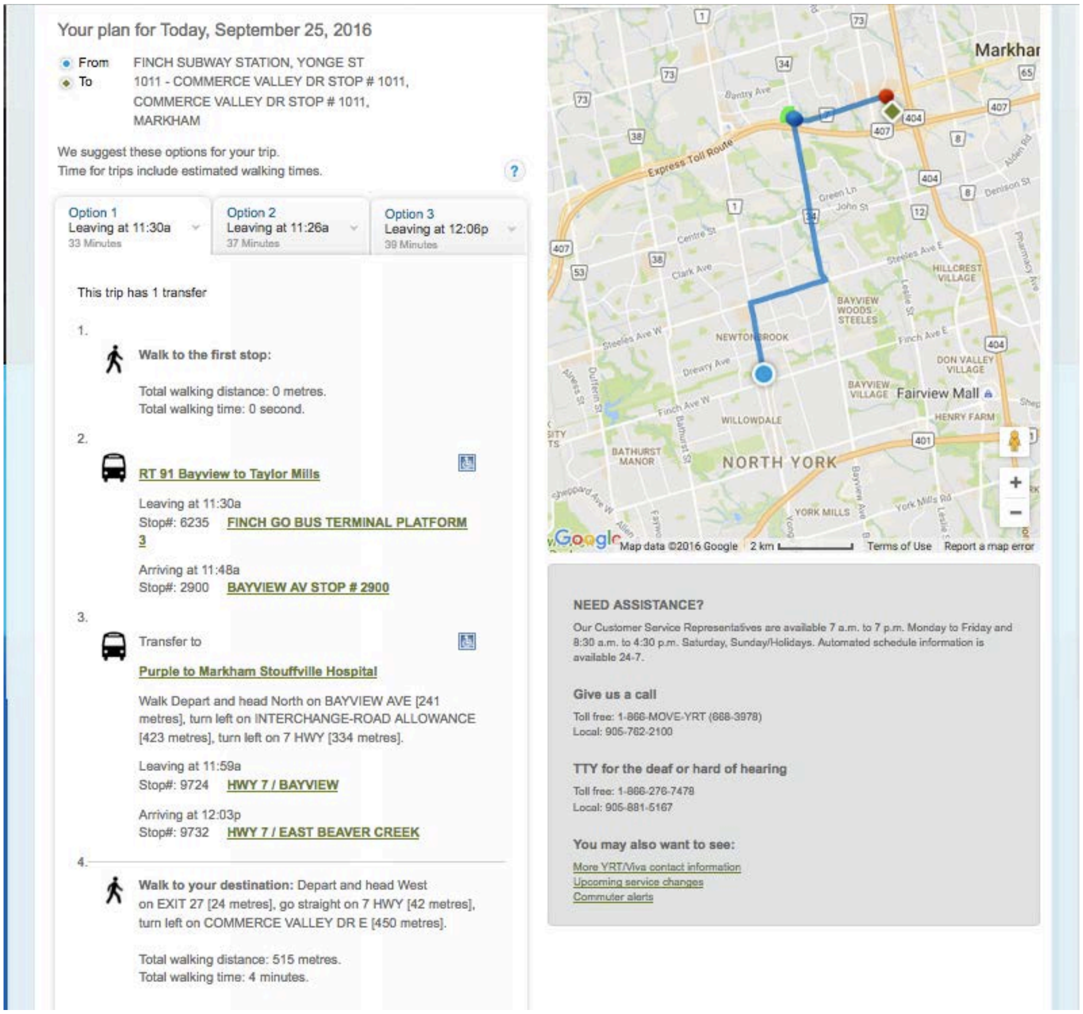
2.1 Hassle factors – Mental effort and Commuter Orientation

Behavioural research suggests that people are cognitive misers and prefer choices that require less mental effort (Garbarino & Edell, 1997). This insight relates to the negative emotions individuals generate each time they make a mental effort – as the required mental effort increases so does the generated negative emotion. Consequently, people try to minimize the negative emotions by moving away from choices that require higher mental effort (i.e., more "hassle"). This insight is useful when considering the need for YRT/Viva commuters to be well oriented when they are on the move. This is also an important insight for new YRT/Viva commuters who are unfamiliar with the transit system. These commuters include those who are potentially shifting from driving to using transit, or who have recently moved to York Region. New residents are an important demographic as immigration is expected to be a large source of York Region's population growth (Regional Municipality of York, 2016). If the mental effort required to navigate the YRT/Viva system is high, the probability of the person using YRT/Viva again reduces further as they associate a high negative emotion with taking the public transit compared to other modes of transport.

The observational study conducted during this research for YRT/Viva found a lack of navigation aids. Specifically items include:

- Lack of bus signage directing commuters to the YRT/Viva bus platform at large transit hubs like Finch Station. This can frustrate commuters who are new to YRT/Viva services and are transferring from other transit lines such as the TTC.
- Many YRT/Viva bus stops only provide the bus stop number and the YRT/Viva phone number which could cause confusion for new commuters. Little information is available about which bus stops to go to in order to access various bus routes (refer to Figures 2 and 3 for an example). In addition, the bus signage does not always advertise that real-time information on bus arrivals can be accessed online or by calling the phone number that is posted on the bus signage.

Figure 2. Screenshot of a travel route used in the observational study conducted for this report



Participant was asked to travel from Finch Station to 1 Commerce Valley Drive E. Note that the route requires a transfer from route 91 (bus stop #2900) to Viva Purple (bus stop #9724).
(Source: YRT/Viva Trip Planner)

Figure 3. Travel path required to transfer from route #91 to Viva Purple at Bayview/Highway 7

Figure 3a. Area surrounding bus stop #2900 that services bus route #91. No clear signage indicated how to get to other bus routes such as the Viva Purple which can confuse commuters during their commute.

Figure 3b. Map of area surrounding bus stops #2900 and #9724. Commuters need to be aware that accessing the Viva Purple line at stop #9724 requires going down a flight of stairs through a YRT/Viva connecting hub. While stairs to the YRT/Viva station are very close to bus stop #2900, instructions on the YRT/Viva trip planner were confusing and did not specify using the YRT/Viva connecting hub.

(Image source: Google Maps)

YRT/Viva can derive significant benefit from including features of a good wayfinding system such as user-centric, informative, and intuitive directions to bus stops and popular destinations.

There are several best practice examples in this regard, with London (UK) and Vancouver (Canada) among the growing number of cities focused on ensuring commuters (including those who use transit and active transportation) are well-oriented. London also introduced clear maps that provide people with estimations of cycling times from various locations (Wiltshire, 2014).

Figure 4. Maps by Transport for London indicating walking/cycling durations

(Source: Wiltshire Walking & Cycling Wayfinding-Outline Strategy Report for Wiltshire Council, 2014)

In Vancouver, improvements to bus signage took place in 2011 with the goal of facilitating wayfinding (Willis, 2011) along with installing new pedestrian maps and other features. While there are no specific numbers on the impact of the improved signage, 82% of people using the new navigation system said they were more likely to walk between places because of the maps (City of Vancouver, 2014). While York Region's demographics and development differ from these two cities, the ideas behind the specific actions are worth considering for YRT/Viva to improve the transit ridership experience and increase active transportation.

2.2 Perceived Progress towards a Destination

Research indicates that individuals prefer situations in which they appear to be constantly moving towards their destination (Deci and Ryan, 1985). This is consistent with research indicating that when people find themselves in a situation where they are focused on reaching a specific destination, they consciously make choices that aid them in reaching this goal (Locke & Latham, 1990). This research is directly relevant to transportation because of its focus on how people react to different path characteristics, especially those that hinder progress and are seen as obstacles. One common obstacle

is the presence of idle time (including delays and wait times linked to transfers) during a journey.
In general, journeys with idle times are likely to be seen as inefficient and associated with low perceived progress (Friman, Edvardsson, & Gärling, 2001). Commuters will be motivated to maximize progress by choosing services that have less idle time. Wait times are also often overestimated when individuals are asked to evaluate an experience retrospectively (Soman, 2015). Further, research has also shown that an individual's satisfaction with a service is influenced by waiting time and has an impact on the satisfaction-loyalty relationship. (Bielin & Demoulin, 2007). Give these two factors, the Region may want to be especially attentive towards the idle time associated with journeys on its public transportation network.

For a transit rider, there are two different types of idle times – wait times and unexpected delays. Unexpected delays usually result from the transportation provider not delivering on its schedule (and this could be due a multitude of reasons such as traffic and car accidents). Wait times on the other hand are built into a commuter's travel plan and is time that a commuter expects to spend idling at a bus stop, in traffic, or finding parking. While it is known that commuters want to minimize wait times, the location of the wait time within the journey can affect transportation choice.

1) *Comparing travel paths between driving and transit and the placement of "wait" time from parking*

Assuming two paths have the same total travel time, research by Soman and Shi has shown that individuals prefer travel paths that have wait times occurring farther away from their origin point (Soman & Shi, 2003). People want to make the maximum amount of progress towards their specific targets and will try to move wait times as far away from the point of origin as possible.

Consider the options available for traveling to the Markham area (e.g. East Beaver Creek/Commerce Valley Drive) to and from work, from the Newmarket area (Highway 404/Davis Drive). Assuming a commuter wants to depart from Newmarket around 7:30 am for example, he/she may consider two travel options:

1) Travel directly by car or,
2) Travel to the Newmarket carpool lot and take the YRT/Viva Express Shuttle (Route 320 – Newmarket/Beaver Creek Express).

Assuming both routes take approximately the same time, drivers may opt to travel directly by car rather than commute via YRT/Viva because they perceive they are more progress is made when driving. The decision to either travel by car, or stop and take an express bus occurs close to the Highway 404 entrance by Davis Drive. Table 1 below lists the peak half hour time slots for York Region car drivers and passengers. For the Highway 404/Davis Drive highway entrance, traffic may not always be problematic as the peak half hour for Newmarket is between 1700-1729. Given that Highway 404 traffic is not always problematic at this highway entrance, drivers may not feel the need to stop and change their travel mode. Commuting via YRT/Viva requires the driver to “idle” earlier in their travel as they need to stop, find parking, and possibly wait to board the express shuttle. Since the commuter wants to make as much progress as possible, stopping and taking a YRT/Viva express shuttle may not seem attractive compared to driving. Furthermore, driving from the Highway 404/Davis Drive area to the Markham/Richmond Hill region can be completed within 28 min – 50 min, depending on traffic (see Figure 5c.). This is within the reasonable amount of time a driver would spend commuting via car (Regional Municipality of York, 2016).

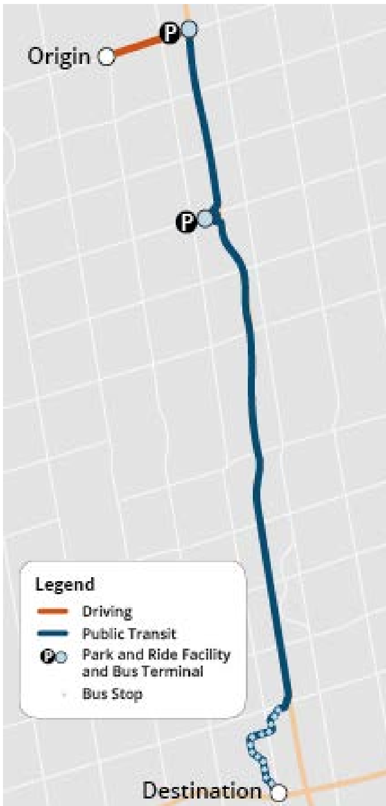
Idle time due to traffic could be experienced further south such as in the Richmond Hill and Markham regions, where the peak half hour time is between 8:00-8:29. But the commuter has already made the choice to travel by car. Also, YRT/Viva express buses do not have a dedicated HOV/bus-only lane along Highway 404. A driver may perceive that there is no added benefit to using an express shuttle if it is also stuck in traffic with regular vehicles and makes the same amount of progress as a car.

Table 1. Peak half hour time slots for York Region car drivers and passengers

Municipality	Peak Half Hour
Georgina	1700-1729
East Gwillimbury	1700-1729
Newmarket	1700-1729
Aurora	800-829
Richmond Hill	800-829
Whitchurch-Stouffville	1700-1729
Markham	800-829
King	1600-1629
Vaughan	800-829

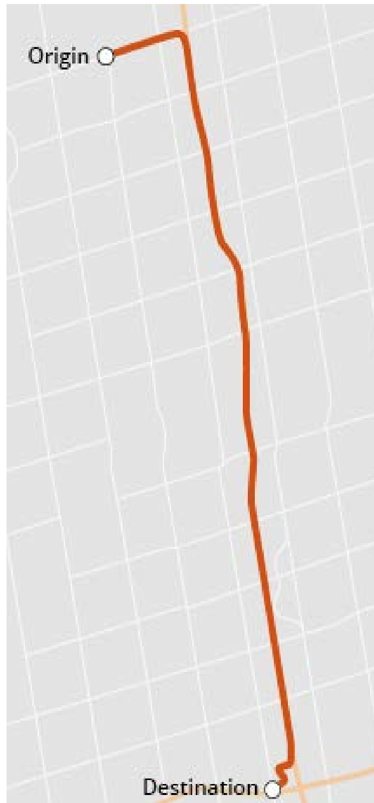
(Source: Regional Municipality of York)

Figure 5. A comparison between a car commute and an express bus commute from Davis Drive/ Highway 404 to AMD corporate office (1 Commerce Valley Drive East. Markham)



TRANSIT

Figure 5a. A visual representation of bus route #320. For a driver planning to use the commuter lot and take route #320, he/she will need to make a stop at the carpool lot by Highway 404/Davis Drive, which occurs early in the commute.



DRIVING

Figure 5b. A visual representation of driving from Highway 404/Davis Drive area to Markham. Research by Soman and Shi suggests that a driver might be tempted to continue driving if there is low traffic volume at this highway entrance because they want to continually make progress. The driver does not need to “idle” their journey early on by stopping to find parking and taking a YRT/Viva bus, but can continue to make progress towards their destination. Wait time due to traffic volume are experienced further down the journey closer to Richmond Hill (refer to figure 5c).

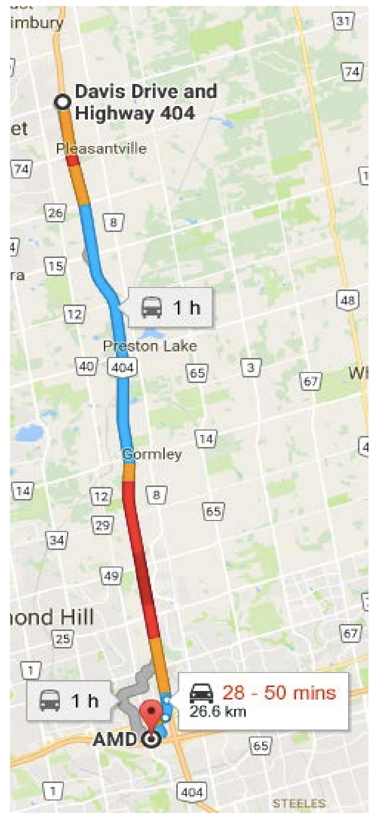


Figure 5c. A screenshot of traffic volume (from Google Maps) for a journey from the Highway 404/ Davis Drive area on a weekday at 7:30 am. Traffic volume is most problematic further south of Newmarket, closer to Richmond Hill and Markham.

Locating commuter parking lots and express shuttles (servicing the commuter lots) by HOV/bus-only lanes may help commuters feel that it is worthwhile to stop and park to use transit. In an interview with Eric Miller, a professor in Civil Engineering at the University of Toronto and Director of the University of Toronto Transportation Research Institute, it was noted that the implementation of HOV lanes helped increase ridership with the TTC (Miller E., personal communication, September 29, 2016). Toronto residents perceived transit to be the more convenient choice as buses were given more priority over vehicles and seemed to be making more progress in traffic than driving.

2) The effect of unexpected delays when using public transit

When the commuter has chosen to use public transit, unexpected delays due to traffic, operational issues, or emergencies are important issue to manage. Research in behavioural science note that individuals are risk averse when it comes to losses (Soman, 2015). Unexpected delays are viewed as a loss by the commuter, as it adds an additional time cost to their travel plan that they did not budget for. Also, commuters are not always certain about the amount of time they need to wait, which makes the delay less palatable (Soman, 2015). In particular, unexpected delays at transfer stops are an important factor for transit commuters. A survey conducted by researchers at the University of California, Berkeley noted that long delays at transfer stops were found to be especially frustrating for commuters and could potentially reduce transit usage. Commuters were more likely to reduce transit use if they had experienced long unexpected delays at a transfer stop rather than at their origin stop (Carrel et al., 2013).

Unexpected delays at a transfer stop can make the service seem unreliable not only because it makes the travel time longer, but it can also cause the commuter to miss their connecting bus. Transfer delays become especially critical if bus services are not frequent (more than ten minutes between services). The frustration with missed transfers was also expressed in the focus group discussion conducted for this research study. Participants travelling in York Region highlighted their frustration with long waits for the next public transit vehicle if they missed one by a short amount of time. Commuters are more patient with delays if they are presented with information regarding the nature of the unexpected delay – whether it was due to an accident or unavoidable traffic (Carrel et al., 2013) - and if they know approximately how long they need to wait. The New York Bus Time program provides information on when delays are occurring in the transit system (Brakewood, Macfarlane, & Watkins, 2015). This is one example of a solution YRT/Viva may want to examine in addition to broadening the current RideNow service. Easy access to real-time information can further ease friction arising from commuters who experience unexpected delays during travel.

2.3 Physical Environment Surrounding the Travel path and The Effect on The Commuter

Recent research in behavioural decision-making suggests that an individual's assessment of an experience is made up of a sequence of events (Carmon & Kahneman, 1996). Assessments of experiences is not significantly influenced by the actual duration of the experience, but by the highlight (i.e., the happiest moment) of the experience and how the experience ends (Fredrickson & Kahneman, 1993; Kahneman, Fredrickson, Schreiber, & Redelmeier, 1993). In the context of public transportation and path characteristics, commuters may opt to drive instead of taking public transit or cycle because the experience at the end of the transit journey or bike ride leaves the commuter frustrated or dissatisfied compared to driving. This could be due to several factors:

1) Walking facilities close to a commuter's home or destination may be perceived as unsafe or inconvenient (too far to walk). Table 2 below shows the average walking distances for various parts of York Region. As expected, commuters living in urban areas such as Richmond Hill and Markham can access public transit quite readily as the average walking distance is under 300 metres. However, residents living in more rural areas such as King City and Whitchurch-Stouffville, live over 1.6 kilometres from a transit station. While YRT offers Dial-a-Ride services in these areas – where commuters can hail a taxi to the nearest bus stations - services must be requested well in advance which increases the cognitive effort needed to use public transit in comparison to driving.

Table 2. Average walking distance to transit in York Region

Municipality	Average Walking Distance to Transit (m) Straight Line	Manhattan
Richmond Hill	171	212
Newmarket	198	244
Markham	217	265
Aurora	235	289
Vaughan	245	301
East Gwillimbury	694	837
Georgina	752	889
King	1357	1672
Whitchurch-Stouffville	2299	2656
Southern Three	**216**	**265**
Northern Six	**682**	**812**
York Region Total	**353**	**426**

(Source: Regional Municipality of York)

In addition to walking distance, perceived levels of safety is a large determinant to whether commuters will travel by foot (Regional Municipality of York, 2016). Transit stops in locations that require commuters to walk along regional roads, secluded areas or along dirt paths can discourage commuters from using public transit. Appendix 1 provides some examples of bus stops at various high school locations that are convenient for students and also examples of bus stops that could discourage a commuter. Bus stop locations for schools and universities are an important focus as there has been a significant uptake to using cars as the primary mode of transportation in getting to school (Regional Municipality of York, 2016). There also remains a large opportunity to shift travel behaviour within this population as car ownership among young adults is becoming less of an attractive option (Ross, 2014) and fewer young people are carrying driver's licences (Regional Municipality of York, 2016).

2) Cyclists may experience several barriers during the bike journey as they often need to share the road with vehicles which can affect perceived levels of safety. For example, cyclists along Highway 7 have mentioned that they are scared to cross the Highway 404 ramp due to merging vehicles. While Highway 7 has dedicated bike lanes and bike boxes, small barriers such as the location of the Highway 404 ramp can potentially deter cyclists from cycling along that route (Regional Municipality of York, 2016). Providing a physical barrier between vehicles and cyclists can increase the perception of safety (refer to Figure 6 for examples) and has been shown to increase cycling (Lusk et al., 2011).

Figure 6. Cycling infrastructure that separates vehicles from cyclists

Figure 6a. Toronto. Bollards along Bloor St. W. (by St. George St.).

Figure 6b. Montreal. Cycle tracks along Ave. Christophe Colomb (by Rue Prieur E.)

(Image source: Google Maps)

3) Social comparisons can be easily made while commuting. If transit commuters and drivers share the same road path during the last portion of the trip, the commuter may feel less satisfied as they compare themselves to drivers. Drivers

may seem to effortlessly drive into the parking lot close to their office or school while the transit commuter may still need to walk a considerable distance to their office from the bus stop. Since this occurs during the last portion of the trip, how the commuter feels during these moments can significantly influence in a commuter's decision to take transit again.

Best practices in increasing bicycle ridership and cyclists' safety

Good physical protection or effective separation from automobile traffic is a common feature amongst cities that have the highest cycling levels. Those cities that have grown cycling levels within in a short period. In Seville (Spain), the number of bike trips went up by a multiple of 11 within a few years after a network of connected, segregated, bike lanes was built.

The segregation of Seville cyclists is twofold – bike lanes are fenced as well as being raised up to the level of the pavement (slightly higher than the traffic on the road alongside). The results have been impressive with the average number of bikes used daily in Seville rising from 6,000 to more than 70,000. In 2014, an audit found that 6% of all trips in the city were made by bikes. (Walker, 2015)

London (UK) offers another example of an innovative attempt to increase cyclist's safety in the form of early release system on traffic lights. Certain intersections in London will have dedicated traffic lights for cyclists that will turn green a bit earlier, giving cyclists priority to turn at intersections. (Transport for London, n.d.)

Oulu (Finland), often called the winter cycling capital of the world, provides an innovative way of managing snow conditions. Despite having snow on the ground for over 100 days each year, 20% of all trips in the city take place on bikes, with the number remaining at 12% during the winter. Oulu has a bicycling and pedestrian network that connects, schools, workplaces, homes and other places that people visit regularly. It is approximately 800 kilometres (500 miles) in length and over 98% of this network is maintained during winter with innovative techniques such as using snow storage that provide additional protection to cycling routes. (Cleve, 2015)

2.4 Parking Management and Commuter Parking

Regulating parking is a critical component of shifting travel to public transit and other transport modes. In the case of York Region, with its spread out communities and low density population areas, parking management has the potential to increase YRT/Viva ridership and influence commuters to use active forms of transportation such as cycling.

Parking costs are clearly an influence in changing commuter behaviour and this has been validated by several researchers. In Los Angeles, research models predicted that the provision of employer-paid parking significantly raised the probability of people driving to work (Wilson, 1992), where 25% to 34% fewer automobiles were driven to work when parking costs had to be covered by the workers themselves. In Vancouver, a study indicated that commuters changed their transportation choices in response to parking fees and road pricing policies. When free road and parking was replaced by $1 fee for parking and a $1 road pricing, the probability a person driving alone to work went down by 8% (Washbrook et al, 2006). A research study in Montreal (Zahabi et al, 2012) found that a $1 increase in the per-hour cost of parking in downtown Montreal would result in a 5% increase in the share of commuters using public transit.

Simply raising parking fees may be viewed as an unpopular measure by a majority of York Region commuters since most residents drive to their destination and parking is free of charge at various commuter lots and workplaces. If parking fees are implemented at offices (such as the Region's offices themselves) or post-secondary institutions, the Region should consider a pricing strategy that combines parking fees with incentives and other benefits for public and active transportation. This will make parking fees more palatable as well as encourage a shift in travel behaviour. Annual parking passes at workplaces or post-secondary institutions should be used minimally so that commuters consider their travel options on a daily basis rather than on an annual basis (refer to the Access MIT Pass for a best practice example). If parking fees are increased, the Region should also consider regularly communicating and highlighting how the funds generated from parking fees are utilised. The visibility of this information is likely to make residents more supportive of the parking fees charged (Leonard et al., 2008).

Access MIT Pass, MIT, 2016

In 2010, MIT's Parking and Transportation Office in collaboration with the Transit Lab launched a pilot program called the Mobility Pass. To shift travel behaviour, eligible staff who typically parked at campus were given free access to Massachusetts Bay Transportation Authority (MBTA) subways and buses. The pilot involved approximately 1000 employees and given its success, MIT launched the Access MIT pass commuter program.

The Access MIT pass is a commuter benefits program that includes free, unlimited subway and bus usage, as well as increased subsidies for commuter parking at MBTA stations and commuter rail tickets.

In addition to the Access MIT program, MIT revised their campus parking pricing strategy by offering only pay-per-day parking instead of annual parking passes at most of their campus lots. Pay-per-day parking encourages staff to consider their transit and driving options on a daily basis. Annual parking passes, on the other hand encourages staff to review their commuting behaviour on an annual basis and commit to driving to campus for the rest of the year.

Overall, the new commuter program makes transit a more attractive and prominent option given the number of benefits and discounts available, whereas parking on campus remains an out-of-pocket cost with no benefits. The Access MIT pass is also conveniently part of the staff's campus ID which reduces the possibility of losing the pass and its associated benefits, and makes the option of taking transit more prominent. (Guilleman, 2016)

It is also important to note that the linkage of parking management with other forms of transport is intrinsic to ensuring the growth of sustainable travel. For example, there are clear benefits to increasing the walkability of destinations from parking locations in general. Increasing the walkability would result in an increase in instances in which the traveller needs to park once as opposed to driving and parking multiple times to accomplish various tasks (Victoria Transport Policy Institute, 2016). Similarly, several steps outlined previously such as increasing the safety of cyclists, an intuitive wayfinding system are integral to successfully implementing changes in parking policy and its associated pricing policy.

For commuter parking lots, the Region should consider locating lots to HOV/bus-only lanes so that commuters can reach their destination faster than driving. Residents have indicated that they would be willing to pay for parking if it meant that they could get to their destination faster (Regional Municipality of York, 2016). Such initiatives reinforce each other and should be implemented together to derive the maximum impact.

Best practice example: Calgary is similar to the York Region in that a majority of the inhabitants in both geographical regions live in suburban environments with a predominance of single-family homes. Public transit ridership in Calgary, however, is rising well beyond the increase expected with a rising population. A significant part of this success is due to parking policy and regulations.

Over the decades, authorities have taken multiple steps to regulate parking, especially in downtown areas. The government has successfully managed parking supply downtown, partly by owning a huge proportion of the spaces. The specific number of parking spaces that can be built downtown has also been limited by law. Over time this has resulted in a proportional decrease in the number of parking spaces in the downtown area. In 1981, there were 25 million square feet of offices downtown and 33,000 parking spaces (1,130 spaces per square million feet) and in 2013 while the office spaces rose to 40 million square feet there were only 47,000 spaces (an 11% decrease to 1,175 spaces per million square feet). Consequently, Calgary has one of the most expensive parking markets in North America.

In compensation for the high parking prices, the government has invested in over 17,000 park-and-ride spaces with over 30% reserved for people who pay a monthly fee ($85 – significantly below downtown rates which can go up to $32 per day). These policy steps seem to have worked as the share of downtown workers taking public transit in Calgary rising from 37% in 1998 to 50% in 2014. (Freemark, 2014)

2.5 Insights for the Region

A literature review of relevant transportation research as well as the observational study conducted in York Region for this report suggest that it is important to continue paying close attention to the physical characteristics of the door-to-door path, especially during the last mile for both public and active transportation. It is also important that YRT/Viva continue to manage unexpected delays (especially at transfer stops), and wait times in general. In regards to parking, studies indicate that increasing parking fees does have an impact on travel mode choices. But like other research cited in this report, the studies are contextual and the Region would need to consider York Region's unique context (population, demographics, culture etc.) before implementing higher parking fees which may be unpopular with residents at the onset.

Beyond the financial cost of public transit of a transit fare, a commuter also associates costs with other barriers or frictions. The matrix below connects the factors to the associated potential costs that are imposed on the commuter. If actual and perceptual costs can be lowered through targeted interventions in York Region, then it is possible that this would result in increased use of YRT/Viva.

Table 3. Factors affecting a commuter's choice for transit

Factor	Costs				
	Financial	Tangible		Perceptual	
		Time	Distance	Waiting	Walking
Financial:					
Ticket price	×				
Parking costs	×				
Time Schedule:					
Vehicle scheduling (frequency)		×			
Reliability		×		×	
Availability of real-time information				×	
Transfer connection and reliability		×		×	
Origin / transfer station facilities:					
Ease of access			×		×
Amenities				×	×
Safety and security				×	×

(Source: Modified from Taylor et al., 2009)

While research has noted the cost of wait-time and delays on service evaluations, it is important to note that an individual's perception of time can be managed. The matrix above shows that there is a difference between the perceptual and tangible nature of several features. The following section builds on this concept from the viewpoint of increasing information availability to the commuter, allowing them to make well-informed travel decisions and manage the perception wait-time and delays. It also provides specific best practice examples that the Region may want consider implementing as part of its public transportation and active transportation strategy.

3. The Role of Informational Availability on Transit Usage

When it comes to transportation choices, uncertainty is inherent in the decision due to the multitude of external events that can impact the outcome – a traffic jam, an accident, a delay in the arrival of the public transport, a lack of cabs at the nearest intersection etc.

Consequently, several biases come into play when a person is choosing a transport mode that can be leveraged to increase customer satisfaction. Many of these biases pertain to last mile frictions – problems arising at the exact moment when an individual is interacting with a product (in this case, a transport service). And if these biases and frictions project a negative impression for public transit options, then it is likely that people would avoid taking public transit even when it would have been the most efficient form of transport (Innocenti, Lattarulo, & Pazienza, 2013).

To understand some of the last mile frictions for commuters travelling on the YRT/Viva, a small observational study was undertaken for this research report. Participants were asked to take the YRT/Viva to make a round trip to and from a randomly chosen destination within York Region and use the YRT/Viva trip planner to plan their travel route. A qualitative analysis of the resulting observational journals and focus group discussion resulted in several common themes being highlighted – these are summarized in the table below along with the relevant elements from behavioural science. This section examines the last mile frictions encountered and how insights from behavioural science can be used to address specific frictions. Where possible, the section also provides examples of successful interventions that were implemented in other public transit systems and how each of these interventions resulted in increased usage of public transportation.

Table 4. Last mile frictions highlighted in observational study conducted for this report and the associated behavioural insights

Observational study experience	Relevant behavioural science insight
Lack of prominent, real-time arrival information for buses at various YRT/Viva bus stops can cause uncertainty and commuter dissatisfaction	*Certainty bias* - options that have an uncertain outcome are often avoided as guaranteed costs and yields weigh are preferred over uncertain ones. *Time budgeting* and *loss aversion*: Commuters typically have an approximate of amount of time budgeted for their commute which makes them sensitive to potential losses due to unexpected delays.
Lack of information on alternative paths to and from a destination. This is especially important in case the commuter encounters a delay or missed a connecting bus.	*Certainty bias* - commuters want to be certain that they will arrive at their destination even when they encounter a delay or miss a connecting bus. *Time budgeting* and *loss aversion* - commuters will focus more on the time they have lost due to the delay they are encountering if they do not have an alternative path to their destination.
Lack of information on various transportation services and the associated savings (financial or time) associated with taking public transit	*Salience* - individuals systematically focus on items or information that is prominent or salient and ignore items or information that is less visible.
Lack of information (and existence) of possible incentives associated with taking public transit	*Prospect theory* – one of the key insights from prospect theory is that losses are generally more painful than gains. Without prominently highlighting the benefits of public transportation or rewarding commuters who use transit or shift travel behaviour, potential commuters (who currently drive) may focus on the things they give up rather than what they could gain.
Lack of information on peers' transportation choices	*Social proof* - people refer to the actions of others in an attempt to assess what is the correct behaviour for a given situation.
Lack of comfortable / interesting bus stations with entertainment options	By making desired behaviour fun, people can be nudged into specific choices.

Each item listed in Table 4 is further explained below:

3.1 Lack of prominent, real-time information on arrival times

While YRT/Viva has a real-time online information service (RideNow) that is fairly accurate, it is not prominently marketed to the public at bus shelters or online, and may not be utilised as often as it could be.

Commuters create a time budget for their travels, which makes them sensitive to time lost due to unexpected delays and also makes them risk averse (Soman, 2015). The oft-quoted phrase "better safe than sorry" refers to certainty bias - (Tversky & Kahneman 1981) where options that have an uncertain outcome are often avoided.

For a commuter travelling with YRT/Viva, if information on the arrival times of transit vehicles is not easily accessible, then taking public transit becomes an option with an uncertain outcome. Given the relative certainty and control offered by driving, it is understandable that people would often prefer the latter, especially as it provides them with a feeling that they can accurately estimate their travel time.

Best practice example: New York City introduced Bus Time, a passenger information system in 2011. The interface provides easily accessible real-time updates on Metropolitan Transportation Authority buses operating in the city. The information is accessible through countdown timers on bus stops, online, and also through Short Message Service (SMS).

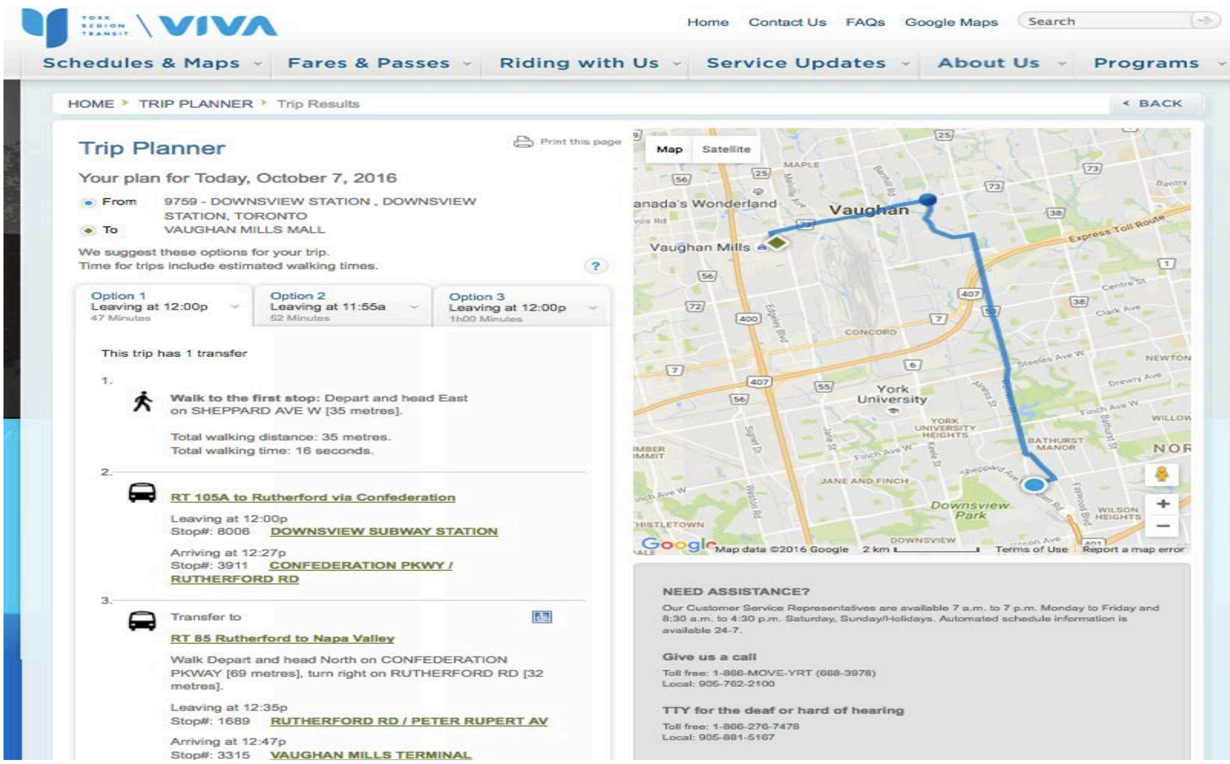
Impact on bus ridership: A research study tracking bus ridership between 2011 and 2013 reported a 2% rise in ridership as a direct result of providing real-time information, creating an additional $6.3 million in revenues (Brakewood, Macfarlane, & Watkins, 2015).

3.2 Lack of information on alternative paths to and from destination

Trip planners such as the YRT/Viva trip planner provide information for a single, one-way trip. However, YRT/Viva should consider changing the trip planner interface so that commuters are prompted to plan for a round trip (similar to websites for airlines). That way, the commuter will use the most efficient routes for the departing and return trip, which will improve commuter satisfaction.

During the observational study undertaken for this report, a participant was asked to travel from Downsview Subway Station to Vaughan Mills, and then travel back to Downsview Station using the YRT/Viva transit system. The YRT/Viva trip planner showed a route that resulted in the participant taking two busses (see Figure 6. below) to Vaughan Mills. Once the participant was at Vaughan Mills she had noticed a different route was available (route 360 - Vaughan Express) that took her directly to Yorkdale Station (a subway station relatively close to Downsview) with no bus transfers required. Although she had indicated her start place to be Downsview and assumed she would need to use the same travel route for the return trip, she wished the trip planner had directed her to this new route as this would have saved her a considerable amount of time.

Figure 7. YRT/Viva trip planner route from Downsview Station to Vaughan Mills



(Source: YRT/Viva Trip Planner)

Information on alternative routes are not just important at the start of a journey, but are also important throughout a journey as well. This information is necessary if a commuter is to make informed decisions about how he/she should be altering their travel plan if they miss a bus or run into an unplanned situation like a traffic jam.

During the focus group session, a participant noted he would consider walking from one stop to the next if he had just missed his bus and felt he could continue to make progress by simply walking. He voiced his frustration at the possibility of having to wait at a bus stop not being sure if walking or waiting was the best thing to do. Real-time information on alternative routes would be useful as it would allow the passenger to know when walking to the next stop is a better option than waiting for the bus. There is also research that indicates both a preference amongst commuters to have real-time formation on alternative routes (Ericsson, 2015) as well as a high utilization of this information when provided with it (Petrella, Minnice, & Lappin, 2014), especially in areas with regular traffic congestion and delays.

Currently YRT/Viva does provide dynamic, real-time information on alternate routes. However, information is only available at the start of any journey and to get up-to-date information, commuters who have internet access need to proactively re-enter their travel details into the trip planner and plan accordingly. Apps such as Waze and Google Maps are two platforms that YRT/Viva may want to look to that provide dynamic, real-time information on alternative routes – with the former automatically prompting users to take the shortest route available to them if traffic conditions change. The popularity of these services (the Waze app has been downloaded over 5 million times on Google app store) is a clear indicator of the demand for this information.

It is important to note here that while it is likely that providing real-time information on alternative routes would increase customer satisfaction, this choice needs to be appropriately managed. There is evidence showing that when individuals are provided too many choices, they may not choose the product offering at all – when offered 30 choices of marmalade individuals tend not to buy the product while 30% buy it when offered only six varieties of the product (Iyengar and Lepper, 2000). Accordingly, YRT/Viva may want to restrict the number of alternative routes it offers a passenger real-time information on.

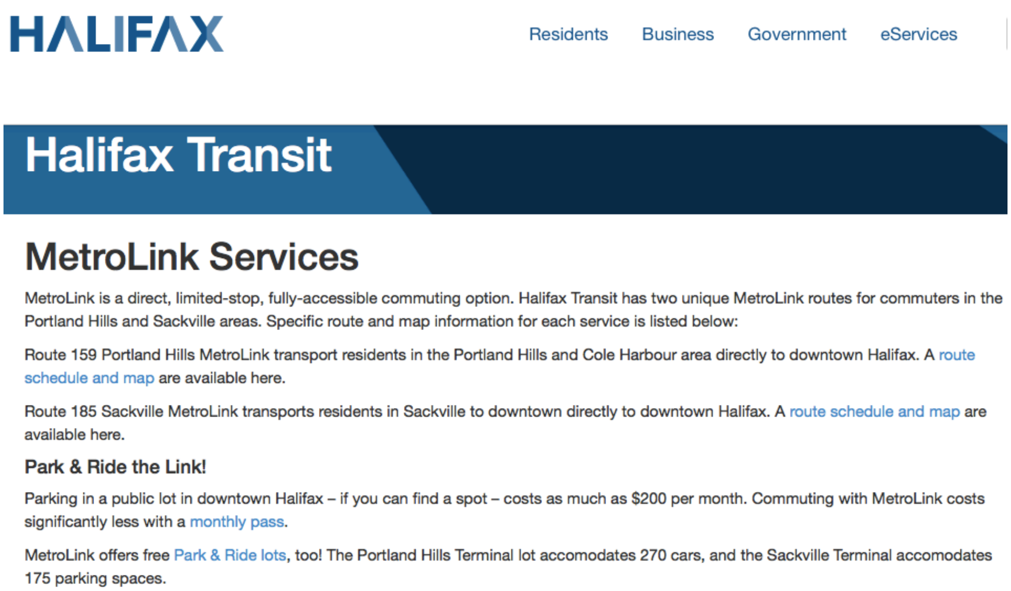
3.3 Lack of information on various transportation services and the associated savings

Human beings are biased towards focusing on information that is prominent to them (Tversky and Kahneman, 1974). This bias can be used by the YRT/Viva to inform and educate passengers on the various transport options available to them and the associated time and cost savings. If there are multiple public transit options available, then there is a greater likelihood of being able to offer something of interest to all commuters.

This emphasis on choice and multi-modal transportation is vital for York Region which varies in population density. With the average walking distance to the nearest public transit varying from 200 metres to 2 kilometres, it is clear that YRT/Viva services on their own will not fulfill the needs of all potential passengers – especially for those that live in areas with a greater than average walking distance to the nearest public transit. Offering information on multi-modal transit choices, from bikesharing to using Uber to travel from one location to another would allow YRT/Viva to increase its customer base. Providing Uber and similar options within a multi-modal journey (through mobile apps such as RideTap and within the YRT/Viva app) would ensure that commuters remain within the reach of the YRT/Viva even when they are not using public transit.

YRT/Viva should also consider further highlighting the financial or time savings associated with taking public transit. For example, Halifax Transit advertises on their website that the cost of parking in downtown Halifax is more than double the cost of a monthly transit pass (Halifax Regional Municipality, 2017). The Los Angeles Metro has been running successful marketing campaigns comparing the benefits associated with use of public transit and this have been directly associated with an increase in public transit (EMBARQ, 2011). YRT/Viva's Go Easy campaign falls in this domain and such efforts need to continue to educate passengers and hopefully attract a greater ridership base.

Figure 8. Halifax Transit web page - time and cost benefits of commuting with Metrolink are compared to single occupant vehicle driving


HALIFAX

Residents Business Government eServices

Halifax Transit

MetroLink Services

MetroLink is a direct, limited-stop, fully-accessible commuting option. Halifax Transit has two unique MetroLink routes for commuters in the Portland Hills and Sackville areas. Specific route and map information for each service is listed below:

Route 159 Portland Hills MetroLink transport residents in the Portland Hills and Cole Harbour area directly to downtown Halifax. A route schedule and map are available here.

Route 185 Sackville MetroLink transports residents in Sackville to downtown directly to downtown Halifax. A route schedule and map are available here.

Park & Ride the Link!

Parking in a public lot in downtown Halifax – if you can find a spot – costs as much as $200 per month. Commuting with MetroLink costs significantly less with a monthly pass.

MetroLink offers free Park & Ride lots, too! The Portland Hills Terminal lot accomodates 270 cars, and the Sackville Terminal accomodates 175 parking spaces.

(Source: Halifax Transit)

Figure 9. Los Angeles “Opposites” campaign for public transit

(Source: Los Angeles County Metropolitan Transportation Authority)

Best practice examples:

Los Angeles Metro’s “Opposites” campaign, that was part of a larger rebranding of the organisation, contributed to a 12% increase in discretionary ridership, The campaign is also credited with helping to pass a proposed ½ cent tax increase through the legislature that would fund major projects of the transit authorities (EMBARQ, 2011).

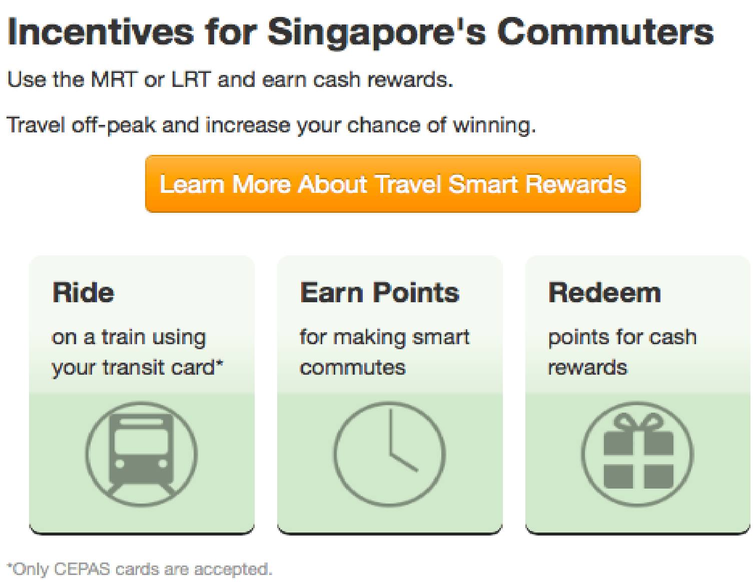
A research study in Washington, D.C. found that public transit ridership was positively associated with CaBi (Capital Bikeshare) ridership at the station level. The authors noted a 10% increase in annual CaBi ridership contributed to a 2.8% rise in average daily Metrorail ridership (Ma, Liu, & Erdoğan, 2015).

3.4 Lack of information (and existence) of possible incentives associated with taking public transit

A related observation on existing efforts by YRT/Viva and best practices elsewhere pertains to the creation and marketing of incentives for regular users of public transit. Most people are susceptible to irrational behaviour when it comes to lotteries and raffles as the decision to participate in a lottery is influenced by the potential gain they could stand to win from a lottery than on the actual outcome (Kahneman and Tversky, 1979). This results in the person focusing on the potential winnings from a particular lottery scheme rather than taking a rational approach, and calculating his/her odds of actually winning and then looking at the implied utility of this transaction.

In terms of how this could impact transit ridership, Singapore provides a great example through its Incentives for Singapore Commuters pilot study (Pluntke and Prabhakar, 2013). The pilot program, roughly equivalent to loyalty programs offered by airlines, allowed people to gain points for each journey on the public transit system – with the point increasing when this journey was made during off-peak hours. The points could either be cashed out or be used to enter a raffle (chosen by most participants) to win prizes ranging from Singapore $1 to $100. The pilot resulted in around 2% of all passengers shifting to travelling in off-peak hours. Similar incentives could be devised, offering rewards for using public transit.

Figure 10. Travel Smart Rewards Program - benefits outlined by local authorities



(Source: Land Transport Authority, Singapore)

Another example of a travel incentive program worth noting is the Eco Pass program in Boulder, Colorado. An annual bus pass purchased by employers, the Eco Pass provides employees with unlimited rides on most regular transit services. A unique feature of the program is the Guaranteed Ride Home program – a guarantee that any person with the pass can take a free cab ride home if they have taken the bus, bike, or car/vanpool to get to work and have an unplanned emergency. This is a very innovative way to work around the uncertainty of using transit when there are unexpected emergencies at home, or work schedule changes. A feasibility study based on various pilots indicated that the program would result in a 62% increase in annual ridership in public transit, and the program is now being implemented in Boulder (Boulder County, 2014).

Other best practice examples: Following the introduction of Merci - a pilot loyalty program offered to 20,000 commuters - the Société de transport de Montréal reported an increase in public transit usage by 24% of Merci pilot participants. The Société also noted that during the six-month pilot, 45% of the participants invited a friend to ride with them on the public transit and 57% visited new destinations using public transit (Marsan, 2014).

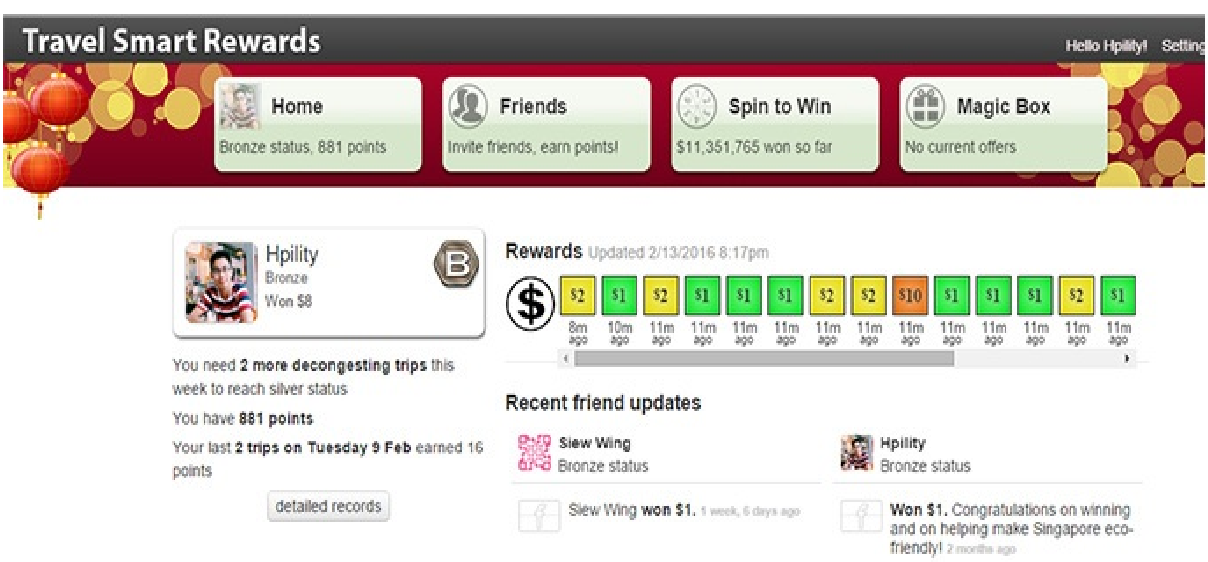
Edmonton Transit Systems created a loyalty program that offered recognised air travel points to commuters purchasing their monthly passes online. The sales of the adult monthly passes jumped by 21% after the introduction of the program (Ministry of Transportation, 2012).

3.5 Lack of information on peers' transportation choices

These are but a few ways in which improved information availability can reduce last mile frictions and increase ridership on YRT/Viva. A notable area for action includes adding a social element in YRT/Viva services – including encouraging transit users to sign up their friends, sharing their experiences and creating social competitions amongst users.

This social element is a significant part of the Incentives for Singapore Commuters pilot mentioned earlier (Pluntke and Prabhakar, 2013) and its successor, the Travel Smart Rewards program, where you can invite your friends to the program and compare your behaviour with their behaviour.

Figure 11. Travel Smart Rewards Program – user interface including ability to track friends

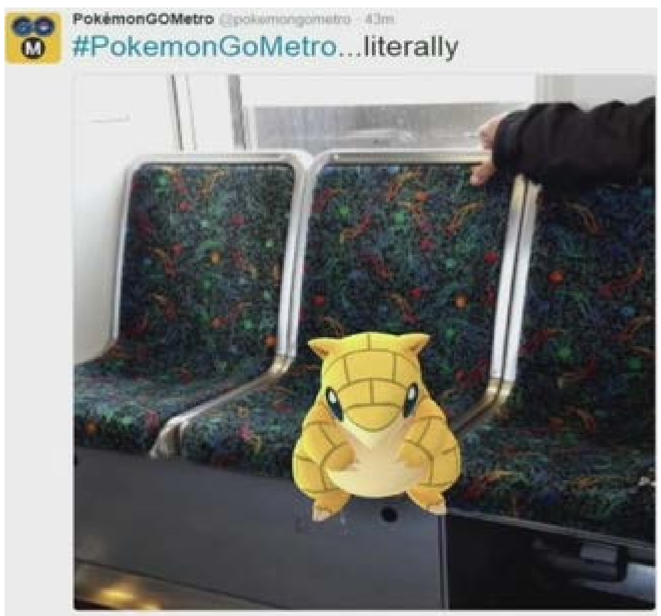


(Source: Hpility SG)

3.6 Lack of comfortable / interesting bus stations with entertainment options

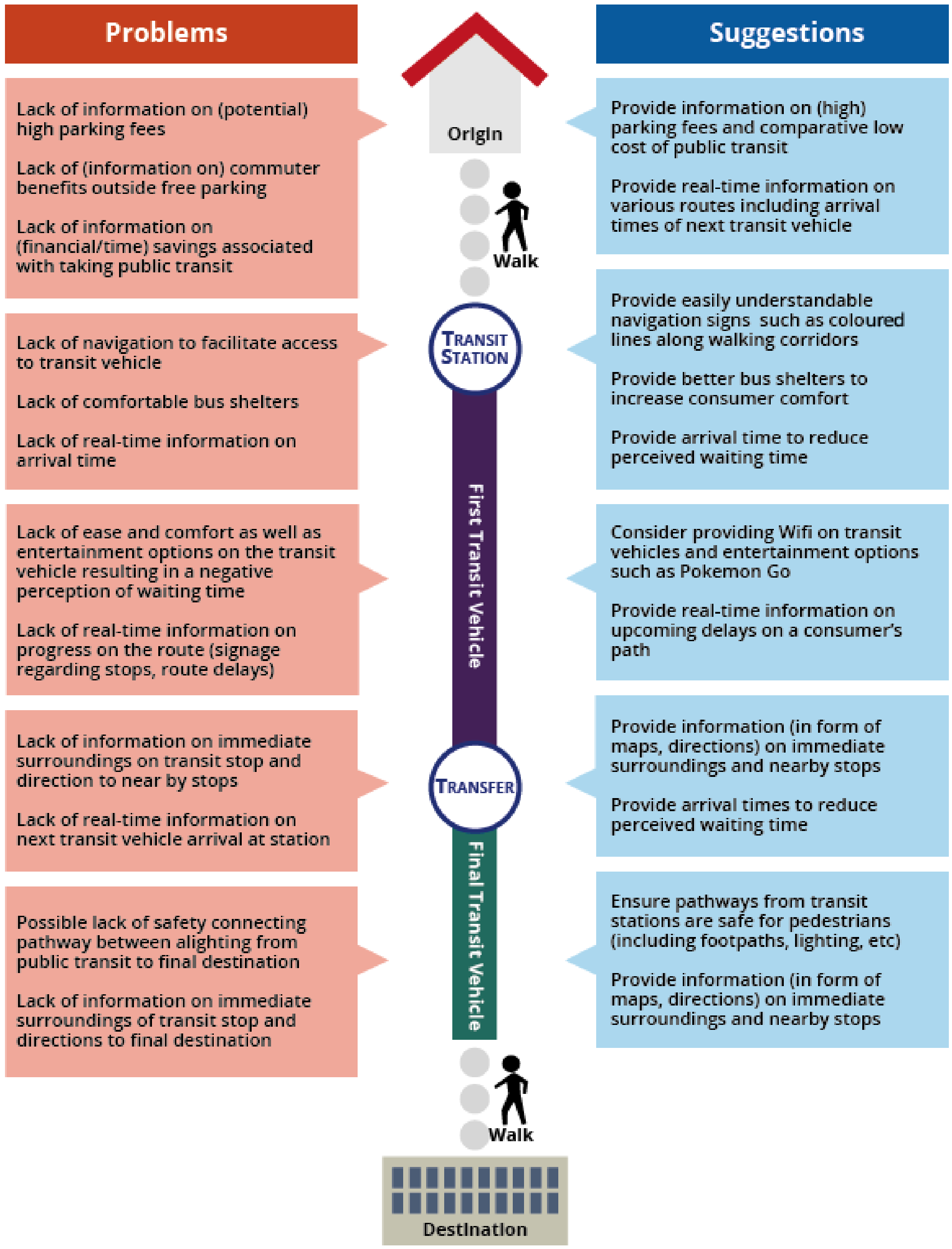
Equally, given the significant share of youth using transit and the need to make public transit a "fun" choice, there are potential synergies in understanding and utilizing trends such as location-based augmented reality games like Pokémon Go. Location-based augmented reality games are just one example of how to make taking public transit a "destination" rather than simply a transport medium to get to an actual destination. In other words, taking public transit becomes, in and of itself is a reward because of the added entertainment value. The success of innovative efforts such as the marketing campaign by Los Angeles Metro is proof that efforts in this direction will not be unrewarded.

Figure 12. Los Angeles Metro's use of Pokémon Go on social media and in transit



(Source: Los Angeles County Metropolitan Transportation Authority)

Figure 13. Summary of guidelines related to path characteristics and information availability



4. Connected and Autonomous Vehicles

Within York Region, cars are the primary mode of transportation mode for individuals (Regional Municipality of York, 2016). However, over the next twenty years, the driving and public transit experience could significantly change due to innovations in automotive technologies that will create vehicles with varying levels of automation.

Traditionally, driving is considered a human-centered experience, where the driver takes an active role in maneuvering and controlling the vehicle. In a highly automated vehicle, the driving behaviour changes as driving responsibility becomes shared with the vehicle and makes the act of driving less of an active experience. Instead, it becomes more focussed on monitoring the vehicle's driving performance. For fully automated vehicles, the human driver is not required to operate the vehicle and the human driver does not need to pay full attention to their surrounding environment.

Because of the differences in driving behaviour with automated vehicle technology, transportation infrastructure may need to be modified to accommodate the varying levels of automated vehicles that will exist on roads,

Furthermore, driving has a social component as eye contact and hand gestures (Sivak & Schoettle, 2015) are used to confirm who has the right of way. Without the presence of a fully attentive driver, new communication techniques should be explored to help pedestrians, cyclists, and traditional cars communicate with autonomous vehicles.

This section of the report will provide a short description of the varying levels of car automation and connected car technology. A discussion of the implications of car automation and connected technology on travel and driving behaviour is discussed. Guidelines are then provided to help the Region accommodate autonomous vehicles on roads and utilize connected and automated technologies to shift travel and driver behaviour.

4.1 Categorization of Automated Vehicles

According to the Society of Automotive Engineers (SAE International), there are six levels of automation (SAE, n.d.)

No-Automation (Level 0): Vehicles in this category are the standard vehicles typically on the road. The driver is always in control of the vehicle and maintains control over the braking, steering, throttle, and motive power.

Driver Assistance (Level 1): Level 1 vehicles have features that automate functions such as vehicle steering or acceleration/deceleration. The human driver remains responsible for monitoring the environment and for the remaining driving tasks (such as changing lanes and turning etc.). Adaptive cruise control, is one example, where the vehicle maintains a specific speed limit and distance from the vehicle in front.

Partial Automation (Level 2): Level 2 vehicles can automate both steering and acceleration/deceleration driving functions. An example would be a lane-centering feature working in combination with adaptive cruise control. This combination could potentially be used to relieve the individual of driving along certain stretches of road along a provincial highway. However, the driver remains responsible for other driving functions (such as lane changing, turns, responding to critical events) and for monitoring the driving environment.

Conditional Automation (Level 3): Level 3 vehicles can drive themselves under certain environmental conditions. In addition, Level 3 vehicles need to monitor for conditions where the human driver needs to resume control of the vehicle and notify the human driver. It is then the driver's responsibility to resume control of the vehicle.

High Automation (Level 4): Level 4 vehicles can drive without human intervention under certain conditions. The human driver also does not need to take back control of the vehicle.

Full Automation (Level 5): Vehicles categorized in this level are completely autonomous and the driver is expected to only provide navigational input (e.g. origin and destination information).

4.2 Connected Technologies

1) ***Short range connected technology - Vehicle to Vehicle (V2V) and Vehicle to infrastructure (V2I) Technology*:** Connected vehicle technologies allows vehicles to send and receive information to and from other vehicles (V2V) as well as from the transportation infrastructure (V2I). V2V and V2I technology may use a dedicated short range communication (DSRC) protocol to wirelessly connect to other vehicles and to the transportation infrastructure. While this protocol is still in development, the protocol allows vehicles to broadcast data such as location, speed, and direction. To maintain privacy, information transmitted via DSRC is anonymous. (Harding et al., 2014)

2) ***Connected technology using Onboard Diagnostics Port (OBDII):*** In addition to V2V and V2I technology, telecommunications companies such as AT&T[1] and startup companies such as Mojio and Dash use data taken from a vehicle's OBDII port to analyse travel and driving behaviour. Using the data, companies can provide feedback on driving behaviour (whether you are braking too fast or making a sharp turn), as well as analyse fuel usage and suggest better travel routes.

4.3 Travel Behaviour Changes with Autonomous and Connected Vehicles

1) Enhanced Mobility

In addition to allowing individuals to reclaim commuting time that is lost to driving, it is widely recognized that autonomous vehicles could increase mobility options for those who are unable or have difficulty driving. Most recently, Nevada became the first state to issue an autonomous vehicle driver's licence to an individual (Gitlin, 2016). The licence was issued to a quadriplegic who will be driving a semi-autonomous vehicle developed that can use head movements to control the vehicle. The vehicle has been labelled autonomous since the driver cannot fully control the vehicle like a traditional vehicle. To ensure safety, the licence requires the driver to be accompanied by a passenger who can overtake the vehicle if necessary and restricts the driver from driving under ice or snow conditions. While the driver's licence is restrictive, it demonstrates the new mobile opportunities new automated technologies can provide and how regulations can be updated to accommodate such technologies.

2) Addressing the first and last mile issue of public transit via automated transit systems

In addition to autonomous vehicles being tested on the roads, autonomous buses are also being piloted. One of the key advantages of autonomous buses is that they can operate at higher service frequencies with lower costs (CityMobil2, 2016) as there is no

[1] Refer to the AT&T website https://www.att.com/devices/audiovox/car-connection-elite-series.html#sku=sku6900244

need for a human driver. Cities in Europe, Singapore, and the UK[2] are currently trialling low-speed driverless transit systems (level 4) that could serve as a first or last mile connection. One of the earliest automated transit systems is the Parkshuttle which was implemented in the city of Capelle aan den IJsse in the Netherlands and serves over 2000 passengers on a daily basis. The shuttle system connects passengers from the city's subway station to the Rivium business park[3]. These buses can also be re-programmed as driverless taxis that can be hailed using an app[4].

Given the bus's ability to have dynamically programmed routes, multi-stop trips that are of short distances could potentially be serviced by driverless community buses using ride sharing apps. In York Region, about 85% of travel trips under two kilometres are being completed by vehicle, while 95% of two kilometre to five kilometre trips are also completed by vehicles (Regional Municipality of York, 2016). These short distance trips could potentially be serviced by driverless community taxis and encourage citizens to use public transit services instead of driving the car. Consequently, this reduces reliance on vehicle ownership and increases the use of public transit services.

[2] Refer to www.venturer-cars.com
[3] Refer to www.2getthere.eu/projects/rivium-grt/
[4] Refer to easymile.com/mobility-solution/

CityMobil2 Automated Transport Project. CityMobil2 is a project funded by European Union's Seventh Framework Programme (FP7) for research and technological development, with the goal of improving mobility through automated vehicles. It is a multi-stakeholder project, with about 45 partners including automated road transport system suppliers, city officials, and the research community.

One of the main activities of the project is to pilot Automated Road Transport Systems (ARTS) in various cities across Europe, primarily to address the first and last mile problem. Each pilot lasts between four to six months and currently, CityMobil2 has facilitated demonstrations in the cities of Vantaa (Finland), San Sebastian Oristano (Italy), CASA- Communauté d'agglomération de Sophia Antipolis (France), and San Sebastián (Spain). It has facilitated larger scale demonstrations in Saint-Sulpice - West Lausanne (Switzerland), La Rochelle (France), and Trikala (Greece). For the most part, automated vehicles that operate in ARTS are segregated from regular vehicles (due to the either legislation or technical barriers) and use a dedicated route. On top of the piloting ARTS, research is conducted to study the technical, financial, cultural, behavioural aspects, and effects on land use policies. In terms of ridership, the pilots were quite successful (refer to Table 5) and residents surveyed for various pilot indicated that they would prefer to ride an automated vehicle equally, in not more than a traditional bus. (CityMobil2, 2016).

Table 5. Bus and ridership details for cities participating in the CityMobil2 trial

	Oristano	La Rochelle	Lausanne	Vantaa	Trikala	Sophia Antipolis	Donostia / San Sebastian
Duration	17/07/2014-04/09/2014	17/12/2014 -25/04/2015	17/04/2015 -28/08/2015	10/05/2015 -09/08/2016	10/11/2015 -29/02/2016	01//02/2016-31/03/2016	01/04/2016 -30/06/2016
Route length (km)	1.3	1.9	1.5	0.9	2.4	1	1.2
N° of stops	5	4	6	2	9	5	6
N° of vehicles	2	6	4	4	6	4	3
Riders	2580	14660	7000	19000	12150	4059	2750

. (Source: CityMobil2: Cities Demonstrating Automated Road Passenger Transport. Experience and recommendations)

In addition, while public transit initiatives have focused on shifting single vehicle occupants to use public transportation, less attention has been paid to shifting transportation choices within families. About 86% of work trips are completed by vehicle (Regional Municipality of York, 2016) and one of the reasons may be that families need to drive to multiple locations before arriving to work. Parents may drop their child off at a daycare or school close to home before heading to work. For parents with more than one child, they may make multiple stops at different schools or daycares before arriving to work. These multi-stop trips make utilizing public transit difficult and could be serviced by driverless taxis or community buses. A family could hail a driverless taxi together that would make a stop at the nearby school before dropping the parents off at the closest transit station.

Driverless Taxi Trial, Singapore (2016). Singapore announced the launch of their autonomous vehicle, mobility-on-demand trials. The autonomous vehicles (AV) trials come under the Singapore Autonomous Vehicle Initiative (SAVI), which manages the AV research and the development of related applications and solutions. SAVI was formed as a collaboration between the Land Transport Authority (LTA) and the Agency for Science, Technology and Research (A*STAR). The focus of these trials is to create an on-demand service for first and last-mile connections to transit systems and intra-town (short distance) travel. (Kheong & Sheun, 2014)

Driverless taxi services are currently offered in One North – a two square kilometre (200 hectare) business park selected to be Singapore's AV test bed. Taxi services are free of charge and the pilot will last for three years, with the goal of creating an operational service by 2022 (Delphi, 2016).

Two companies – Delphi Automotive Systems and nuTonomy were selected to be the service providers and operate taxis along pre-determined routes within the district. Delphi's taxis operate on a 6.4 kilometre route (Delphi, 2016) and nuTonomy also operate a route of similar distance within One North. While the vehicles operate the vehicle autonomously, a human driver is present as the backup driver who is ready to take over if needed. Recently, nuTonomy expanded its service outside of the One North district into adjacent regions in collaboration with Grab – a ride hailing service. Because it is outside of the One North test bed, the human driver will still need to take over the driving responsibility once the vehicle is outside of One North. (Yuniar, 2016)

3) Using data for better road maintenance and real-time traffic updates

The vast amount of data collected from vehicles could be analyzed and used as feedback to help individuals change their driving behaviour and improve their travel routes. In aggregate, vehicle and travel data could help transportation officials identify road issues as well provide up-to-date traffic information and efficient driving routes to the individual in real-time. In the Netherland city of Eindhoven, IBM and NXP collaborated with transportation officials to pilot a smarter traffic program using data from connected vehicles. IBM and NXP equipped 200 vehicles with computers chips that collected sensor data from the vehicle and used it to identify road issues such as potholes and icy road conditions. During the six-month pilot, the sensor data collected from vehicles highlighted approximately 48,000 incidents, including incidents of heavy rain, use of hazard lights (which could indicate a potential traffic accident), and fog. Information about road conditions as well traffic issues could then be transmitted back to the driver (via their navigator or smartphone) so that drivers can change their travel and driving behaviour.

Drivers can slow down if the app alerts of icy road conditions, and the navigator can suggest a new route based on real-time traffic conditions. (IBM, 2013). Another example is Japan, which has the most extensive V2I system to date and has realized several safety benefits from this technology. A V2I system was installed on an accident prone-curve on an expressway in Tokyo that warned drivers of upcoming traffic along this curve, allowing drivers to adjust their driving behaviour accordingly. Adding a V2I system, along with other interventions such as road markings reduced the incidence of rear-end collisions by 60% in this location. (United States Government Accountability Office, 2015)

Application of Connected Technology to Address Road Issues: Japan uses V2I technology to process electronic tolling charges as well providing safety alerts and travel route information to drivers. Data collected from vehicles is also used to identify and resolve road issues. Transportation officials used data that was collected through their V2I system to identify roads in need of repair.

In one instance, officials noticed from the data that vehicles were suddenly braking at various locations. One hundred and sixty locations were identified from the data and in need of further investigation, Officials addressed safety issues (such as trees that obstructed a driver's line of sight) at these locations, which reduced sudden braking by 70% and accidents involving injuries and fatalities by 20% (United States Government Accountability Office, 2015).

4.4 Risks with Highly Automated and Fully Automated Vehicles and Implications on the Traffic System

While automated driving features can enhance mobility, and reduce the driver workload, the unintended consequence of having such features is that the individual's driving behaviour will change. There are several aspects of traditional driving behaviour to note when considering how automation affects driving behaviour. Understanding these different aspects will help the Region assess if transportation infrastructure needs to be modified to improve the predictability and safety of driving in a traffic environment that has mixed levels of automation:

1) Driving is an active experience but will become more of a supervisory role

Driving requires the full attention of the driver and is an activity that can have a high cognitive workload. Within a stretch of road, it is the driver who processes and evaluates the road conditions surrounding the vehicle, and makes decisions on how the vehicle should react in light of its surrounding conditions. Road conditions can change within minutes or even seconds. According to the Ministry of Transportation, drivers should be constantly moving their eyes, scanning the road and checking their side mirrors every five seconds or so to constantly assess the road conditions. (Ministry of Transportation, 2015)

As automobiles move towards automation, the vehicle becomes more responsible for the monitoring and executing of driving tasks and the driver becomes less engaged in the actual driving task. Driving will become more about monitoring the vehicle's driving performance and resuming control when needed. It is reasonable to expect that drivers will divert some of their attention to a secondary task (such as checking their phone or reading a book) that is unrelated to driving. Consequently, they will be less aware of the traffic environment compared to traditional driving.

While it is assumed that Level 3 vehicles will provide drivers with a comfortable transition time to resume control of the vehicle when requested, it is unclear how long this transition time will be. Some estimates have shown that the transition time needed to resume control of the vehicle is about 40 seconds (Venturer, 2016; Merat, Jamson, Lai, Daly & Carsten, 2014). However, it is unclear whether this applies to all driving scenarios. When the driving environment is simple (low traffic, no pedestrians or cyclists), resuming control of the vehicle may be a relatively straightforward action however this is not always the case. Research using driving simulators has shown that when drivers are pre-occupied with an unrelated driving task, they are less able to handle surprise driving situations such as an obstruction in one's lane (Merat, Jamson, Lai, & Carsten, 2012). The Region will need to partner with automakers to identify driving scenarios that require this shift in driving responsibilities. Transportation infrastructure may need to be added or modified to give drivers enough time to reorient themselves before driving. One potential situation is at highway exits – an automated vehicle may drive itself on the highway but may need the driver to resume control to merge the vehicle into the exit lane, where it is about to exit the highway.

Certain driving situations remain difficult to navigate for the autonomous vehicle and may require the human driver to take over. Some of these situations include (Ng & Lin, 2016):

> *Unclear or non-existent lane markings:* Automated vehicles rely on lane markings when driving. Roads that have unclear lane markings or no lane markings make it hard for automated vehicles to navigate. If a road has two or more lane markings visible, the vehicle may be confused as to which marking to follow.
>
> *Officers or workers using hand gestures to navigate traffic:* Automated vehicles may not be able to interpret a construction worker who is using hand gestures to manage traffic flow. In a similar situation, automated vehicles may not understand a police officer's hand gestures if they are navigating traffic at an intersection.

Traffic signals that are unclear at certain times of the day: Automated vehicles find it difficult to interpret traffic signals when the sun is behind the traffic signal itself. Infrastructure changes to the traffic signals could be made to reduce this issue.

Weather conditions such as fog and snow where car sensors cannot provide adequate information to the vehicle's computer system. (Sivak & Schoettle, 2015)

2) Driving is a social interaction

Traffic laws and road signs (such as crosswalks, speed limits, and stop signs) outline a set of driving rules drivers must comply with when on the road. On top of obeying road signs and traffic laws, human drivers communicate their driving intent to other vehicles, pedestrians, and cyclists. At intersections, a turn signal may give surrounding vehicles and other road users notice of the vehicle's intent to make a turn. However, surrounding road users still need to confirm whether the turn signal is legitimate. The turn signal may have been left on by accident and a cautious driver will look for other cues (such as speed, whether the driver is turning the steering wheel) to confirm the turn signal reflects the driver's actual intentions.

As an informal method of communication, eye contact and hand gestures are a common method for drivers to confirm their driving intent (Sivak & Schoettle, 2015) and allow other road users to act accordingly. The Ministry of Transportation recommends that drivers make eye contact with cyclists, pedestrians, and other drivers at intersections in order to make their driving intent clear. (Ministry of Transportation, 2015). At unmarked intersections or those with stop signs, traffic laws stipulate who has right of way but the driver still needs to confirm that the traffic law is obeyed, and the corresponding driver will take the right of way. (Vanderbilt, 2008). Eye contact that may be accompanied by a hand wave or a driver's nod helps to confirm this interaction. One key issue with autonomous vehicles is that the human driver is not present or not fully aware of the traffic environment. Consequently, other drivers should not rely on eye contact or hand gestures to confirm a vehicle's driving intent. While V2V technology can help vehicles understand each other's driving intent, other communication methods may be needed for traditional vehicles that do not have V2V technology. Given that V2V technology is not mandated yet, dedicated lanes for automated vehicles may be required at the onset while the interaction between traditional and automated vehicles is further explored.

Figure 14. Use of eye contact and hand gestures by pedestrians and drivers at unmarked intersections

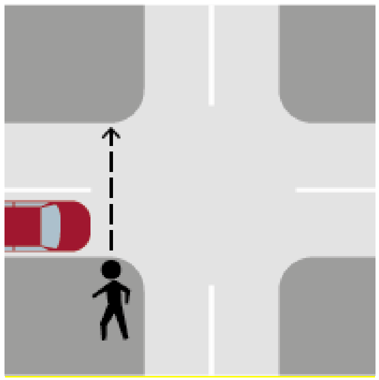


Figure 14a. Illustration of a pedestrian crossing in front of a vehicle at an unmarked intersection. Pedestrians will use a variety of cues to confirm that the car has detected them and will be giving them the right of way. This includes making eye contact with the driver and observing the vehicle's behaviour (whether they are decelerating and coming to a complete stop etc.).

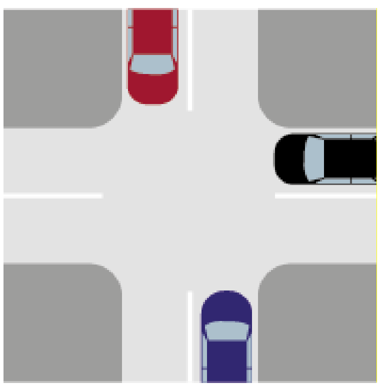


Figure 14b. At an unmarked intersection with three vehicles that have arrived about the same time, drivers may use hand gestures and eye contact to confirm who has the right of way.

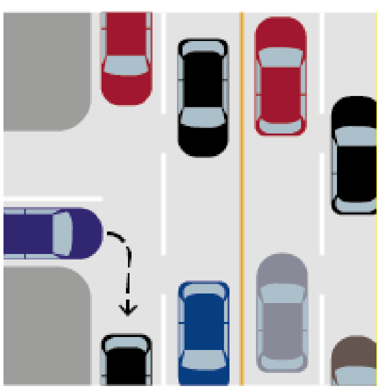
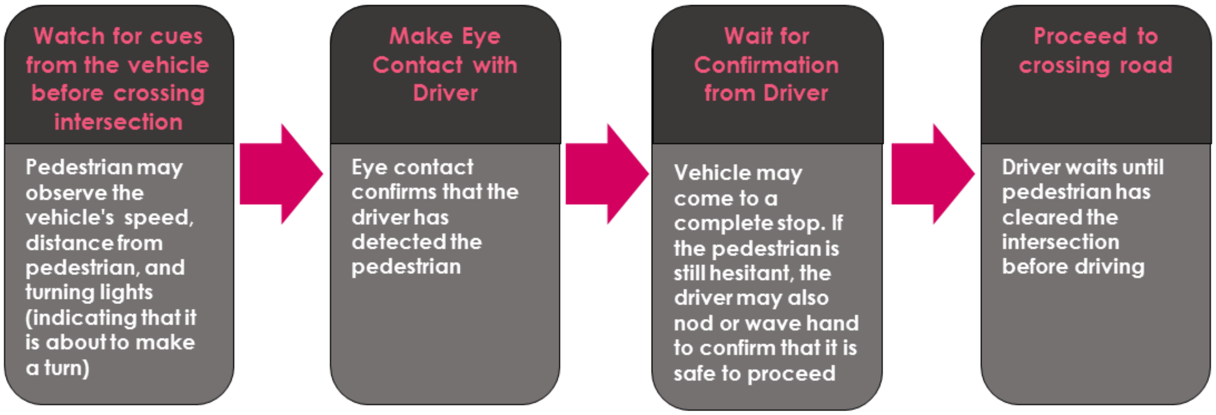


Figure 14c. A vehicle that is entering a large regional road has just been given the right of way by a vehicle. To confirm that the vehicle is yielding, a driver may make eye contact while also observing the vehicle's behaviour.

For pedestrians crossing an intersection, eye contact and other confirmations signals from the driver are also important even though the pedestrian may use additional cues before crossing in front of a vehicle.

Figure 15. How pedestrians may use eye contact with vehicles when crossing an intersection



For example, pedestrians may observe whether there is a sufficient gap between traffic before attempting to cross (Clamann, Aubert, & Cummings, 2015). They may also observe other cues such as the vehicle's speed and whether the vehicle is about to stop or make a turn (Merat, Madigan, Louw, Dziennus, & Schieben, 2016)

As a best practice, pedestrians are encouraged to confirm that a driver has detected their presence before crossing the road using eye contact. (Ministry of Transportation, n.d.). Once eye contact is made, a driver can nod or wave their hand as confirmation that they have detected the pedestrians. Appendix 3 provides a table of the communication channels used by various road users.

With automated vehicles, pedestrians will not be able to use the same signals they use with a human driver to confirm that a vehicle has detected them. From a pedestrian's point of view, this decreases the predictability of the vehicle's driving intent and possibly, their trust in the vehicle. Thus, the social interaction that existed with human drivers and pedestrians needs to be replaced with a different mechanism.

3) Drivers may adjust their driving behaviour based on the behaviour of surrounding vehicles (including driverless ones)

In addition to changing some of the social interactions, the presence of autonomous vehicles can potentially change driving norms. Past research has demonstrated that drivers are influenced by the behaviour of other drivers in the traffic environment. If a driver believes that most of the surrounding vehicles are driving above the speed limit, they may find it acceptable to do the same (Haglund & Åberg, 2000).

A human driver that is surrounded by driverless vehicles may follow the cue of the driverless vehicles even though it may be unsafe. One example is following distances – where it is recommended that a driver maintain a safe following distance that is at least two seconds between themselves and the car in front (Ministry of Transportation, 2015).

Automated vehicles however, can have a faster reaction time and it is technologically possible to maintain a safer but shorter following distance. While more studies need to be conducted, early research has shown that a driver's following distance from the car in front may change with the presence of automated vehicles. In a driving simulator study conducted by researchers in the United Kingdom and Germany, researchers observed that drivers were more likely to maintain shorter following distances between themselves and the vehicle they were following, if they were driving beside automated truck platoons. (Gouy, Wiedmann, Stevens, Brunett, & Reed, 2014). While the guideline for following distance is two seconds, this may be hard to estimate for the driver as it requires calculating following distance as a function of speed and time. In addition, drivers may feel social pressure to maintain shorter following distances if they believe that others are also maintaining shorter following distances. Driver feedback via connected technologies could be used to help correct this perception. Another possible method is to use road markings that, for example, indicate how a two second following distances should look, distance-wise, along a stretch of road.

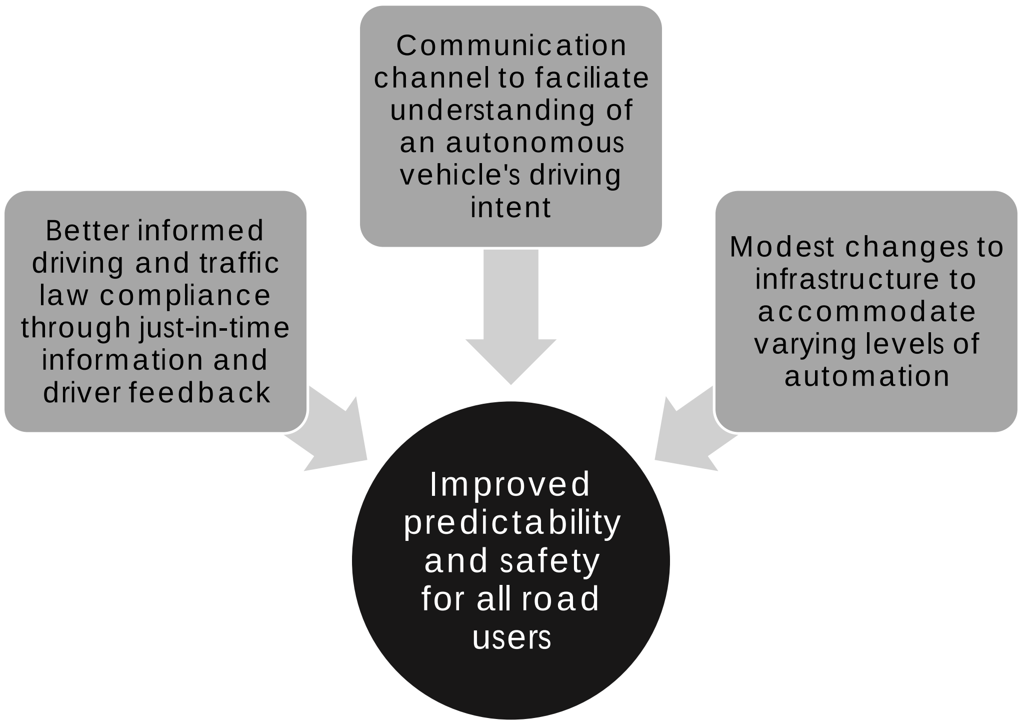
4.5 Insights for the Region

When considering how connected and autonomous vehicles will affect road users, the Region should focus on two major factors:

- How the presence of autonomous vehicles could create ambiguity for other road users such as pedestrians and traditional vehicles: With the removal of the human driver, it is more difficult for other road users to understand the driving intentions of autonomous vehicles. Pedestrians particularly may feel less confident to cross intersections when they are unsure whether the driverless vehicle has detected them and is giving them the right of way. (Lundgren et al., 2017)
- Whether the presence of connected and autonomous vehicles will increase the predictability of driving (and hence, safety) for road users: Connected car technologies such as V2V and V2I will make driving more informed and predictable by providing drivers with timely information. Further, transportation officials should also consider using aggregate data collected from vehicles to identify and resolve road issues and improve road safety. While there may be many benefits to connected car technologies, certain risks are present with highly and fully autonomous vehicles that may require changes to infrastructure. These risks are related to the limitations of the technology itself and how the transition of driving responsibility will be shifted from the vehicle to the driver in the case of highly autonomous vehicles (level 3).

Given these considerations, there are three areas the Region should consider:

Figure 16. Factors contributing to improving predictability and safety for all road users



1) Providing a communication channel for pedestrians and other road users in order to understand an autonomous vehicle's driving intent

Much of the driverless vehicle testing has focussed on testing the vehicle's capability on actual road conditions and improving the software and technology accordingly. However, less emphasis has been placed on helping pedestrians, cyclists, and traditional vehicles interact with driverless vehicles. In a survey conducted by researchers at the University of Leeds and German Aerospace, pedestrians noted that the most important piece of information they would like from driverless vehicles is whether the vehicle has detected their presence. (Merat, Madigan, Louw, Dziennus, & Schieben, 2016; Gough, 2016). This is especially important with young children. Consider school bus crossings, where a school bus has stopped and is unloading children in a residential area. Children will need to learn how to identify whether an automated vehicle has detected them before crossing in their path.

Car manufacturers are currently exploring various methods to communicate with pedestrians (see Appendix 2 for examples). In addition, NHTSA's Safety Assessment for Driverless Vehicles also indicates that car manufacturers should consider how driverless vehicles will communicate with other road users (NHTSA, 2016). One example of a car company placing considerable focus on this issue is from Drive.ai – a startup company that develops autonomous vehicle retrofit kits for business fleets. While the company's kit gives existing vehicles the capability to driver autonomously, the kit also includes an electronic display that uses text and emojis to signal the vehicle's driving intention to pedestrians. (Ackerman, 2016). However, these techniques may not be effective and the challenge still remains with designing an effective communication channel pedestrians will pay attention to (Clamann et al., 2015).

Given that car manufacturers may not agree on a standard form of communication and that the effectiveness of these techniques requires more study, the Region should consider how V2I infrastructure could communicate a vehicle's driving intention to pedestrians and cyclists at intersections. As an example, current pedestrian signals used at intersections could be modified to indicate when a driverless vehicle has fully stopped. School buses may also be equipped with similar technology that notifies students when it is safe to cross an intersection.

Figure 17. Example of a pedestrian crossover that could be modified for V2I use

Electronic text boards that display a vehicle's driving intention could be added to a pedestrian crossover and make crossing intersections safer for pedestrians
(Image source: Ministry of Transportation)

2) Better informed driving and traffic law compliance through just-in-time information and driver feedback

Connected car technologies can improve safety by alerting the driver to potential issues and reminding them to re-evaluate the driving conditions. Compared to traditional driving, V2V communications makes driving more predictable as drivers can be more certain about the driving intentions of the surrounding vehicles. V2I technology also has the ability of making driving more predictable as drivers receive more information about the traffic environment that they may not be aware of.

In addition, vehicle data can be used to provide feedback on driving behaviour, which can help improve an individual's driving habits. A field trial conducted using intelligent speed adaptation systems in Sweden found that simply warning drivers that they were about to exceed the speed limit could potentially reduce the incidence of collisions by 10-15%. (Transport Canada, 2011). Driver feedback combined with incentives can also be effective in curbing bad driving habits. In a study conducted by the Ministry of Transportation and the University of Toronto, researchers found that drivers who were given feedback on their driving behaviour and were rewarded for driving safely, engaged in fewer dangerous driving behaviours such as tailgating and speeding (Merrikhpour, Donmez, & Battista, 2014).

Application of Connected Technology to Change Driving Behaviour: The New York City's Department of Transportation (NYCDOT) recently trialed a similar program in collaboration with Allstate Insurance and other corporate partners. The DriveSmart program was launched in 2015 as a one-year pilot program. Drivers received mobile apps that provided them feedback on their driving behaviour and fuel usage. It also included a trip incentives app that rewarded drivers for shifting their travel to off-peak hours and on less congested streets. In addition to shifting travel behaviour and encouraging safer driving, vehicle data collected from participants will be used to analyze how New York City's street network is being used.

(Source: https://www.drivesmartnyc.com)

3) Modest changes to infrastructure to accommodate varying levels of automation

Given the limitations in autonomous vehicle driving technology and the possibility of vehicles having varying levels of automation on the road, it is important to identify areas where autonomous vehicles will have limited operation, and add infrastructure to allow autonomous vehicles to work well. Current driverless vehicle trials in states such as California and Nevada require a trained driver to be present in the vehicle who is ready to take over when the autonomous vehicle experiences an issue. Regulation, however, is beginning to allow the next stage of automation (Levels 4-5) to be tested. States such as Florida and Michigan have recently allowed autonomous vehicle testing without the need for a trained driver to be present inside the vehicle (Eggert, 2016). The Region should begin identifying infrastructure changes in partnership with automakers that will support driverless vehicles where a trained driver is not present. Construction zones for example, that alter the lane markings and use humans to direct traffic will need to update maps used by autonomous vehicles so that vehicles are aware of the new traffic conditions. In addition, construction workers and police officials who are directing traffic should be equipped with specialized mobile apps that can communicate wirelessly with a driverless vehicle.

Another area that should be examined is how road infrastructure can facilitate the transition from autonomous vehicle mode to active driving mode in highly automated (Level 3) vehicles. Just as rumble strips on highway roads can remind the driver that they are about to steer out of their designated lanes (Ministry of Transportation and Infrastructure (TranBC, n.d.), research should be conducted to examine how transportation infrastructure could ensure that the driver has enough situational awareness about the traffic environment before taking over driving responsibility from the vehicle.

5. Conclusion

When considering how to improve public transit ridership, active transportation, and the commuter experience, the first factors which come to mind are more frequent services and improved access to transit networks (the first and last mile connection). While it is widely known that delays and attention to the first and last mile problem is important, research in psychology and related behavioural sciences provides a more nuanced view as to how the delays and the physical infrastructure influence commuter choices. These issues are critical to a successful transit service however other factors such as information availability and the wise use of incentives can also influence a commuter's transit choices.

While improving transit ridership and active transportation is important, vehicle use will remain a part of the traffic environment. Emerging technologies like automated vehicles will introduce cars that have varying levels of automation into the traffic ecosystem. Consequently, it is important for the Region to understand the associated changes with driving behaviour and social interactions between road users. This in turn helps identify the appropriate infrastructure changes that will make the roads safer and predictable for everyone. In addition, the Region should further consider leveraging automated and connected technologies to solve the first and last mile issues (such as the use of ARTS) as well as change driver and travel behaviour.

Appendix 4 summarizes the guidelines and suggestions that would be helpful for the Region to consider for improving transit goals and managing risks associated with the presence of highly autonomous and driverless vehicles. It is important to note that experimentation and pilot programs are an important step with regards to implementation. Reported results in best practices may have a contextual component – where the characteristics of a particular region or city (such as culture, population density, and street layout) makes the intervention effective in a particular region but not in another. Interventions should be tested in the form of pilot programs or trials that help evaluate the intervention's effectiveness within the York Region context, and collect more information that will inform the Region's future initiatives.

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Appendices

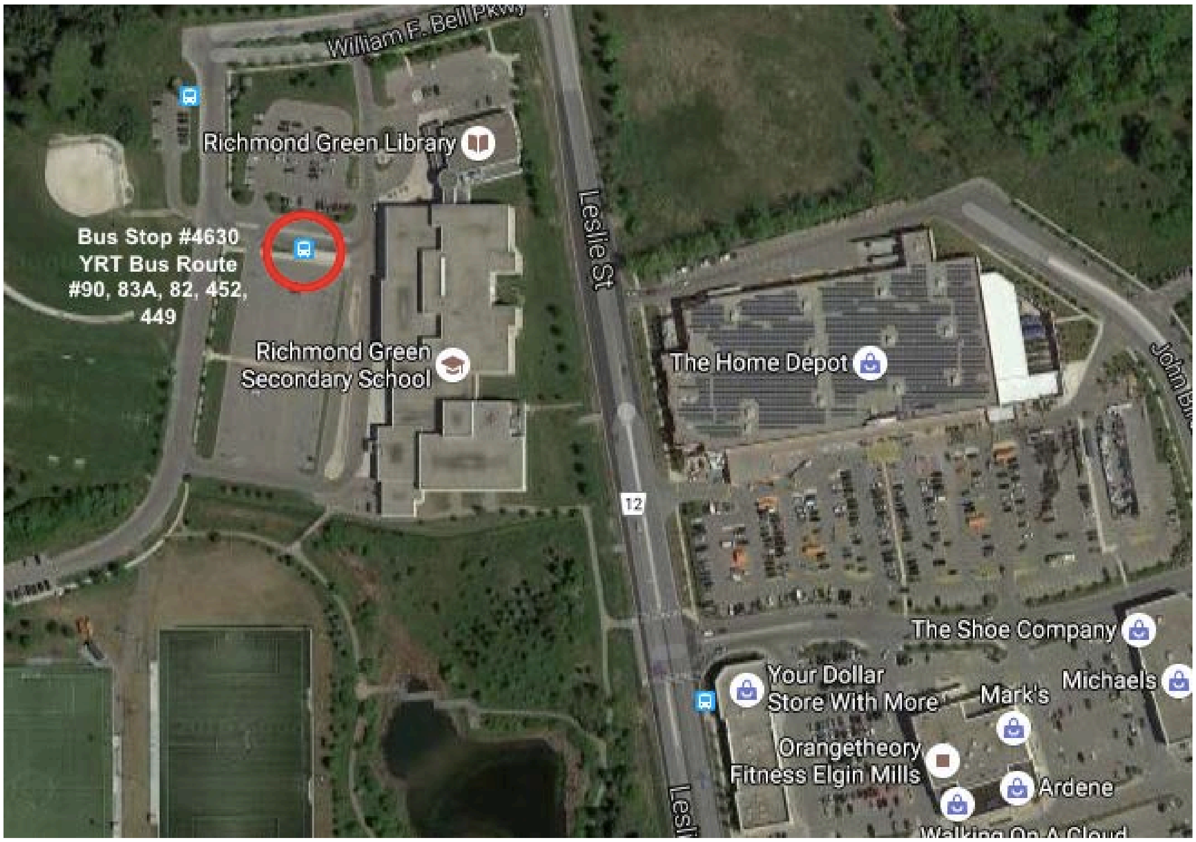
Behavioural Economics in Action at Rotman

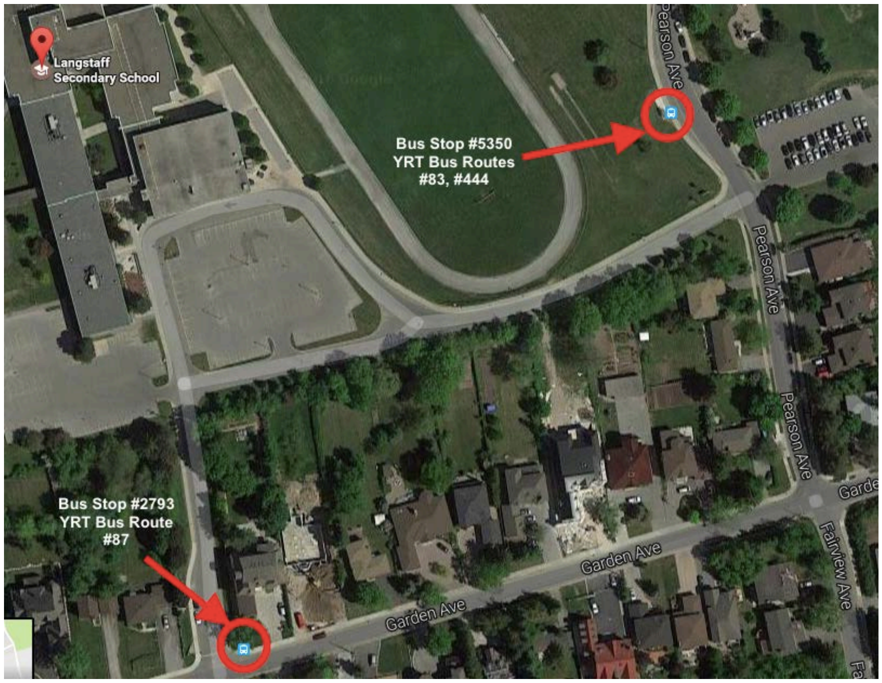
Appendix 1 - Location of Closest Bus Stops for Various Schools within York Region

Bus stop locations for schools are an important focus as there has been a significant uptake to using cars as the primary mode of transportation in getting to school (Regional Municipality of York, 2016). The following is a list of bus stops at various high school locations - the first two examples show bus stops located in great locations while the remaining examples show bus locations that could discourage a commuter.

Bayview Secondary School

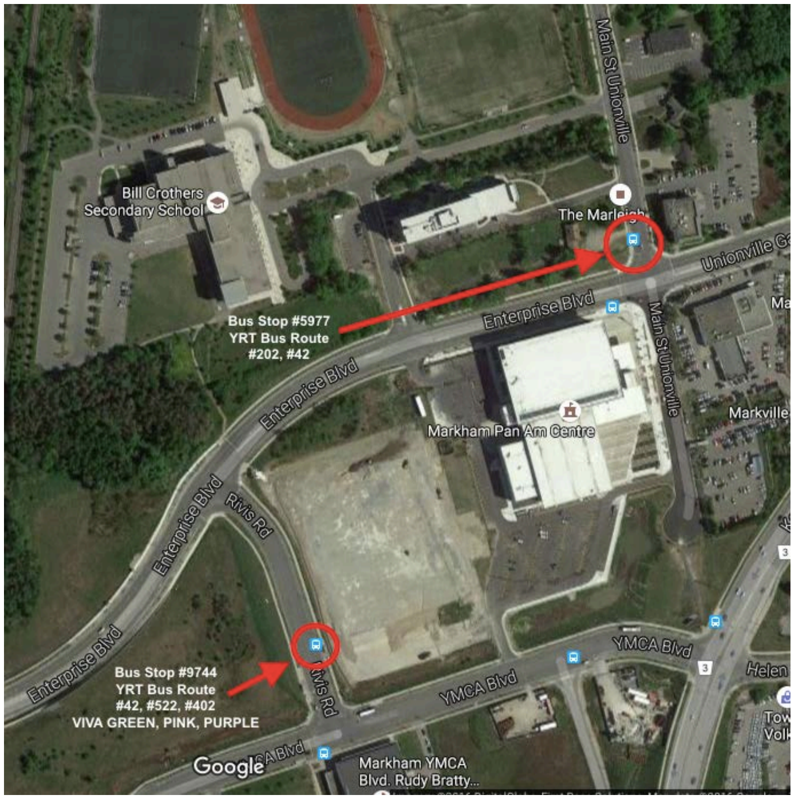
• Bus stop #2824 - approximate distance: 37.3 m. • Bus stop is located at a great location for students, as it is directly outside of the school entrance and bus service is also frequent. Additional bus stops are also located within 200m of the school.

Richmond Green Secondary School

• Bus Stop #4630 - approximate distance: 113.9 m. • Bus stop is located at a great location for students as it is quite close to the school entrance and bus service is frequent.

Langstaff Secondary School

• Bus Stop #5350 - approximate distance: 286.9 m. • Bus stop #2793 - approximate distance: 13.6 m. • Both stops have regular buses that arrive approximately every 30 minutes, making transit quite accessible. However, walking paths to both bus stops require students to cross through quiet and secluded areas surrounded by trees. This walking path could be perceived as unsafe after dark or early morning, and may discourage some students from using transit if they participate in before, or after school extra-curricular activities. If it is possible, it is recommended that YRT/Viva provide bus stops that are closer to the school entrance. Alternatively, YRT/Viva could provide limited service (before and after school hours), where students are dropped off or picked up at a location that is closer to the school entrance.

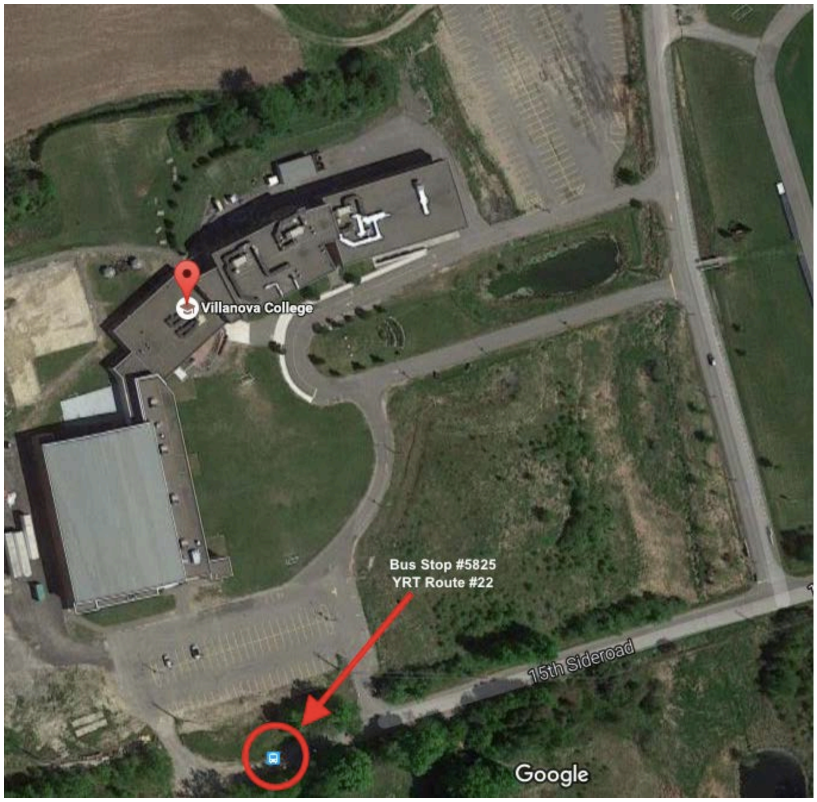
Middlefield Collegiate Institute

- Bus Stop #5773 - approximate distance from school: 199.1 m.
- Stop is quite close to school however service is limited as the bus (YRT #2) only arrives at 8:14 am and 3:21 pm.
- A more frequent bus service is available along 14th Ave and Middlefield Rd. (YRT #14) at bus stop #4949 but the distance quite far (approximately 469 m., which is more than the average walking distance from a bus stop in Markham – refer to Table 2). It is recommended that YRT/Viva explore how bus stops closer to Middlefield Collegiate Institute (such as bus stop #5773) could better service students before and after school.

Bill Crothers Secondary School

• Bus Stop #5977 - approximate distance: 256 m. • Bus stop #9744 - approximate distance: 412 m. • Bus stop #5977 is serviced by route #42 and #202 which make limited stops during the morning and afternoon hours. The walking paths from the bus stop to the school is also somewhat secluded and could be perceived as unsafe after dark or early morning. This would discourage students from taking transit if they need to participate in before or after school extra-curricular activities, especially during the winter season. • Bus stop #9744 provides more frequent bus services but it is farther away from the school. It is also located behind an empty lot by the Markham Pan Am Centre. Area is quite secluded and to save time, students may opt to take the short path through the secluded greenery which can be perceived as unsafe after dark. It is recommended that York Region and YRT/Viva explore how to make walking paths to bus stops safer for students or if possible, provide bus stop locations that are closer to the school.

Behavioural Economics in Action at Rotman

St. Thomas of Villanova College School



- Bus Stop #5825 - approximate distance: 483.4 m.
- Service is not frequent (YRT #22 services this stop at 7:44 Am., 7:49 am. and then at 2:50 pm.) and may not accommodate for students who participate in early morning or after-school programs. Bus stop is also in a remote area behind the parking lot which can be perceived as unsafe after dark or early morning – this may discourage students even if bus services were more frequent.
- While the school is a private institution and bus stop locations are limited (school may be located along private property), it is suggested that the bus stop be located closer to the school or in a less secluded area.

(Source for bus distances from high school locations: YRT/Viva Trip Planner - https://tripplanner.yrt.ca/hiwire?.a=iLocationLookup; Image source: Google Maps.)

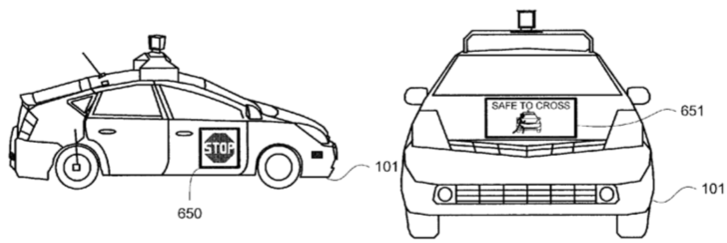
Appendix 2 – Examples of Current Vehicle-to-Pedestrian Communication Techniques

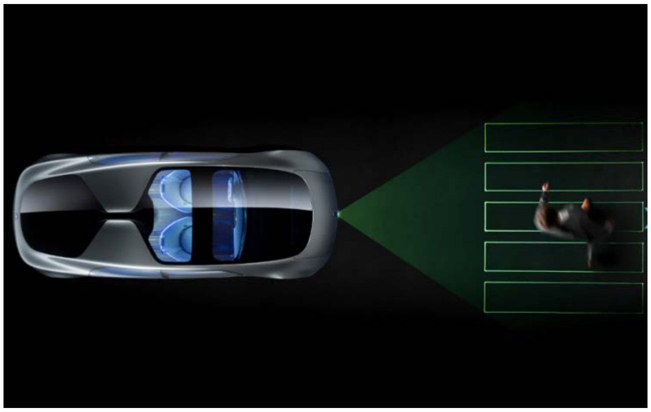
Drive.ai

Image source: Drive.ai.

Drive.ai is a startup company that develops deep learning software for autonomous vehicles. It produces a retrofit kit that turns a car into a self-driving vehicle. The kit includes an electronic sign board to be fitted on top of the vehicle that can communicate the vehicle’s driving intent.

Source: http://spectrum.ieee.org/cars-that-think/transportation/self-driving/driveai-solves-autonomous-cars-communication-problem
http://mashable.com/2016/08/30/drive-ai-launch/?utm_campaign=Mash-Prod-RSS-Feedburner-All-Partial&utm_cid=Mash-Prod-RSS-Feedburner-All-Partial#r4fC4fHFlkqu

Google
 Image source: Google.
In 2015, Google filed a patent outlining how a vehicle would notify their driving intention to a pedestrian. The illustrations within the patent show that a vehicle may use electronic signs to communicate driving intent to pedestrians. The vehicle may also audibly communicate their driving intentions or use a physical arm or eye that mimics the hand waves and eye contact a human driver provides to signal driving intent. Source: http://pdfpiw.uspto.gov/.piw?PageNum=0&docid=09196164&IDKey=51D7F153B940&HomeUrl=http%3A%2F%2Fpatft.uspto.gov%2Fnetacgi%2Fnph-Parser%3FSect1%3DPTO2%2526Sect2%3DHITOFF%2526u%3D%25252Fnetahtml%25252FPTO%25252Fsearch-adv.htm%2526r%3D1%2526p%3D1%2526f%3DG%2526

Mercedes-Benz
  Image sources: Mercedes-Benz.
The Mercedes-Benz F015 Autonomous Vehicle Research Car communicates with the environment visually and acoustically. The vehicle can communicate it's driving intentions by displaying short messages on LED displays located on the front and back of the vehicle. The vehicle also has an LED projector that can display a zebra crossing, to indicate that the vehicle has stopped for the pedestrian. It can also audibly communicate with the pedestrian, to confirm that the pedestrian been given the right of way. Source: https://www.mercedes-benz.com/en/mercedes-benz/innovation/research-vehicle-f-015-luxury-in-motion/

Appendix 3 – Communication Channels for Various Road Users

Road User	Communication Channels	Meaning interpreted by other road users
Vehicle	Turn Signals	Signals driver's intent to turn at an intersection
	Car Horn High Beams	Using a car horn can have many interpretations depending on the context but is primarily used to get other road users to pay attention to the driver. Some examples are: • At an intersection, drivers may use a car horn to alert and stop a vehicle who is illegally turning into an intersection. • Alerts a pedestrian that they are crossing an intersection illegally
	Eye Contact (informal)	Can be used with hand gestures to confirm driving intentions at intersections such as giving right-of-way.
	Hand Gestures	See above. Also used for social etiquette. E.g. a "thank you" wave is given to the vehicle who has allowed a driver to merge into a busy lane.
Cyclist	Arm Signals	Signals when the cyclist is about to turn or proceed straight ahead.
	Eye Contact (informal)	Can be used to ensure that other road users such as vehicles have detected them.
	Hand Gesture (informal)	Can be used for social etiquette (giving a "thank you" wave).
Pedestrian	Eye Contact (informal)	Ensure that the driver in the vehicle has detected the pedestrian.
	Hand Gesture (informal)	Can be used for social etiquette (such as giving a "thank you" wave).

Appendix 4 - Summary of Guidelines and Best Practices

<u>Improving Active Transport (walking and cycling) and Transit Ridership</u>

Path Characteristics:

The following recommendations refer to how path characteristics can affect active transport and public transit ridership. Path characteristics is defined as the physical, perceptual, and time-related features associated with door-to-door travel path of a commuter.

Problem Statement	• Lack of understandable directions to transit stops and orientation on immediate surroundings around stops, resulting in disoriented/delayed commuters.
Rationale	• People prefer choices that require them to make a lower mental effort (Garbarino & Edell, 1997). This insight relates to the negative emotion individuals generate each time they make a mental effort – as the required mental effort increases, so does the generated negative emotions related to that choice. • A lack of understandable directions to different transit stops resulted in disorientation for the commuter and can potentially cause travel delays. Observation studies conducted during this research found a general lack of orientation aids including a lack of guidance for pedestrians and cyclists and confusing bus stop signage. This implies that each time a person takes the YRT/Viva, the mental effort required is high (especially if the person is travelling on a new route). Each time this high effort is required, the probability of the person using YRT/Viva the next time reduces further as they associate a high negative effect with taking the public transit compared to other modes of transport. Source: Garbarino, E. C., & Edell, J. A. (1997). Cognitive effort, affect, and choice. *Journal of Consumer Research*, *24*(2), 147-158.
Best Practice Findings (if available)	• <u>TransLink, Vancouver (2011)</u>: Improved bus stop signage and pedestrian maps was implemented to facilitate wayfinding. TransLink made gradual introduction of changes, starting with ID signs on bus stops and the use of pilot programs to assess response from transit riders and pedestrians. Source:

	TransLink. (2011, September 8). *TransLink's new transportation wayfinding strategy*. Retrieved from http://buzzer.translink.ca/2011/09/new-ways-to-find-your-way-an-interview-about-translinks-new-transportation-wayfinding-strategy/ • Southampton City Council, UK: As part of a "legible city" initiative, City council created clear signage that listed clear walk times, safe routes and connection to public transport for longer distances. Source: Southampton City Council. (2008, August). *Direct/Guide/Show: Southampton Legible City*. Retrieved from http://www.city-id.com/assets/publications/southampton_legible_city_id_direct-guide-show.pdf
Recommendations	• **Ensure seamless movement (including transfers) by using navigation aids such as info panels at bus stops and transit hubs (such as Finch Station). Signage on the YRT/Viva network should be user-centric, informative, intuitive, coherent and consistent.**
Potential Impact (if available)	• Vancouver: 82% of people using TransLink's new navigation system said they were more likely to walk between places because of the pedestrian maps. Source: City of Vancouver. (2015, August 15). *New wayfinding increases likelihood of walking*. Retrieved from http://vancouver.ca/news-calendar/new-wayfinding-increases-likelihood-of-walking.aspx
Timeline (Short, Medium, Long Term)	Medium

Problem Statement	• Various bus stops are located on streets that are secluded and are not well-lit, affecting commuter's perception of safety.
Rationale	• Perception of safety – commuters may avoid taking transit because the walk from their destination to the bus stop is not well-lit or has low pedestrian traffic. (Refer to Appendix 1 for examples of bus stops at various high school locations that are convenient for students and also examples of bus stops that could discourage a commuter).
Best Practice Findings (if available)	• Edmonton, AB., 2011: Survey conducted by Edmonton Transit System showed that passengers considered a well-lit transit stop to be a "must-have" feature. Source: City of Edmonton. (2016, July 14). *Factors Affecting Transit Ridership*. Retrieved from https://www.edmonton.ca/transportation/RoadsTraffic/transit_factors_ridership.pdf

	• Calgary, AB.: Calgary Transit's guide offers specific guidance on features and design elements that make for a transit friendly environment. Source: Calgary Transit. (2006, April). *Transit Friendly Design Guide*. Retrieved from https://www.calgarytransit.com/sites/default/files/reports/transit_friendly.pdf
Recommendations	• **Continue to ensure and further place priority on improving perception of safety at transit bus stops and surrounding walking facilities are well-illuminated and convenient.**
Potential Impact (if available)	• A study conducted using data collected from the Ottawa-Carleton Transportation Commission attitude survey showed that transit way station safety led to 3.2% change in transit ridership while personal security accounted for a 3.1% variance in transit ridership. Source: Syed, S. J., & Khan, A. M. (2000). Factor analysis for the study of determinants of public transit ridership. *Journal of Public Transportation*, *3*(3).
Timeline (Short, Medium, Long Term)	Medium

Problem Statement	• Cyclists have dedicated lanes on certain roads and still need to share the road with other vehicles.
Rationale	• Perception of safety – cyclists do not feel safe when sharing the road with other vehicles which can be a barrier for novice cyclists.
Best Practice Findings (if available)	• Good physical protection or effective separation from automobile traffic is a common feature amongst cities that have the highest cycling levels and those cities that have grown the cycling levels within in a short period of time. • Seville, Spain: Number of bike trips went up by a multiple of 11 within a few years after a network of connected, segregated bike lanes were built. Method of implementation: A campaign by cycling enthusiasts eventually won government support. A sustainable mobility consultant was hired to design the network of segregated lanes with 80 kilometres being built in one go. Source: Walker, P. (2015, January 28). How Seville transformed itself into the cycling capital of southern Europe. *The Guardian.* Retrieved from https://www.theguardian.com/cities/2015/jan/28/seville-cycling-capital-southern-europe-bike-lanes

Recommendations	• **Encourage use of dedicated cycle tracks/protected cycling lanes in the planning and design of road improvements.**
Potential Impact (if available)	• Montreal: Cyclists were 2.5 times more likely to use cycle tracks than other streets for cycling (Lusk et al., 2011). Streets that have installed segregated cycle tracks include Rue Rachel St. (between Rue St. Urbain and Rue Marquette) and Ave. Christophe Colomb (between Boulevard Gouin E. and Rue Jarry E.). Source: Lusk, A. C., Furth, P. G., Morency, P., Miranda-Moreno, L. F., Willett, W. C., & Dennerlein, J. T. (2011). Risk of injury for bicycling on cycle tracks versus in the street. *Injury prevention*. 17(2), 131-135.
Timeline (Short, Medium, Long Term)	Medium

Parking Management and Commuter Parking

The following recommendations refer to how commuter parking regulations can be leveraged to improve transit ridership:

Problem Statement	• Most trips in York Region currently undertaken in cars with the parking policy not directly contributing to a reduction in automobile usage.
Rationale	• Parking costs are clearly an influence in changing commuter behaviour. Regulating the amount of parking spaces available in York Region and as well as the availability of commuter lots might have a direct impact on the transport choices of York Region inhabitants.
Best Practice Findings	• Calgary : The local government has focused on reducing the growth of parking spaces downtown, resulting in the creation of an expensive parking market. In compensation for the high parking prices, the government has invested in over 17,000 park-and-ride places with over 30% reserved for people who pay a monthly fee ($85) that is much lesser than the downtown parking fees. These steps seem to have worked with the share of downtown workers taking public transit in Calgary rising from 37% in 1998 to 50% in 2014. Source: Freemark, Y. (2014, December 10). Calgary's soaring transit use suggests high ridership is possible even in sprawling cities. *The Transport Politic*. http://www.thetransportpolitic.com/2014/12/10/calgarys-soaring-transit-use-suggests-high-ridership-is-possible-even-in-sprawling-cities/

	• Access MIT Pass, MIT, 2016: MIT's commuter benefits program includes free, unlimited subway and bus usage, and increased subsidies for commuter parking at Massachusetts Bay Transportation Authority (MBTA) stations and commuter rail tickets. The rollout of the new program was based on the success of a 2010 pilot where eligible staff who parked at campus were given free access to subways and buses. In addition, MIT revised its pricing strategy by offering only pay-per-day parking instead of annual parking passes at most of their campus lots. Officials at MIT noted that annual passes encouraged staff to consider whether their travel options on an annual basis and encourage staff to drive to campus for the entire year. Pay-per-day parking on the other hand encourages staff to consider their travel options on a daily basis. Source: Guilleman, A. (2016, June 14). New Access MIT program offers free public transit to MIT employees. *MIT News*. Retrieved from http://news.mit.edu/2016/access-mit-program-offers-free-public-transit-to-mit-employees-0614

Recommendations	• **The Region should consider discouraging use of autos in densely populated business centres by:**
	  • **Regulating the amount of parking spaces available (by owning/partnering with parking space providers) to ensure an expensive parking market and increase parking fees accordingly to discourage single occupant vehicle driving.**
	  • **Investing further in park-and-ride locations that whenever possible, have access to HOV/bus-only lanes, and have some space reserved for people who pay a monthly fee.**
	  • **Working with employers to create programs incentivizing office workers to take public transit.**

Potential Impact (if available)	• In Vancouver, when free road and parking was replaced by $1 fee for parking and a $1 road pricing, the probability a person driving alone to work went down by 8%. Source: Washbrook, K., Haider, W., & Jaccard, M. (2006). Estimating commuter mode choice: A discrete choice analysis of the impact of road pricing and parking charges. *Transportation*, 33(6), 621-639.
Timeline (Short, Medium, Long Term)	Long

Information Availability

The following recommendation pertains to how the availability of information can affect travel experience:

Problem Statement	• Lack of prominent, real-time information on time of arrival of public transit caused uncertainty and commuter dissatisfaction at some YRT/Viva stations.
Rationale	• Perceived waiting time is longer when a bus's arrival time is uncertain and could affect service evaluations.
Best Practice Findings (if available)	• New York City, New York, Bus Time Program, 2011: A real-time bus tracking system was gradually launched on a borough-by-borough basis beginning in 2011. Method of implementation: Initially rolled out as a pilot program offered through a mobile-friendly website and text message. Gradually leading to full rollout with additional features such as countdown clocks on bus stops. Source: Melanson, D. (2 May 2011). *Brooklyn bus riders get real-time bus tracking via cellphone*. Retrieved November 25, 2016, from https://www.engadget.com/2011/02/05/brooklyn-bus-riders-get-real-time-bus-tracking-via-cellphone/
Recommendations	• **Further promote the availability of real-time information on arrival times through mobile apps and phone.** • **Continue and extend the provision of real-time information on electronic message boards. If electronic message boards are not feasible, it is recommended that a majority of bus stops advertise that real-time information is available through apps and the YRT/Viva information phone line.**
Potential Impact (if available)	• New York City, New York, Bus Time Program, 2011: A research study tracking bus ridership between 2011-2013 reported a 2% rise in ridership as a direct result of providing real-time information, creating an additional $6.3 million in revenues. Source: Brakewood, C., Macfarlane, G. S., & Watkins, K. (2015). The impact of real-time information on bus ridership in New York City. *Transportation Research Part C: Emerging Technologies*, *53*, 59-75.
Timeline (Short, Medium, Long Term)	Short

Problem Statement	• Lack of information on alternative paths/detours to and from destination in case one route encounters a delay / misses a transport choice.
Rationale	• Commuters typically create a mental budget for their travel time. When there is an unexpected delay and/or the commuter has missed a connecting bus, the extra time lost to the commute is viewed as a loss. Commuters may face uncertainty if they do not have information regarding alternate routes to their destination. Research in behavioural sciences note that individuals are more sensitive to losses than gains and dislike uncertainty. • Perceptual waiting time (and commuter dissatisfaction) is lower when real-time information is available to the traveler. • Providing information on alternative paths when they have missed a bus reduces the focus on the missed bus and gives commuters an alternative option to help them make progress towards their destination. Source: Watkins, K. E., Ferris, B., Borning, A., Rutherford, G. S., & Layton, D. (2011). Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders. *Transportation Research Part A: Policy and Practice*, *45*(8), 839-848. Soman, D. (2015). *The Last Mile: Creating social and economic value from behavioral insights*. University of Toronto Press.
Best Practice Findings (if available)	• Google Maps and Waze: Provide dynamic, real time information on alternative routes with the former focusing on driving while the latter also includes public transit. Both provide real-time comparisons and facilitate commuters to shifts routes to avoid delays. Source: Google. (2015, September 30). *Never be late for a very important date*. Retrieved from https://maps.googleblog.com/2015/09/never-be-late-for-very-important-date.html
Recommendations	• **Provide real-time information on alternate routes dynamically and proactively to and from specific destination via web and mobile apps.**
Potential Impact (if available)	• Osaka, Japan: In Japan, real-time alternative-route travel time information, made available through dynamic message signs resulted in a 3.7% divergence rate during periods of congestion. This resulted in detoured motorists saving an average of 9.8 minutes per vehicle. If similar time saving can be realized through providing real-time alternative routes, then customer satisfaction for YRT/Viva users will rise. Source: US Department of Transportation – Office of the Assisstant Secretary for Research and Technology. (1998, October). *Benefits Database*. Retrieved from

	http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/515EB4BCB7A2806285256B4A005A1A1F?OpenDocument&Query=BMeasure
Timeline (Short, Medium, Long Term)	Short

Problem Statement	• Lack of information on integration of services and associated savings (financial / time) associated with taking public transit.
Rationale	• Individuals systematically focus on items or information that is prominent or salient and ignore items or information that is less visible. Making the savings associated with transit more salient will increase awareness and encourage more people to use public transportation.
Best Practice Findings	• Los Angeles Metro has been running successful marketing campaigns comparing the benefits associated with use of public transit – using simple, catchy visuals and messages. Source: Arpi, E. (2009, December 8). Transit Agencies Need to Invest in Marketing: A Lesson from Los Angeles. *TheCityFix*. Retrieved from http://thecityfix.com/blog/transit-agencies-need-to-invest-in-marketing-a-lesson-from-los-angeles/
Recommendations	• **Prominently market and display savings (financial or time-related) associated with taking public transit / multi-modal transit. Ideally the savings should be integrated into journey planners (both YRT/Viva/3rd party).**
Potential Impact (if available)	• Los Angeles, California, LA Metro campaign: Discretionary riders (those who have the choice to either travel by car or transit), have increased from 24% to 36%. Source: Arpi, E. (2009, December 8). Transit Agencies Need to Invest in Marketing: A Lesson from Los Angeles. *TheCityFix*. Retrieved from http://thecityfix.com/blog/transit-agencies-need-to-invest-in-marketing-a-lesson-from-los-angeles/
Timeline (Short, Medium, Long Term)	Short

Problem Statement	• Lack of information (and existence) of possible incentives associated with taking public transit.
Rationale	• Prospect theory – people make decisions on potential values of losses or gains rather than the outcome.

Best Practice Findings	• Singapore, INSINC, 2012: Incentives for Singapore Commuters pilot. The frequent commuters reward program included a strong social element where participants could invite their friends from social media and then follow their transit movements (while also receiving credits when their friends signed up). The pilot resulted in around 2% of all commuters shifting their travel to off peak hours. Method of implementation: initially rolled out as a 6-month pilot, then extended for 18 months and is now a part of local transit plans as the "Travel Smart Rewards" program. Source: Pluntke, C., & Prabhakar, B. (2013). INSINC: A Platform for Managing Peak Demand in Public Transit. *JOURNEYS, Land Transport Authority Academy of Singapore*, 31-39.
Recommendations	• **Create visible incentives/rewards for public transit users, especially those exhibiting desired behaviour.** • **Provide information on other's transport choices and associated benefits.**
Potential Impact (if available)	• Montreal, 2013: a pilot loyalty program (Merci) was offered to 20,000 commuters. The Société de transport de Montréal reported that use of transit increased for 24% of the program participants during the six-month pilot and while 57% of the participants visited new destinations using public transit. Source: Marsan, C.D.. (2014, January 17). Cloud-based Analytics Keeps Montreal's Buses Full and Ridership Growing -- GCN. *GCN*. Retrieved from https://gcn.com/Articles/2014/01/17/Montreal-Metro.aspx?Page=1
Timeline (Short, Medium, Long Term)	Short

Connected and Autonomous Vehicles

The following recommendations pertain to the effect of connected technologies and autonomous vehicles on the traffic system. It also pertains to the potential benefits connected and automated vehicle technology could provide with managing road safety as well as complementing the current public transit network.

Problem Statement	• With the removal of the human driver, it is more difficult for other road users to understand the driving intentions of the autonomous vehicles. Pedestrians particularly may feel less confident to cross intersections when they are unsure whether the driverless vehicle has detected them and is giving them the right of way.
Rationale	• Human drivers communicate their driving intent to other vehicles, pedestrians, and cyclists. At intersections, a turn signal may give surrounding vehicles and other road users notice of the vehicle's intent to make a turn. However, surrounding road users still need to confirm whether the turn signal is indeed legitimate. • As an informal method of communication, eye contact and hand waving are common methods for drivers to confirm their driving intent and allow other road users, to act accordingly. The Ministry of Transportation also recommends drivers make eye contact with cyclists, pedestrians, and other drivers at intersections to make their driving intent clear. Source: Ministry of Transportation. (n.d). *Road safety: Pedestrians*. Retrieved November 15, 2016, from http://www.mto.gov.on.ca/english/safety/pedestrian-safety.shtml Merat, N., Madigan, R., Louw T., Dziennus M., & Schieben, A. (2016). *What do vulnerable users think about ARTS*? Retrieved from http://www.citymobil2.eu/en/upload/Final_conference/1%20-%20Interractions%20with%20road%20users%20-%20Natasha%20Merat.pdf Sivak, M., & Schoettle, B. (2015, January). *Road safety with self-driving vehicles: General limitations and road sharing with conventional vehicles* [Pdf]. Ann Arbor, Michigan: University of Michigan Transportation Research Institute.

Best Practice Findings (if available)	• National Highway Traffic Safety Administration (NHTSA), Safety Assessment for Driverless Vehicles, 2016: NHTSA recommends that car manufacturers consider how driverless vehicles will communicate with other road users. • Drive.ai: Develops autonomous vehicle retrofit kits for business fleets. Kit also an electronic display that uses text and emojis to signal the vehicle's driving intention to pedestrians. (see Appendix 2 for other examples). Source: National Highway Traffic Safety Administration. (2016, September). *Federal Automated Vehicles Policy, Accelerating the Next Revolution in Roadway Safety.* Retrieved from www.nhtsa.gov/nhtsa/av/pdf/Federal_Automated_Vehicles_Policy.pdf Clamann, M., Aubert, M., & Cummings, M.L. (2016) Evaluation of Vehicle-to-Pedestrian Communication Displays for Autonomous Vehicles. *Traffic Research Board (Under Review).* Retrieved from https://hal.pratt.duke.edu/sites/hal.pratt.duke.edu/files/u10/Clamann_etal_TRB2016.pdf
Recommendations	• **The effectiveness of current vehicle communication techniques designed by car manufacturers remains uncertain. (Clamann et al., 2016). It is recommended that research be conducted on how V2I infrastructure could communicate a vehicle's driving intent to pedestrians and cyclists at intersections.**
Potential Impact (if available)	
Timeline (Short, Medium, Long Term)	Medium to Long Term

Problem Statement	• Understand the implications of V2I infrastructure on the traffic ecosystem and how data collected from V2I or other connected car technologies can help.
Rationale	• A potential benefit of connected car technology is the availability of real-time data that can help drivers find better travel routes and transportation officials identify and manage potential road issues. • Data collected from the vehicle can be used to provide feedback on driving behaviour and improve an individual's driving habits.
Best Practice Findings (if available	• Winnipeg, Manitoba, SafeMiles, 2009: In a study conducted by the University of Toronto, researchers found that drivers who were given feedback on their driving behaviour and were rewarded for driving safely, engaged in fewer dangerous driving behaviours such as tailgating and speeding.

	Source: Merrikhpour, M., Donmez, B., & Battista, V. (2014, October 1). A field operational trial evaluating a feedback–reward system on speeding and tailgating behaviors. *Transportation Research Part F: Traffic Psychology and Behaviour*, 27, 56-68. • Japan: has one of the largest V2I systems and is used by transportation officials and drivers for processing electronic tolling charges as well providing safety alerts and travel route information. Data collected from vehicles is also used to identify and resolve road issues. Transportation officials used data collected through their V2I system to identify roads in need of repair. In one instance, officials noticed from the data vehicles were suddenly braking at various locations. One hundred and sixty locations were identified from the data and in need of further investigation. Officials addressed safety issues (such as trees that obstructed a driver's line of sight) at these locations, which reduced sudden braking by 70% and accidents involving injuries and fatalities by 20%. Source: United States Government Accountability Office. (2015). *Intelligent Transport Systems - Vehicle-to- Infrastructure Technologies Expected to Offer Benefits, but Deployment Challenges Exist*. Retrieved from http://www.gao.gov/assets/680/672548.pdf • New York City Department of Transportation, New York, Drive Smart Pilot Program, 2015: DriveSmart launched a pilot program in collaboration with Allstate Insurance and other corporate partners. Drivers received mobile apps that provided them feedback on their driving behaviour and fuel usage. It also included a trip incentives app that rewarded drivers for shifting their travel to off-peak hours and on less congested streets. Source: Metropia.(2015, September 3). *NYC DOT Launches "Drive Smart" Initiative That Uses Technology Innovations To Help NYC Drivers Save Money, Save Time, And Drive More Safely*. [Press Release]. Retrieved from http://www.metropia.com/blog/nyc-dot-launches-"drive-smart"-initiative-uses-technology-innovations-help-nyc-drivers-save
Recommendations	• **To explore the use of V2I technology and other wireless connected technology to complement current road and safety management initiatives.** • **Given that V2I technology requires consumer adoption, it is recommended that the Region explore other connected technologies such as ones utilizing data from a vehicle's Onboard Diagnostics Port (OBDII).** • **It is also recommended that the Region explore the development of a driving program that will shift travel and driving behaviour using driver feedback and incentives (such as insurance discounts, free taxi rides etc.).**

Potential Impact (if available)	• Sweden, 2002: A field trial conducted using intelligent speed adaptation systems found that warning drivers who exceeded speed limits reduced the incidence of collisions by 10-15%. Source: Transport Canada. (2011). *Road Safety in Canada*. Retrieved from http://www.tc.gc.ca/eng/motorvehiclesafety/tp-tp15145-1201.htm
Timeline (Short, Medium, Long Term)	Medium Term

Problem Statement	• Given the limitations in autonomous vehicle driving technology and the possibility of vehicles having varying levels of automation on the road, it is important to identify areas where autonomous vehicles will have limited operation, and add infrastructure to accommodate vehicles of varying levels of automation.

Rationale	• Current driverless vehicle trials in states such as California and Nevada require a trained driver to be present in the vehicle who is ready to take over when the autonomous vehicle experiences an issue. Regulation, however, is beginning to allow testing of level 4-5 vehicle – where no human driver will take over the vehicle.
	• Issues that need to be examined include:
	  ◦ Construction zones that alter the lane markings and use humans to direct traffic will need to update maps used by autonomous vehicles so vehicles are aware of the new road layout. Construction workers and police officials who are directing traffic should be equipped with specialized mobile apps that can communicate wirelessly with a driverless vehicle.
	  ◦ How road infrastructure can facilitate the transition from autonomous vehicle mode to active driving mode in highly automated (Level 3) vehicles. This may be necessary.
	
	Source:
	National Highway Traffic Safety Administration. (2016, September). *Federal Automated Vehicles Policy, Accelerating the Next Revolution in Roadway Safety*. Retrieved from www.nhtsa.gov/nhtsa/av/pdf/Federal_Automated_Vehicles_Policy.pdf
	
	Ng, A., & Lin, Y. (2016, March 15). Self-Driving Cars Won't Work Until We Change Our Roads-And Attitudes. *Wired*. Retrieved from https://www.wired.com/2016/03/self-driving-cars-wont-work-change-roads-attitudes/

Best Practice Findings (if available	• British Columbia: To encourage safer driving behaviour, rumble strips on highway roads can remind the inattentive driver that they are about to steer off their lane. In British Columbia, shoulder rumble strips reduced collisions where motorists went off the road

	to their right, by 22.5%. Centre line rumble strips on undivided rural highways reduced head-on collisions and collisions where drivers went off the road to their left by 29.3%. Source: Ministry of Transportation and Infrastructure (TranBC). (n.d.). *Let's Get Ready to Rumble: A Story of Rumble Strips*. Retrieved from http://tranbc.ca/2012/07/11/lets-get-ready-to-rumble-a-story-of-rumble-strips/
Recommendations	• **Research should be conducted to examine how transportation infrastructure could ensure that the driver has enough situational awareness about the traffic environment before taking over driving responsibility from a vehicle. Regional authorities should partner with auto manufacturers to identify potential driving hazards for semi-automated and driverless vehicles.**
Timeline (Short, Medium, Long Term)	Medium to Long Term

Problem Statement	• One of the issues with using public transit is access to the public transit network. In rural areas, such as King City, the average distance from a bus stop is between 1.6 kilometre – 2.6 kilometre. In more urban areas such as Richmond Hill, the average distance is about 200 m, and the frequency of bus services connecting to a rapid transit network like YRT/Viva can vary, discouraging the commuter from using transit.
Rationale	• Autonomous transit systems could help connect more commuters to larger transit networks and facilitate the first and last mile connection. • Key advantage for automated transit systems versus traditional buses is the potential to operate at a higher service frequency with less cost as fewer bus operators are required. Source: CityMobil2. (2016). *CityMobil2: Cities Demonstrating Automated Road Passenger Transport. Experience and recommendations.* Retrieved from http://www.city mobil2.eu/en/upload/Deliverables/PU/CityMobil2%20booklet%20web%20final_17%2011%202016.pdf
Best Practice Findings (if available	• <u>CityMobil2, European Commission, 2012 – 2016</u>: One of the main activities of the project is to pilot automated road transport systems (ARTS) in various cities across Europe, with each pilot lasting between four to six months. For the most part, automated vehicles that run in ARTS are segregated from regular vehicles (due to the either legislation or technical barriers) and use a dedicated route. On top of the piloting

	ARTS, research is conducted to study the technical, financial, cultural, behavioural aspects, and effects on land use policies. Source: CityMobil2. (n.d.) About CItyMobil2. Retrieved from http://www.citymobil2.eu/en/ About-CityMobil2
Recommendations	• **To explore the use of automated road transport systems (ARTS) as a first or last mile connection to larger transportation networks. The first ARTS should be implemented as a research initiative that will further the development of future automated road transport systems. It should also involve automated road transport suppliers, research institutions, and other relevant industry vendors as project partners.**
Potential Impact (if available)	• <u>Capelle aan den IJsse, Netherlands, Rivium GRT, 1999-2016</u>. The Parkshuttle is an automated transport system that services the Rivium business park. A 1.8 kilometre system using a dedicated track mapped using magnetics. The shuttle serves two business parks and a residential area, serves over 2000 passengers daily and is profitable. • <u>CityMobil2, European Commission, 2012 – 2016:</u> Cities participating in the CityMobil2 project have seen wide acceptance – ridership during the short trials ranged from approximately 2000 riders to 15,000 riders (refer to Table 5). Source: 2getthere. (n.d.) *Rivium GRT*. Retrieved from http://www.2getthere.eu/projects/rivium-grt/ CityMobil2. (2016). *CityMobil2: Cities Demonstrating Automated Road Passenger Transport. Experience and recommendations.* Retrieved from http://www.city mobil2.eu/en/upload/Deliverables/PU/CityMobil2%20booklet%20web%20final_17%2011%202016.pdf
Timeline (Short, Medium, Long Term)	Medium – Long Term

Problem Statement	• While public transit initiatives have focused on shifting single vehicle occupants to use public transportation, less attention has been paid to shifting transportation choices within families. For families who need to make multiple stops, using public transit can be difficult compared to driving.
Rationale	• About 86% of work trips are completed by vehicle (Regional Municipality of York, 2016) and one of the reasons may be that families need to drive to multiple locations before arriving to work. Parents may need to drop their child off at a daycare

	close to home before heading to work. For parents with more than one child, they need to make multiple stops at different schools or daycares. These multi-stop trips could be serviced by driverless taxis or dynamically programmable community buses. Source: Regional Municipality of York. (2016, July). *The Regional Municipality of York Transportation Master Plan*. Retrieved from http://www.york.ca/wps/wcm/connect/yorkpublic/d7ec2651-8dc5-492e-b2a0-f76605edc122/2016 TMP Big Book.pdf?MOD=AJPERES
Best Practice Findings (if available)	• Singapore, August 2016: Announced the launch of autonomous vehicle, mobility-on-demand trials. The focus of these trials is to create an on-demand service for first-and-last-mile and intra-town (short distance) travel. The pilot will last for three years, with the goal of creating an operational service by 2022. • One North – a two square kilometre (200 hectare) business park was selected to be Singapore's autonomous vehicles test bed. Recently, service outside was expanded outside of the One North District into adjacent regions in collaboration with Grab – a ride-hailing service. However, once the taxi is outside of the One North region, the human driver will need to take over the driving responsibility because it is outside of the test bed. Source: Kheong, T. C., & Sheun, T. K. (2014). *Autonomous Vehicles, Next Stop*: Singapore. JOURNEYS, 5. Delphi. (2016, August 1). *Delphi Selected by Singapore Land Transport Authority for Autonomous Vehicle Mobility-on-Demand Program*. [Press Release]. Retrieved from http://investor.delphi.com/investors/press-releases/press-release-details/2016/Delphi-Selected-by-Singapore-Land-Transport-Authority-for-Autonomous-Vehicle-Mobility-on-Demand-Program/default.aspx Watts, J. (2016, August 25). World's First Self-Driving Taxis Hit the Road in Singapore. *Wall Street Journal*. Retrieved from http://www.wsj.com/articles/worlds-first-self-driving-taxis-hit-the-road-in-singapore-1472102747 Yuniar, R.W. (2016, September 23). Grab Joins nuTonomy to Offer Self-Driving Taxis in Singapore. *Wall Street Journal.* Retrieved from http://www.wsj.com/articles/grab-joins-nutonomy-to-offer-self-driving-taxis-in-singapore-1474598345
Recommendations	• **Explore the use of driverless taxis for short-distance trips (to reduce reliance on vehicle ownership) and for first and last mile travels, connecting commuters to rapid transit networks such as the YRT/Viva or GO.**
Potential Impact (if available)	
Timeline (Short, Medium, Long Term)	Medium – Long Term