Champlain Bridge Montreal: Impacts of Disruptions to Bridge Capacity

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McMASTER INSTITUTE FOR
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The Champlain Bridge is an important lifeline for the $123 Billion metropolitan economy of Montreal and surrounding region. It links south shore communities to the main island and is the most important bridge crossing in the vicinity for trade with the United States. While the bridge is relatively new compared to others in the region, it has not aged well and is currently requiring significant investment to maintain. These onerous maintenance requirements and the fact that Montreal resides in a seismically active region suggest that partial or total bridge closures are a very real prospect. This report examines the potential impacts of such closures.

It is important to note that even when the Champlain Bridge is fully open to traffic, the situation is often untenable and that the four other crossings linking the main island to the south shore are already very busy. Anecdotal evidence suggests that 40 minute crossings at the Champlain Bridge are not uncommon for a passage which would take 1 to 2 minutes in a free-flow state.

Should some form of closure impact the Bridge, an already serious situation will deteriorate badly:

- A reserve capacity analysis has shown that the four other crossings simply could not accommodate the displaced traffic from a Champlain closure.
- AM and PM Peaks would undoubtedly expand in terms of their duration and intensity. This would dramatically shrink the daytime window that is important for commercial vehicle movements.
- The transit service between the South Shore and Montreal would have to be reorganized with the Jacques-Cartier Bridge losing a lane of vehicular traffic as it takes on the Champlain bus service. A significant proportion of vehicular commuters would have to change the time of their departure and/or their mode of transport.
- Entirely new AM and PM Peaks would be created which would represent travel against the peak directions.
- A plausible economic scenario estimates that a long term loss of the Champlain crossing could reduce economic output by $594 million per annum in the metropolitan area and by $146 million annually in other regions of Quebec.

There should be no illusions about the fact that serious problems with the Champlain Bridge can have a real and tangible impact on Montreal's ability to compete. While the analysis has focused on what could be lost from economic activity that is currently present in the Montreal area, it is critical to note that it cannot account for firms that are discouraged from investing in the region due to congestion issues magnified by Champlain Bridge restrictions. In a realistic worst case scenario, the Champlain Bridge crossing could be unavailable for a period of over five years. The resulting congestion picture would be potentially unappealing to prospective investors.

The overall conclusion from this report is that the possibility of an alternate crossing near the Champlain Bridge needs to be investigated in short order.

Background

This study highlights the key strategic importance of the Champlain Bridge to the Montreal Region and the Quebec Economy. The Bridge is one of the most important transportation links in support of a $123 Billion metropolitan economy. The Champlain Bridge facilitates a key link between Montreal and the United States border and the efficient movements of approximately $20 Billion in goods at nearby border locations. Of the five crossings in the general vicinity, the Champlain crossing is by far the most accessible to serve the U.S. border traffic. Locally, the Champlain Bridge plays a critical role in linking the "south shore" communities of Montreal to the bulk of the metropolitan area. The south shore area of Montreal, an employer of approximately 260,000 people, is an important economic entity in its own right and an influential driver of the overall metropolitan economy.

The six lane bridge was first opened to traffic in 1962 and carries approximately 145,000 vehicles per day. Meanwhile, dedicated bus lanes and the associated service provide an estimated 40,000 person*trips per day. With approaches, the bridge is approximately six kilometres in length. The bridge's particular construction, the effects of corrosion from road salt, and the high volume of truck and other traffic have contributed to its aging. By the early 1990's the Bridge had already deteriorated and a costly replacement of the existing steel deck with an orthotropic steel deck was undertaken. Currently, the federal government has committed $20M per year over the next decade to assist in maintaining the bridge.

A central tenet of this report is that, in its present form, the Champlain Bridge is vulnerable to partial shutdowns or even a complete closure. The latter is possible as the result of a seismic event. There is a very real possibility that if the crossing did close, it would be for a lengthy period of five to seven years. The implications of such restrictions are given careful consideration in this report. The associated analytical work is divided essentially into two components. A link-level traffic analysis, which has been carried out in partnership between Transport Quebec and the McMaster Institute for Transportation and Logistics, seeks to assess the day-to-day congestion impacts of various restrictions imposed on the Champlain Bridge (i.e. reduction to four lanes, reduction to two lanes, complete closure). A system employed by Transport Quebec called MOTREM is utilized. As was anticipated prior to carrying out the work, there is evidence that MOTREM underestimates traffic impacts in some circumstances. When elements of the base case scenario are already quite congested, with low average speeds, (e.g. travel from south shore to the island during AM Peak) MOTREM appears to underestimate the magnitude of further speed reductions. Nevertheless, MOTREM is able to provide considerable insight into the character of induced delays.

Using the traffic analysis results as a guide, a multi-regional input-output model is developed which seeks to assess economic impacts to the Census Metropolitan Area (CMA) of Montreal and surrounding regions from these same restrictions. The model is developed on 14 regions and 43 commodity groups and is intended to highlight the inter-dependency of the key elements of the Canadian economy. The

province of Quebec is split into two regions which are the Census Metropolitan Area of Montreal and the Rest of Quebec. The remaining regions are the provinces and territories.

It is important to describe the basic nature of the economic impact scenarios. For each of the 602 combinations of regions and commodities, there is a "recipe" which describes what commodity inputs from which regions are required to produce a dollar of output. In these scenarios, the contribution of the Montreal CMA to each of the 602 "recipes" is purposely isolated from the rest. Since restrictions on the Champlain Bridge are negative for the local economy, the contributions of the Montreal CMA are essentially down-weighted for each of the 602 recipes. For many of the recipes, for example the recipe for producing furniture and fixtures out of British Columbia, the contribution of Montreal is very minimal so the down-weighting is of little significance. For others though, such as the production of motor vehicles out of Ontario, the linkages are much stronger and the negative impacts larger.

The analysis differentiates short-term impacts from longer-term impacts. Shorter-term impacts are those that relate to reductions of the Champlain Bridge down to four lanes and two lanes from the original six. These types of bridge restrictions are portrayed as shorter in duration and best measured in weeks. On the other hand, the complete closure of the Champlain Bridge, most likely due to a natural disaster, is portrayed as a long term event since it will potentially take years to replace the crossing. These impacts are portrayed as annual ones and the scenarios are based on the idea that there might be a shift of productive capacity from Montreal to elsewhere as congestion and problems with goods movement become untenable for some firms. In the long run, these down-weightings are really a slight reduction in Montreal's competitiveness. Other regions are represented as "picking up the slack" for Montreal's down-weighting in proportion to how they contribute presently to the given recipe. In the shorter run, there is much less likelihood of such shifts in productive capacity and thus the scenarios are not constructed that way.

In both the short and long run scenarios, three different levels of down-weighting are considered: 0.10%, 0.50% and 1.0%. Even the worst case scenario of 1.0% is not on the surface a staggering blow but the ultimate actual dollar impacts are actually quite surprising. In the longer run, it is quite possible that the 1.0% scenario could understate things if there is a significant shift in productive capacity. One other point about the scenarios is that the down-weightings are arbitrarily restricted to the commodities associated with manufacturing in Montreal. This sector is particularly dependent on the efficient movement of goods and is thus useful to consider. Down-weightings in manufacturing, of course, will have negative impacts on the output of other sectors in Montreal and these are captured by the model.

Prior to the analytical results, a brief literature review considers some relevant background issues. It is noted that excess traffic congestion neutralizes many of the reasons for doing business in metropolitan areas in the first place. Excess congestion reduces the ability of firms to efficiently draw on as diverse a set of potential inputs and it thus drives up costs and reduces profitability. Congestion also plays havoc with just-in-time supply chains. In Montreal, a study by Transport Quebec based on 1998 data estimated a total annual cost of congestion of $779 Million. This analysis was subsequently updated by Transport Canada in the context of a study on several Canadian cities. The total congestion cost for Montreal is based on the value of an hour of delay for commercial and private vehicles, costs for wasted

fuel and imputed costs for extra vehicle emissions. About 90% of these costs are related to the actual time lost. This study differs from past work on Montreal in that it directly considers the real possibility of harmful shifts in productive capacity and what those impacts could be.

Certain key differences are noted between a potential Champlain Bridge closure versus that of the I-35 Bridge in Minneapolis in 2007-2008. The Minneapolis case benefitted greatly from two viable freeway alternatives and several viable arterial alternatives to accommodate displaced traffic. There was no displaced dedicated bus service and also there was room to add extra lanes to alternative crossings. The Champlain crossing over the St. Lawrence River is eight times longer than the I-35 crossing. It was understood in Minneapolis that a replacement crossing would be in place in about a year and meanwhile, the burden was bearable anyway. Many of the costs from the incident were social costs absorbed by the population in the form of longer commutes. Interestingly, modal switches to transit were not prevalent.

Analysis of Current Traffic Patterns

In the Champlain case, a reserve capacity analysis of the five crossings that link the south shore to the main island is carried out. The four other crossings are the Jacques Cartier Bridge, the Mercier Bridge, the Victoria Bridge and the Lafontaine Bridge/Tunnel Combination. This is basically an arithmetic exercise. Even today, with no restrictions on the Champlain Bridge, these crossings are all very busy at peak times. The analysis compares what the crossings carry now with what they potentially could carry. It reveals that:

- In the peak directions, the aggregate reserves across the four crossings are 3,600 vehicles during the entire AM Peak period and 2,700 during PM Peak. These totals are a fraction of the vehicles carried by the Champlain Bridge during these periods and far less than the capacity of even a single lane of traffic across a peak period time span.
- Even against the peak direction, the peak period reserves are little in excess of what the Champlain Bridge carries

These results alone suggest that the system of crossings would be hard-pressed to adapt to traffic restrictions on the Champlain Bridge.

A link-level traffic analysis highlights the character of current delays with no restrictions on Champlain Bridge traffic. One of the scenarios considered is the base scenario which seeks to replicate the current situation. Some key observations are that:

- During peak periods, and with unrestricted movements on the Champlain Bridge, close to 100,000 vehicles are estimated to cross between the island and the south shore in the peak direction.
- According to MOTREM, this translates into crossing times of up to 15 minutes for the Champlain Bridge, 7 to 8 minutes for the Jacques-Cartier Bridge, 13 minutes for the Lafontaine crossing, 10 minutes for the Mercier Bridge and about 20 minutes for the Victoria Bridge. These totals do include any queuing in the approaches to the major crossings.

- In all cases, by contrast, the ideal free flow travel times for these crossings are estimated at less than one minute and up to two minutes in the case of the Champlain Bridge.
- Average velocity maps of AM Peak travel show large areas of the city where the average speed for a trip to the downtown is 15-30 km/h.

Implications of Reducing Champlain Bridge Traffic to Four Lanes

Under this scenario, the bus service continues to operate on the Champlain Bridge and no shift of trips to public transit is assumed. According to the traffic analysis simulations, the delay impacts of a reduction to four lanes will be fairly modest. For trips to the downtown in the AM Peak, extra delays on the south shore of 2.5-4 minutes are estimated and for the PM Peak the delays are only about 1 minute. For trips towards the U.S. the delays envelope much of the island and are in the range of 2-4 minutes in PM Peak and 1 minute in AM Peak. There is a significant possibility that the traffic simulation is underestimating these impacts.

In the AM Peak, crossing the Champlain Bridge toward the island will increase from about 15 minutes to about 17 minutes not including queuing in the approaches and about 85% of the normal traffic volume will be handled. In PM peak, going in the other direction, the crossing time is also about 17.5 minutes with about 90% of the normal volume. The traffic simulation does forecast some incremental delays resulting from the bridge restriction but they are much less dramatic than other scenarios considered.

In terms of economic impacts, the most likely scenario, of the three considered, is the 0.1% scenario. This scenario implies a reduction in output for Montreal of $1.4 million per week, and for Canada as a whole, a reduction of $2.4M. These impacts would be well dispersed over a wide range of firms in the form of interruptions and delays to supply chains. To be more specific, it is the “motor vehicles and other transport equipment and parts” group that suffers the most to the tune of nearly $140,000 per week. “Chemicals, pharmaceuticals and chemical products”, “electrical, electronic and communication products”, “primary metal products” and “wood, pulp and paper products” are all facing output declines in Montreal in the general vicinity of $100,000 per week.

Implications of Reducing Champlain Bridge Traffic to Two Lanes

Under this scenario, the bus service is moved to the Jacques-Cartier Bridge so that at least some traffic can travel in both directions on the Champlain Bridge. A 14% shift of peak direction trips is assumed for the AM and PM peaks.

- In the AM peak, the volume handled by the Champlain Bridge in peak direction is about 2/3 of normal and crossing time is apparently capped out at about 17.5 minutes. The results are similar in the reverse direction for PM Peak
- In the AM Peak, the duration of the average trip from the island to the south shore is forecast to increase by 15% and from the south shore to the island by 2.9%.
- In PM Peak, the duration of the average trip from the south shore to the island is forecast to increase by 16% and from the island to the south shore by 3.2%

- For AM Peak trips in the direction of downtown: Travel time increases are mostly on the south shore and are estimated to be five minutes or less. Trips in these vicinities are shown to take up to 4.0 times the duration of a trip in free flow traffic. Such incremental time increases equate to an increase of about 20% of the free-flow travel times.
- For AM Peak trips in the direction of the U.S.: there are significant areas of the island where the added delays range from 9-12 minutes.
- For PM Peak trips in the direction of the U.S.: delays are estimated as fairly modest and in the range of 3.0 minutes or less.
- For PM peak trips in the direction of the downtown: there are large areas on the south shore where a trip will be extended by 10-15 minutes and where trips take 2.5 to 3.0 times longer than they do in free flow traffic. There are small pockets which take 3.0-3.5 times longer. There are large areas where the travel time increases are equivalent to a near doubling of the free-flow traffic speeds.

With respect to the economic implications, the impacts would be much stronger than the reduction to four lanes. Like the four-lane case, the impacts are shorter term and measured in weeks in keeping with the restrictions on the Bridge. The most likely scenario to apply would probably be the 0.5% scenario which would imply weekly reduction in the output of Montreal of $6.98 million per week that the restriction is in place. The distribution of impacts across the 43 commodity types would be similar to the four-lane case. In terms of how the output declines are shared among the regions: Montreal will endure 57.9%, the rest of Quebec will have a 16.9% share and Ontario will have 17.2% of the decline.

Implications of a Champlain Bridge Closure

As with the 2 lanes closed scenario, the bus service is moved to the Jacques-Cartier Bridge. A 20% shift of peak direction trips to transit is assumed for the AM and PM peaks. It is possible that a subset of these trips simply would not take place.

- In the AM Peak, the duration of the average trip from the island to the south shore is forecast to increase by 32% and from the south shore to the island by 11%. A crossing of the Victoria Bridge towards the island is shown to balloon to nearly 30 minutes.
- In PM Peak, the duration of the average trip from the south shore to the island is forecast to increase by 25% and from the island to the south shore by 10%
- For AM Peak trips in the direction of downtown: the area of Montreal for which the average velocity would decline to 15-30km/h is expanded substantially on the south shore. There is a big percentage increase in the south shore area between the Champlain and Jacques Cartier Bridges where the speed would decline below 15km/h. The biggest net decreases in average speed occur on the south shore at larger distance from the Champlain Bridge and are in the range of decline of about 10km/h. Note that pre-closure average speeds in these areas were 30-45km/h. There are south shore pockets where the trip times increase by 15-20 minutes and large areas where they increase by 10-15 minutes. Trips in these vicinities are shown to take 4.0 to 4.5 times the duration of a trip in free flow traffic. Many of the incremental time increases equate to a doubling of the free-flow travel times.

- For AM Peak trips in the direction of the U.S.: there are significant areas to the west of the Champlain Bridge which will experience trips taking 35-40 minutes longer and 2.0 to 3.0 times the free-flow durations. The area of Montreal for which the average velocity in exiting the city would decline to the range of 30-45km/h is hugely expanded. Significant areas near the downtown show substantial average speed decreases of greater than 20km/h.
- For PM peak trips in the direction of the U.S.: PM Peak trips from areas west of the Champlain Bridge will take 25-30 minutes longer and 3.0 to 4.0 time the free-flow durations.
- For PM peak trips in the direction of the downtown: there are large areas on the south shore where a trip will be extended by 20-30 minutes and where trips take 3.5 to 4.0 times longer than they do in free flow traffic. Only the travel time increases equate to a near tripling of the free-flow travel times.

With respect to the economic implications of the closure, there is little doubt that goods movement in the CMA, particularly with respect to movements between the island and the south shore, would be hampered and movements to the US border would be less efficient as well as along the Trans-Canada Highway to and from the east. Most importantly, there is little that could be done for several years to improve the situation and this suggests the real possibility of a small shift in productive capacity.

As before, there are three closure scenarios for the down-weightings applied: 0.1%, 0.5% and 1.0% and as before the direct down-weightings are concentrated in the manufacturing sector. For Montreal, these correspond to annual output declines of $59.5 million, $297 million and $594 million respectively across the metropolitan economy. The "Rest of Quebec" region would suffer declines in output of $14.7 million, $73.5 million and $146.7 under the respective scenarios largely because it is the most tightly integrated with the fortunes of Montreal. In the closure scenario, the other provinces and regions are portrayed as net beneficiaries of productive capacity as some businesses shift operations. For the 1.0% scenario, the net output decline for the nation is estimated at only $50 million annually since other regions are "picking up slack."

In terms of how other regions benefit, irrespective of scenario, the lion's share would accrue to Ontario to the tune of nearly 68% of the absorbed capacity. Alberta and British Columbia between them would gain nearly 20% and other provinces and territories would compete for the rest. Note that the model did not permit for shifts to the United States which in reality is a distinct possibility.

Under the 1.0% scenario, the biggest potential output gains for Ontario would be in "motor vehicles, other transport equipment and parts" ($82 million), "business and computer services" ($41 million), "primary metal products" ($39 million) and "other finance, insurance and real estate" ($34 million). In those same commodities, Montreal could expect annual declines of $50 million, $46 million, $34 million and $37 million respectively.

Introduction

1.1 Scope and Objectives

The purpose of this report is to evaluate the implications associated with disruptions to the capacity of the Champlain Bridge. In the long run, the Champlain bridge in its current form is likely not viable and will likely need to be replaced either by another bridge or perhaps a tunnel. The recent Economic Action Plan of the federal government has identified the bridge as a key priority and has committed over $200 million to make improvements to the bridge over the next ten years. It is important to note that this investment is associated with maintaining the current bridge with expenditures of approximately $20M per year as opposed to giving serious consideration to replacing the bridge. The intent of this study is to show that there is a very strong case that it is better from a variety of perspectives to consider replacing the Champlain Bridge sooner rather than later.

This study should be considered "high level" in nature. Primarily, it is split into two sections. One is a traffic analysis that is focused on understanding the day-to-day implications on travel time of disruptions to the Champlain Bridge. MITL wishes to acknowledge the efforts of the Transport Quebec (MTQ) in actually running the traffic analysis scenarios on which results here are based. The second section focuses on the possibility that restrictions to the Champlain Bridge, such as its closure, would have the potential to reduce the economic output in the CMA of Montreal and surrounding regions. Impacts of

direct disruptions to Montreal's manufacturing sector are traced throughout the economy with indirect effects being linked to other sectors and regions. The economic impact analysis builds on the results of the traffic analysis and both shed light on the strategic importance of the Champlain Bridge to the region.

There are three primary types of traffic scenarios which are of interest in this report. One is with the complete closure of the Champlain Bridge. The key consideration here is that the Montreal area is in a seismically active region. In the context of a significant seismic event, there is the possibility that the bridge would need to be closed. Conceivably, it could take several years to construct a replacement. The 4-lanes open scenario is intended to capture the most likely state where the bridge develops a need for significant repairs/maintenance and needs to be partially closed. The 2-lanes open scenario is less likely and would represent a serious maintenance closure.

1.2 Description of the Bridge

The Champlain Bridge crosses the Saint Lawrence River and Saint Lawrence Seaway connecting the Montreal boroughs of Verdun and Le Sud-Ouest to Brossard on the South Shore. Construction of the bridge was first announced in 1955 and the structure was opened to the public in 1962. At that time, the city's existing bridges (Victoria, Jacques Cartier and Honore Mercier) had become inadequate to support the amount of traffic that developed between the growing South Shore suburbs and Montreal. For many years, a toll was charged to help finance the cost of the bridge.

The bridge, with approaches, is approximately six kilometres in length while from abutment to abutment it is about 3.4km. It is a steel truss cantilever structure with approach viaducts constructed of prestressed concrete beams supporting a prestressed concrete deck paved with asphalt. The bridge's particular construction, the effects of corrosion from road salt, and the high volume of truck and other traffic have contributed to its ageing. In the early 1990's, a costly replacement of the existing steel deck with an orthotropic steel deck was undertaken. The new deck was lighter and promised greater durability and load capacity as well as a longer life span. This major improvement was done mostly at night and did not require the closing of the bridge.

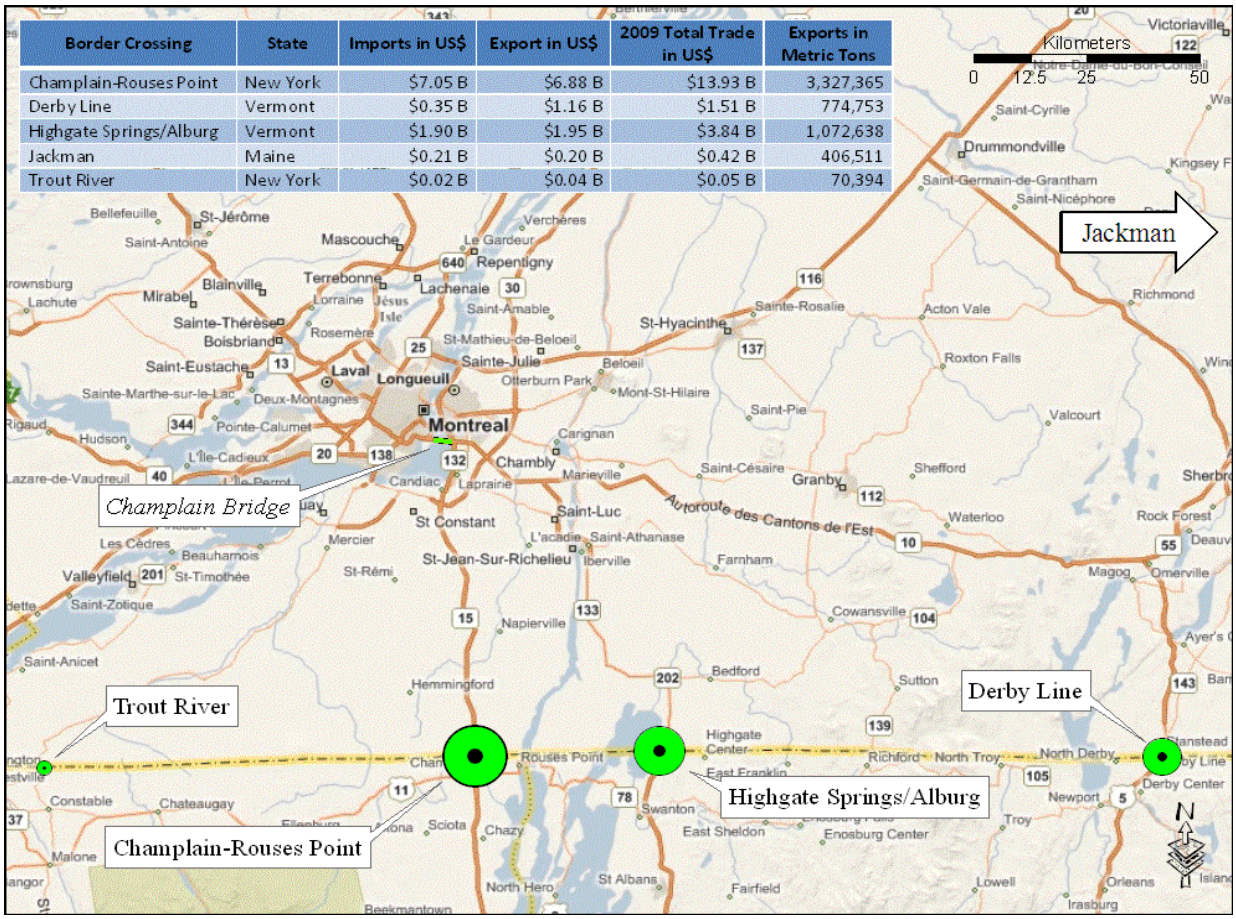
1.3 Usage of the Bridge

Currently, the bridge carries about 145,000 vehicles per day on six lanes making the bridge one of the busiest in Canada. An important attribute of the bridge is that it hosts reversible bus lanes. Associated bus services cater to an estimated 40,000 person trips per day. The bridge is a key element of the overall Montreal transportation network and any disruption to the bridge for even relatively small periods of time would have serious economic repercussions and would also cause negative social and environmental costs.

Exhibit 1 provides some indication of the strategic importance of the Champlain Bridge as a key lifeline for goods movement. The US border is less than 100km from the bridge and for obvious locational reasons the bridge plays a critical role in the movement of approximately $20B in traded goods annually. None of the other bridges in the vicinity are nearly so well-situated to permit interactions between

Montreal and the US border. All key roads, from the U.S. in particular, lead to the Champlain Bridge. The linkage of the bridge to Ontario is also strong.

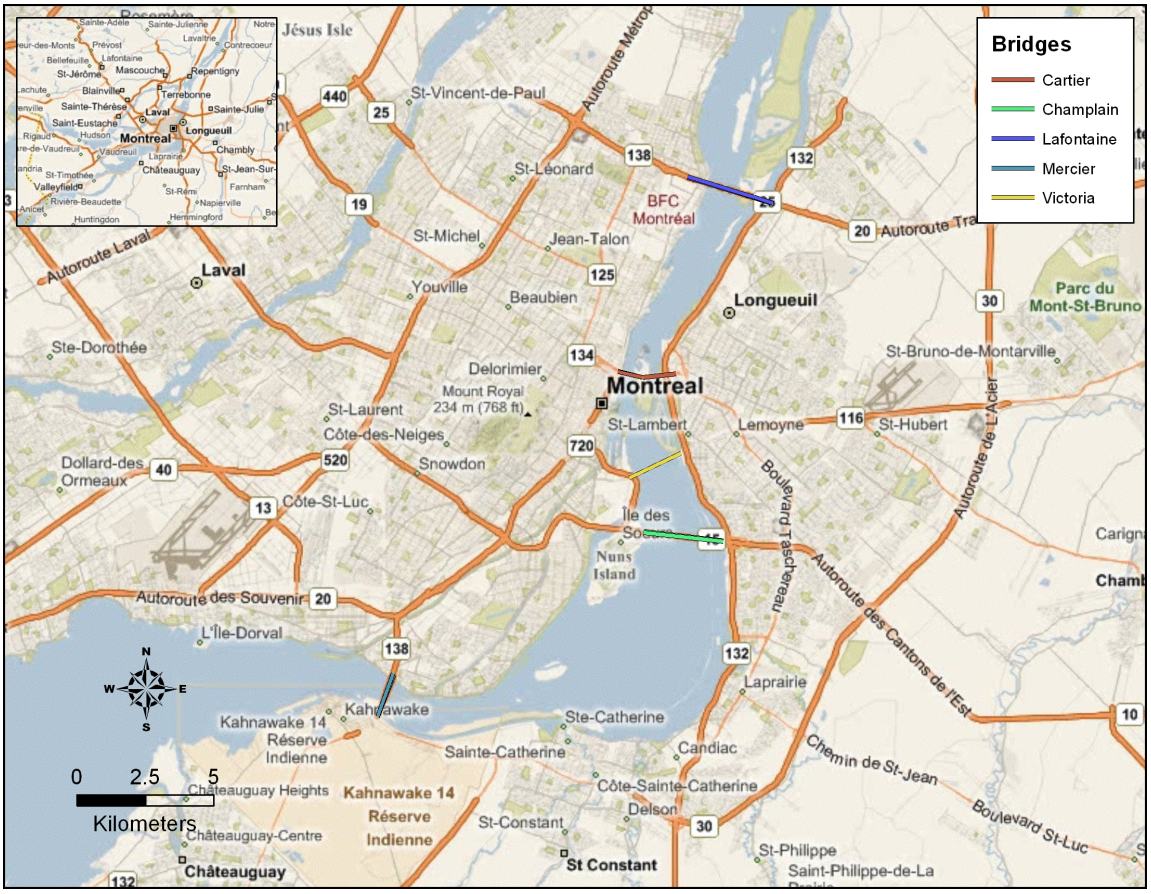
Exhibit 1: Trade Value at Key Quebec-U.S. Border Crossings (2009)



Border Crossing	State	Imports in US$	Export in US$	2009 Total Trade in US$	Exports in Metric Tons
Champlain-Rouses Point	New York	$7.05 B	$6.88 B	$13.93 B	3,327,365
Derby Line	Vermont	$0.35 B	$1.16 B	$1.51 B	774,753
Highgate Springs/Alburg	Vermont	$1.90 B	$1.95 B	$3.84 B	1,072,638
Jackman	Maine	$0.21 B	$0.20 B	$0.42 B	406,511
Trout River	New York	$0.02 B	$0.04 B	$0.05 B	70,394

Zooming in to the immediate study area in Exhibit 2 reveals the positioning of the Champlain Bridge relative to other key river crossings between the main island and the south shore. The Lafontaine crossing to the north is a Bridge/tunnel combination that handles a large volume of vehicles. This crossing is part of the Trans-Canada highway and provides an important link to Quebec City and the Eastern Townships of Quebec on the south side of the St. Lawrence River. One other important note, from the goods movement perspective, is that hazardous materials cannot be transported across at this point. Moving in sequence to the south, the next crossing is the Jacques Cartier Bridge which is the most important direct crossing into the central core of Montreal. This crossing is used by nearly 35 million vehicles per year and recently marked its 80th anniversary. To the south is the Victoria Bridge which was the first crossing of the St. Lawrence in the vicinity when it opened in 1859. The Victoria Bridge provides an important rail route but has lower vehicle capacities than the neighbouring crossings. During peak times, traffic can only travel in the peak direction on this bridge. Approximately 15km to the southwest, on the other side of the Champlain Bridge is the Honoré-Mercier Bridge which opened in 1934 and accommodates an estimated 28 million vehicle crossings annually.

Exhibit 2: Immediate Study Area and Primary River Crossings



Without the Champlain Bridge, the current demand for travel between Montreal and the South Shore cannot be satisfied. Since the reserved bus lane on the Champlain Bridge carries as many people as the subway line between Longueuil-Université de Sherbrooke and Berri-UQAM, the loss of the Champlain Bridge would imply beefing up the transit service between Montreal and the South Shore. The bridges linking Montreal and South Shore are already among the most congested road links in the Greater Montreal Region. When an incident reduces the capacity of one or the other bridges, it has already been observed that travel time between Montreal and South Shore becomes substantially higher than usual.

A Champlain Bridge closure would have major impacts:

- The transit service between the South Shore and Montreal would have to be reorganized
- A significant proportion of vehicular commuters and commercial vehicles would have to change the time of their departure and/or their mode of transport;
- In the long term, a loss of capacity between Montreal and the South Shore would reduce travel, change the location of activities and hinder business investment.

In this analysis, the objective is to examine such potential outcomes in more detail.

Literature Overview

This brief overview is intended to highlight the critical role that congestion plays in metropolitan areas such as Montreal. In recent decades, there has been a strong research emphasis on understanding passenger movements and the issues surrounding commuting and mode choice for commutes. Considerably less research has been directed at the issue of commercial vehicle movements, particularly as they relate to the intra-metropolitan context. In assessing scenarios relating to the Champlain Bridge, for example, it is tempting to say that firms in the area will suffer some incremental delay but that they will muddle through. In reality, businesses in many cases are operating on thin profit margins and are very focused on aspects that drive up the cost of doing business. A key link such as the Champlain Bridge can serve as a very visible reminder of the degree of commitment in keeping Montreal competitive for further business investment.

It is useful to bear in mind that one of the main reasons that large metropolitan areas exist is to facilitate an efficient means to organize production and generate economic and social benefits for society. In metropolitan areas firms can draw on large, diverse and specialized labour pools and the outputs of nearby suppliers to efficiently produce goods or deliver services. In other words, high concentrations of potential labour and material inputs and the ability to draw on these inputs all over the metropolitan area are very good things for the economic development of the area. One of the key impacts of

congestion is that it reduces the ability of firms to efficiently draw on as diverse a set of potential inputs and it thus drives up costs and reduces profitability (Weisbrod et al, 2001 and 2003).

To a large extent, the effects of restrictions on the Champlain Bridge would extend the problem of general congestion at large in Montreal. In the cases of many large metropolitan regions of North America, congestion is a serious problem with even optimal functioning of transportation links. The Texas Transportation Institute carries out a comprehensive process of annually estimating the costs of congestion in every major U.S. city (Schrank and Lomax, 2007). These costs are estimated only for peak periods. The estimates are based on two components: delay costs and fuel costs from delay. The delay costs are an estimate of the value of lost time in passenger vehicles and the increased operating costs of commercial vehicles. The delay cost calculation is driven by some assigned value for time and an estimate of time lost to delay. For commercial vehicles, an hour of time is valued on average at U.S. $77.10 per hour and U.S. $14.60 for passenger vehicles. Passenger estimates are based on occupancy of 1.25 persons per vehicle. Fuel costs are calculated mainly on the basis of average congestion speeds, the cost of fuel, and consumption of fuel at certain speeds.

For the U.S. as a whole, congestion costs based on this method are estimated at $78.2 billion dollars for 2005 and works out to an average of 38 hours per person per year. The methodology has been subject to some criticism because it calculates delay in reference to free-flow travel. The Texas Transportation Institute notes that the goal is not to suggest that a permanent free flow state is necessarily a desirable outcome and that free-flow speeds provide a very convenient and understandable base. Certainly, if a lower speed is used as the base then the costs of congestion would decline somewhat.

Transport Canada (2006) has provided a summary report which reviews estimations of this type that have been carried out in Canadian cities. For Montreal, they report on work carried out, coincidentally, by MTQ. Based on a 1998 origin-destination survey, an estimated cost of congestion of $779M per year was derived. In updated dollars, and using the same free-flow benchmark as the Texas Transportation Institute, this estimate for Montreal would easily exceed $1 billion dollars. Also, since then there is a strong likelihood that congestion has gotten worse anyway. Transport Canada notes that in percentage terms, 90% of costs relate to time lost, 7% relate to wasted fuel and 3% relate to imputed costs of extra emissions.

An interesting comparison case to consider in reference to the Champlain Bridge is the 2007 collapse of the Interstate 35 west bridge in Minneapolis in 2007. Interestingly, that bridge carried 140,000 vehicles per day with four lanes in each direction. The Champlain Bridge carries a similar volume but with fewer lanes. While the traffic volumes are similar, there are many important differences. The new replacement bridge in Minneapolis was opened little more than a year after the collapse but note that the length of the new bridge is less than half a kilometre. The main length of the Champlain Bridge is more than eight times longer. The impacts of the Minneapolis bridge collapse turned out to be relatively muted. Firstly, people and firms understood that a replacement would be in place quickly. Secondly, Minneapolis boasts numerous alternatives for crossing the Mississippi river. Traffic analysis carried out after the collapse (Zhu, 2010) showed that there were no fewer than seven arterial bridge crossings used as an alternative and two significant freeway alternatives. Moreover, Interstate 94, an

important alternative, had sufficient width that it could be restriped to add lanes. Overall, it is estimated that 1/3 of diverted traffic shifted to arterials, 1/3 used other freeway crossings and 1/3 of the former trips simply disappeared in the form of altered destinations, consolidated trips or changes in mode. One interesting note from the experience in Minneapolis was the minor shift to public transit. People much preferred to leave earlier and/or change their travelling route rather than shift modes.

The circumstances surrounding the Champlain Bridge need to be contrasted. As we've seen earlier, there is little reserve capacity on other bridge crossings and very limited arterial bridge links to pick up slack. The Champlain Bridge is already home to an important dedicated bus service which would need to be shifted to the Jacques-Cartier Bridge. Unlike Minneapolis, there would be no restriping possibilities to add lanes on other bridges and in fact a lane would disappear with the shifting of the bus service. Since the Champlain Bridge is much longer, any reconstruction would be over a period of several years which is long enough to potentially seriously impact businesses and the flow of goods.

3

Traffic Analysis

The purpose of this major section of the report is to analyze traffic scenarios relating to various restrictions on the Champlain Bridge. Initially, the situation is viewed from the point of view of reserve capacity on the various possible crossings of the St. Lawrence River. If the Champlain Bridge is removed from the equation then how much traffic can the other crossings handle? From there, the focus moves to actual traffic simulations using MOTREM. This is the traffic software used by MTQ. Results from these simulations are presented in a variety of tables, bar charts and maps to give a good overall impression of potential impacts. It is useful at the outset to note that these results are based on models and do provide some useful insight but these results should not be interpreted as fact.

3.1 Reserve Capacity of Other Area Bridges

One way of analyzing the predicament caused by a closure to the Champlain Bridge is to consider reserve capacities of all crossings between the south shore and the island. Reserve capacity refers to the number of additional vehicles that these other crossings, excluding the Champlain Bridge, could potentially carry if required. The maximum capacity of a lane of highway is in the vicinity of 2000 vehicles per hour per lane. Note that this maximum is encountered at a speed of about 55km/h. Higher speeds do not increase capacity because drivers increase their spacing with other vehicles to help avoid accidents.

As Exhibit 3 shows, the reserve capacity towards the island from the south shore in the AM peak period is only 3600 vehicles. This 3600 is spread out over the four other crossings. This reserve is a small fraction of the vehicle count (i.e. 17,400) that the Champlain Bridge carries toward the island during AM Peak. In fact, .all the reserve capacity between 5 AM and 10 AM (i.e. a very extended AM Peak) is not sufficient to carry all current Champlain Bridge users. In other words, the reserve capacity analysis suggests that it would not be physically possible for all people to get to their destinations on the island within a reasonable timeframe if they choose to drive. The system is better able to cope, in AM Peak, with trips from the island as the reserve capacity is a much higher 15,600. Nevertheless, subsequent traffic scenarios indicate that even this less onerous scenario is associated with greatly increased delay.

Exhibit 3: Reserve Capacity by Crossing (source MTQ)

	AM Peak		PM Peak	
Crossing	to island	from island	to island	from island
Lafontaine	800	2400	1500	700
Jacques-Cartier	1000	5800	3700	1800
Victoria	600	0	0	100
Mercier	1200	7400	5400	100
Total	**3600**	**15600**	**10600**	**2700**

In the PM Peak period, travel from the island to the south shore is would be severely hampered judging by the reserve capacity. Even with a peak period lasting five hours (2:30 PM to 7:30 PM), the other crossings cannot accommodate the current Champlain Bridge users. For the peak period itself, the reserve capacity is only 2700 versus 16,800 vehicles crossing the Champlain Bridge. Such constrained circumstances leave little room for an event such as the closure of the Champlain Bridge. Even against the peak direction, towards the island, the reserve capacity of the other bridges (10,600) is very close to the current flow of the Champlain Bridge (9800). As a result, PM peak would be quite slow in both directions based on reserve capacity. Note that the reserve capacity for the Victoria Bridge is zero in two instances because the bridge is closed to traffic in the non-peak direction.

While the Champlain Bridge would be closed in the event that reserve capacities of the other crossing were put to the test, it is interesting to review its own reserve capacity. Using four hour peak periods, the reserve capacity in the morning is 1158 in the direction of the island and 5069 towards the south shore. In the afternoon peak, the quantities are 1819 towards the south shore and 2642 towards the island. Like the other crossings between the island and the south shore, there is little excess capacity on the Champlain crossing.

3.2 Scenario Particulars

The reserve capacity analysis highlights the fact that the traffic situation with respect to crossing the St. Lawrence River is already very tight and that vulnerability in the wake of Champlain Bridge disruptions would be high. In order to better define the nature of the vulnerability, it is necessary to run detailed traffic simulations. These simulations were carried out by MTQ using their MOTREM traffic analysis package. This software represents all significant traffic links in the Montreal area and utilizes a series of

origin-destination matrices to keep track of where trips originate and where they terminate at various times of the day. A traffic assignment module is able to assign trips a path on the road network to simulate the process of getting from origin to destination.

MTQ noted in the early stages of this work that MOTREM has some limitations. In particular, MOTREM is not designed to do dynamic traffic assignments. While understanding the precise nature of this shortcoming is not required here, one of its implications is that MOTREM may underestimate the slowdowns that occur in moving from a congested situation to a very congested situation. Gridlock is a complex state for a traffic assignment algorithm to represent as there are many interdependencies between separate traffic links and complex queuing realities that need to be captured. To the extent that a model cannot mimic these realities, there is the potential for travel times in such low speed scenarios to be underestimated.

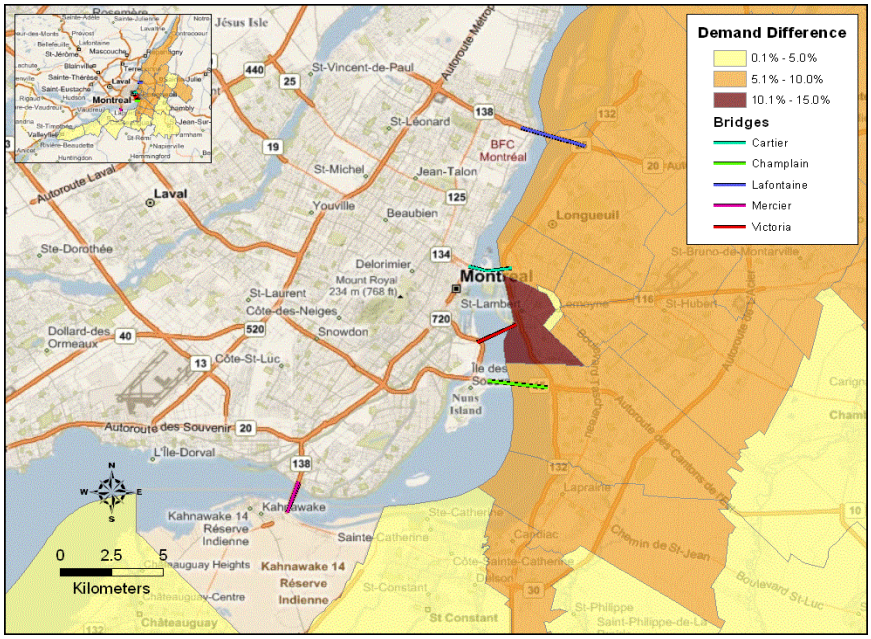
Having generally described that nature of the tool for the traffic simulations, it is possible to outline some specifics of the various scenarios. In the event that the Champlain Bridge is closed, three peak direction lanes would be lost (six lanes all together). One lane on the Jacques Cartier Bridge would be used to recreate a lost bus lane. The loss of this lane for regular traffic would further reduce the peak period capacity by approximately 5800 vehicles. In the circumstance with only two lanes on the Champlain Bridge open, the assumption is that the reserved bus lane would again need to shift to the Jacques Cartier Bridge to permit bi-directional vehicle traffic on the Champlain Bridge. Finally, if four lanes on the Champlain Bridge are open, the reserved bus lane would remain on the Champlain Bridge and would travel in the peak direction along with two general traffic lanes and one general traffic lane going counter to the peak direction. In this circumstance, it is important to note that buses would be passing trucks and other vehicles in the opposing direction much as they would in a two lane rural highway. In this case though, the traffic volumes are much higher, so the potential for serious accidents is greatly increased.

The revised bus lane that would be moved to the Jacques Cartier Bridge would likely have the following route. It would begin at the intersection of Highway 10 and Taschereau Boulevard. This path consists of travelling on Taschereau Boulevard (east of Highway 10) to the Bridge. After crossing the Jacques Cartier Bridge, the lane would continue on Boulevard Ville Marie through Highway 720 and exit onto Mansfield Street. The reverse path back towards the south shore would be very similar.

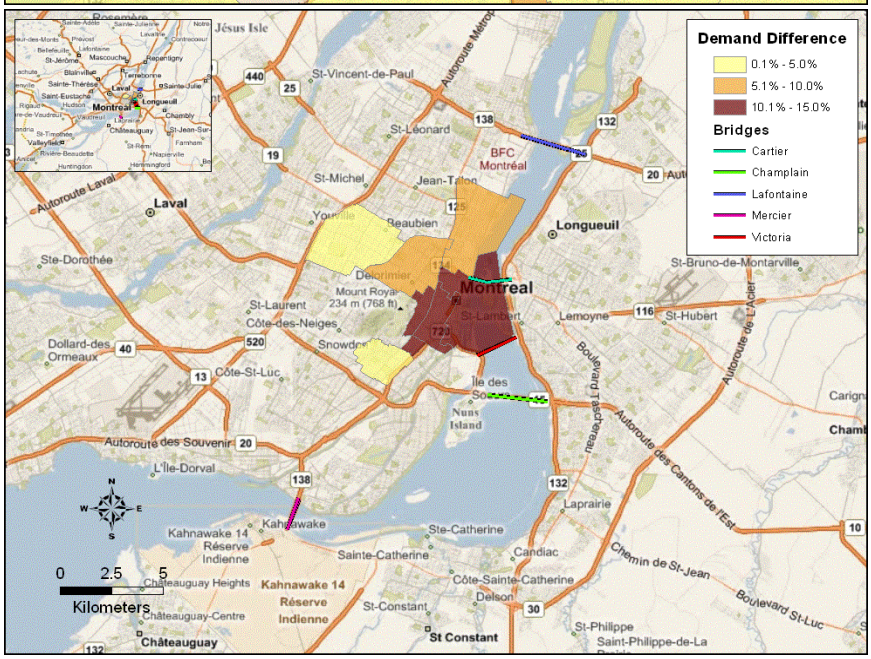
The traffic model is run for five distinct day parts (early AM, AM Peak, daytime, PM Peak and late PM). In this report, the main focus though is on what occurs during the two peaks. It is assumed that the peak periods on the river crossings would not last more than four hours in any one direction. For the off peak periods MOTREM is used but the length of the off-peak periods is reduced to account for a lengthening of the peak periods. Under the complete closure of the Champlain Bridge, the off-peak day period is reduced by one hour: 9:30 AM to 3:00 PM instead of 9:00 AM to 3:30 PM.

Exhibit 4: Percent of Trips Shifted to Public Transit for (A) AM and (B) PM Peaks

A.



B.



Some trips would need to be shifted to public transit in the event that the Champlain Bridge was partially or totally out of service. Exhibit 4 illustrates the assumptions that were made in this regard for the AM and PM peaks. In the former, it was assumed that most locations on the south shore would need to undergo some shift to transit. The largest shift is hypothesized to occur in that area of the south shore in closest proximity to the Victoria and Cartier bridges and with the best access to the metro system. In the PM peak, the relevant demand shift occurs largely in the core of Montreal and is thus much more concentrated. This pattern is consistent with PM work trips that originate in the core and terminate at the place of residence on the south shore.

Exhibit 5: Total Assumed Vehicle Trips by Period, Scenario and Direction

period	scenario	total	s to n	n to s	s to s	n to n
AM Peak	open	1,354,903	93,202	34,415	237,699	989,587
	4 lanes open	1,354,903	93,202	34,415	237,699	989,587
	2 lanes open	1,342,349	80,648	34,415	237,699	989,587
	closed	1,336,152	74,451	34,415	237,699	989,587
PM Peak	open	1,754,852	48,404	96,522	334,378	1,275,548
	4 lanes open	1,754,852	48,404	96,522	334,378	1,275,548
	2 lanes open	1,741,701	48,404	83,371	334,378	1,275,548
	closed	1,736,101	48,404	77,771	334,378	1,275,548

Exhibit 5 illustrates various segmented vehicle trip totals for the Montreal area. In each case, these are the actual trip totals that were utilized in the traffic scenarios. For the entire metropolitan area, the totals are estimated at approximately 1.35 million vehicle trips during the AM peak period and 1.75M during PM peak. These totals are based on four hour peak periods to represent the fact that any alterations to the Champlain Bridge would effectively stretch the peak periods.

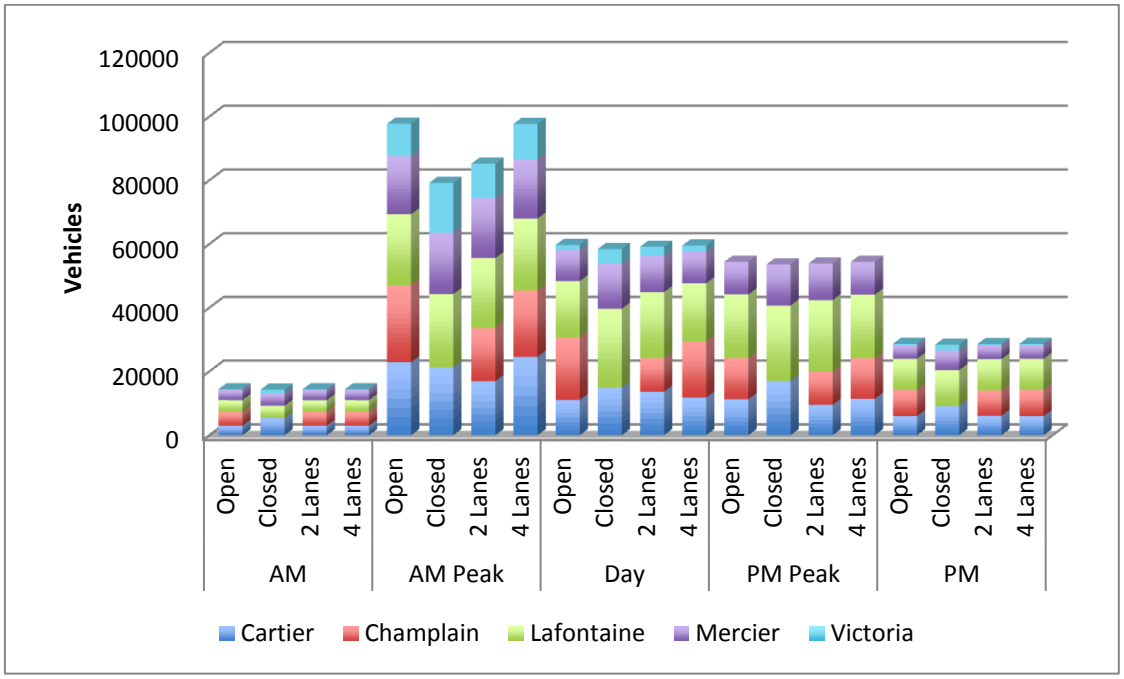
The “s to n” column provides the count of vehicle trips for all movements from the south shore towards the island and which therefore need to cross the St. Lawrence. Note that the AM peak “closed” totals (74,451) are only 80% of the “bridge open” totals (93,202). These totals reflect a diversion of those trips to public transit. Meanwhile, during PM peak, no diversion of trips is assumed for trips toward the island. As would be expected, this column shows that the flow of vehicle trips towards the island is much larger during AM Peak. For the “n to s” column, trips to the south shore are being captured and the results are essentially inverted from the prior column. Transit re-assignment takes place during PM peak instead and the totals are lower in AM peak. The final two columns depict trips that do not need to cross the river. They illustrate how trips that remain internal to the south shore constitute about 25% of the number of trips that are internal to the rest of Montreal.

3.3 Traffic Results by Bridge/Tunnel Crossing

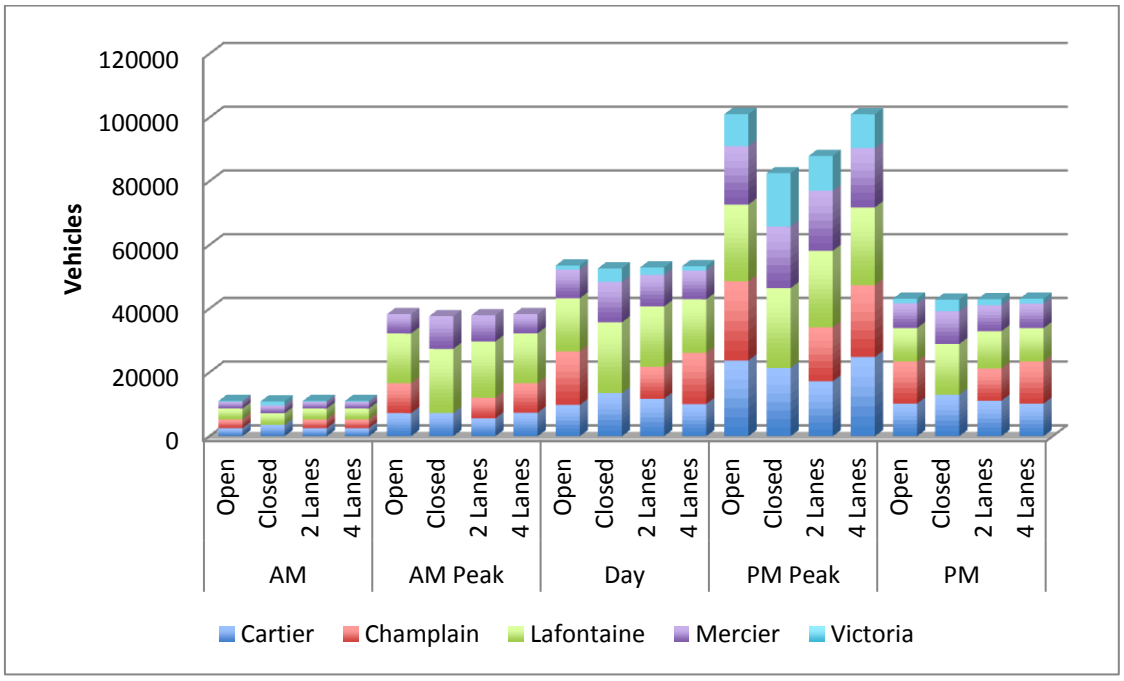
One of the best ways to get an overall sense of the traffic scenarios that have been conducted is multi-dimensional bar charts for each river crossing. This series of bar charts is represented in Exhibits 6 to 12 and give a good sense of how travel on each of these bridges would be affected. Granted that the implications of Champlain Bridge disruptions would affect far beyond the bridges themselves, but these are the most important links in the road network for trips between the south shore and the island.

Exhibit 6 provides an excellent overview of how traffic might allocate itself to the various crossings by time of day and also by scenario. Note that during the peak periods, nearly 100,000 crossings are being made by private vehicles in a given direction and that reductions from these amounts during the peak periods reflect the assumed shift to transit. The graphic also shows how the other crossings “pick up the slack”, in terms of traffic volumes, depending on restrictions imposed by the state of the Champlain Bridge.

Exhibit 6 Total Bridge Volumes (A) Toward and (B) Away from the Island by Scenario



A.



B.

The top graph in Exhibit 6 shows crossings toward the island while the bottom one shows crossings away from the island. Of the various crossings, the Lafontaine Bridge/Tunnel is a "workhorse" crossing that consistently is required to handle quite a bit of traffic at all times and in both directions. The Champlain, Cartier and Mercier Bridges carry their most cars at peak times in the peak direction. The Victoria Bridge, of course, only operates in the peak direction at certain times. In general, there appears to some proportional sharing of the burden imposed by the Champlain Bridge, tempered by the fact that

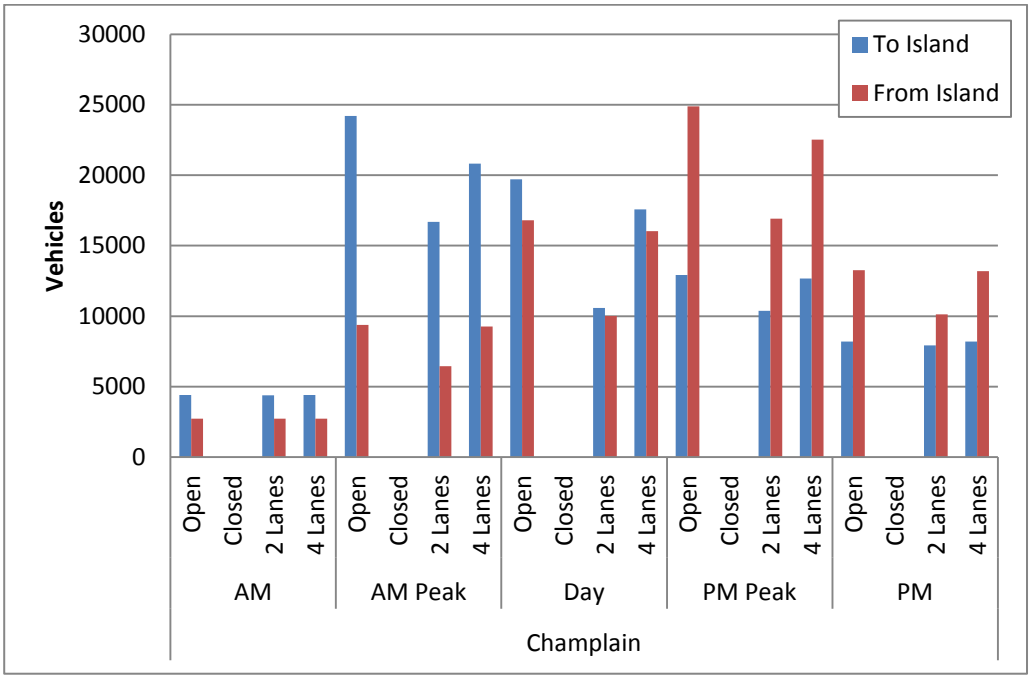
the alternatives have limited reserve capacity. It is interesting to note, for example, that the Lafontaine Crossing picks up more slack against the peak direction in the AM Peak than it does in the peak direction. Presumably, this is an issue of reserve capacity. While Exhibit 6 is an overview graphic, Exhibits 7 to 11 examine each crossing in detail.

Exhibit 7 below represents what would happen on the Champlain Bridge across the various scenarios. Note initially that a bridge closure implies no traffic volumes whatsoever and also no travel times being represented. Note that the "blue" times and volumes are larger in the AM Peak and the "red" ones are larger in the PM peak. This pattern repeats across the bridges and is consistent with the flow of traffic to and from the south shore depending on the time period. The AM set of scenarios, dealing with the early morning hours after midnight is the best representation of what the "free flow" state on the Champlain Bridge is like. The results suggest that a crossing in less than 2 minutes is possible when traffic is a non-issue. Even the fairly extreme two lane scenario is not forecast to have any significant discernable impact on travel times at that time of the overnight.

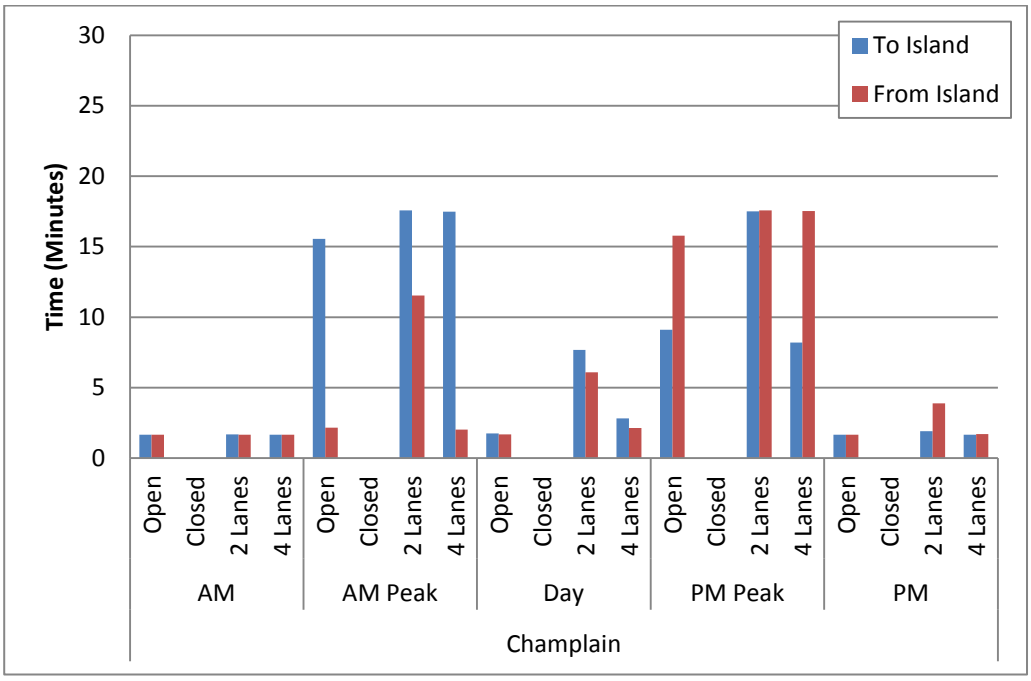
In the AM peak, travel time across the bridge is represented as swelling to seven or eight times the free-flow times. The key observation to be made with the AM Peak scenarios is that even when the bridge is open, the crossing times are very slow. The two lane and four lane scenarios and associated inconvenience do provide some incremental increase to travel times and decreases to the amount of traffic which cross there. Interestingly, in the AM peak, the biggest net impacts to travel time are forecast to be in the direction of the south shore away from the island. It is the trips toward the south shore that actually have room to get slower, in the world of the traffic model, and they do. While there is little impact in that context for the four lane scenario, the travel time swells to about 11 minutes when there is only one lane moving toward the south shore which is the case in the two lane scenario. In general, the scenarios have the expected impacts on travel volumes crossing the Champlain Bridge.

For the PM peak and PM periods, the patterns are largely a mirror image of what is seen in the corresponding AM periods. The main difference is that the PM period up until midnight is associated with more vehicle movements than the early AM period. Also, the "two lane" scenario is having more impact in the later PM time period than in the early AM. There are impacts in the "day" period between the peaks but those impacts are not associated with any major congestion.

Exhibit 7: Champlain Bridge - (A) Volumes and (B) Travel Times by Scenario and Direction



A.

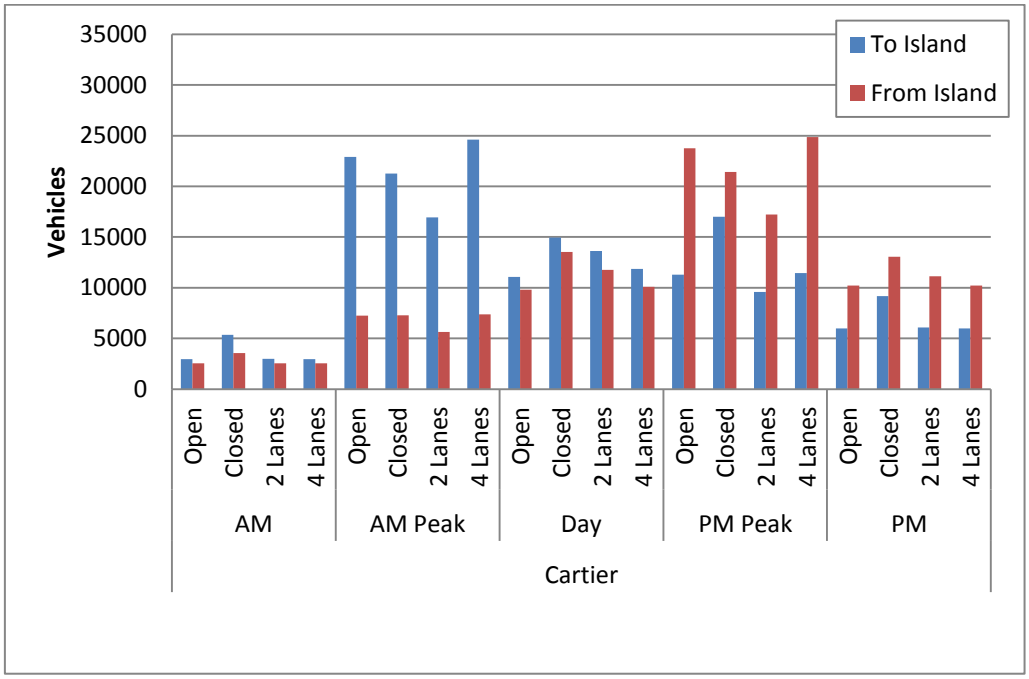


B.

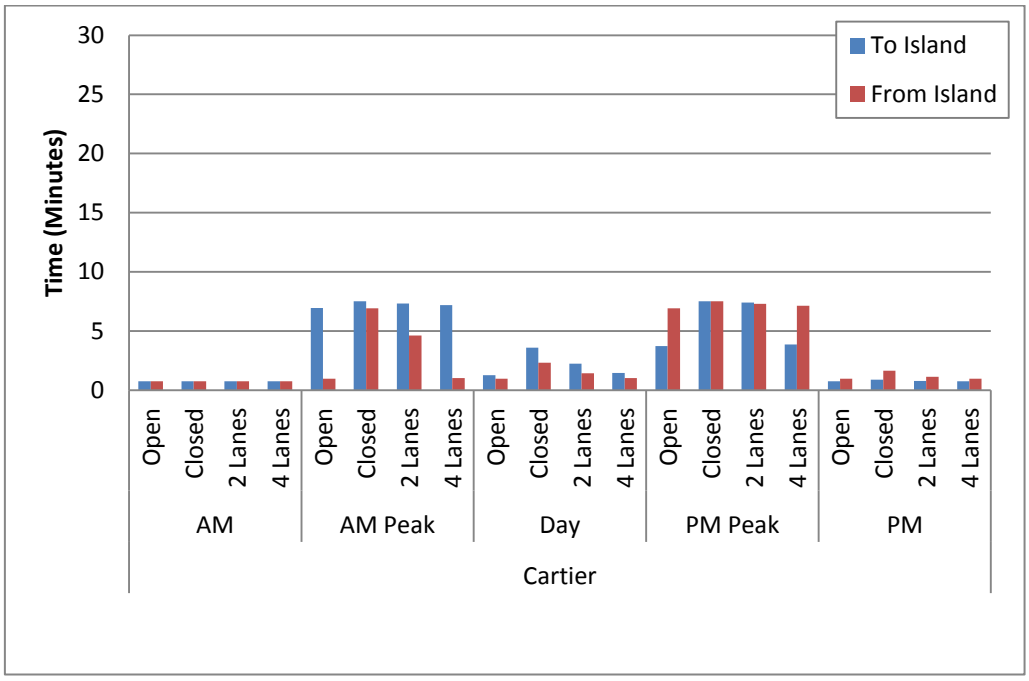
The patterns for the Cartier Bridge (Exhibit 8) show some similar themes. Free flow crossing times in the early AM appear to be a minute or less while peak period crossing times are in the range of 7-8 minutes. These are similar ratios to the ones noted for the Champlain Bridge. The patterns of travel volumes to and from the island by time of day are as would be expected. At the peak times and in the peak direction it is noteworthy that traffic volumes are highest for the four lane scenario, lowest for the two lane scenario and then increase again when the Champlain Bridge is closed. The transit assumptions underlying Exhibit 3 show that the Cartier Bridge will be most affected in terms of vehicle traffic if a large number of vehicle trips switch to transit. For the 4-lane case, no transit shift is assumed but for the 2-lane case a significant shift is assumed and this reduces vehicle trips. When the Champlain Bridge is closed, however, many more vehicles will have no choice but to divert across the Cartier Bridge so this drives up volumes again.

The other big change in the 2-lane and closed scenarios is that a bus lane is added to the Cartier Bridge and thus takes away a lane of traffic in the non-peak direction. In comparing the AM peak travel times for the 4-lane and 2-lane scenarios towards the south shore (in red), this change is apparent. The travel time toward the south shore increases from about one minute to almost five minutes because there is only one lane left travelling in that direction. Associated with that much longer crossing time is a smaller overall volume of cars crossing the bridge in that direction.

Exhibit 8: Jacques Cartier Bridge - (A) Volumes and (B) Travel Times by Scenario and Direction



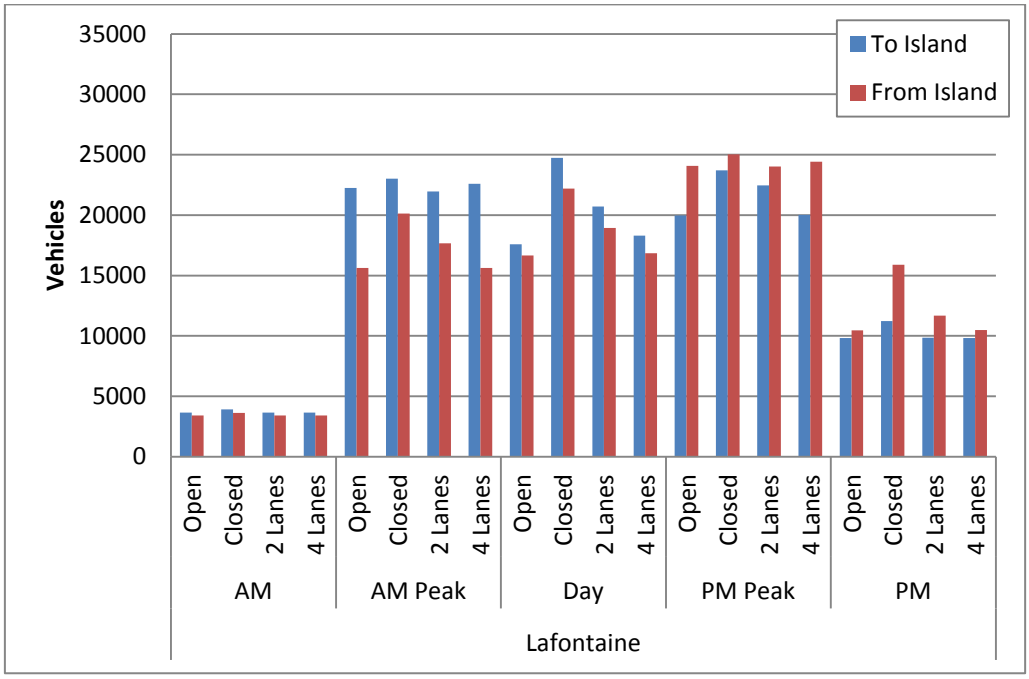
A.



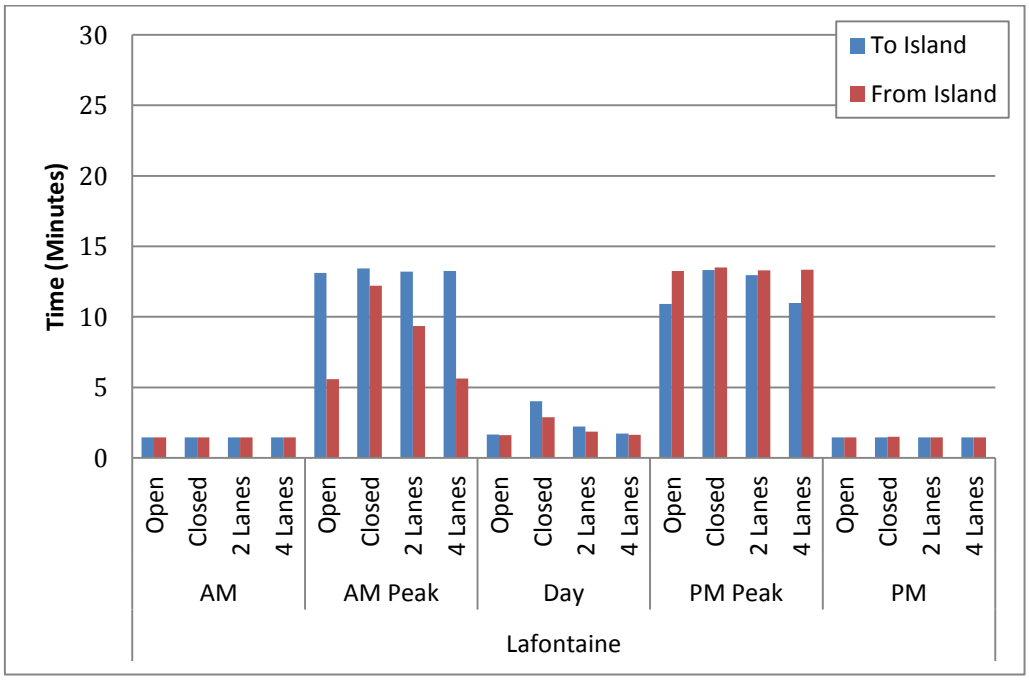
B.

The Lafontaine Bridge/Tunnel combination (Exhibit 9) handles a large amount of traffic across all the scenarios. Traffic levels are generally represented as highest in the PM peak. Similar ratios between peak and free flow travel times are applying for this crossing. Regardless of the scenario in the peak directions, a similar crossing time of about 13-14 minutes is forecast to apply. While peak direction scenarios are shown to be slow irrespective of the scenario, there are more net changes in the non-peak direction by scenario, especially as it relates to AM peak travel away from the island. Unlike the Cartier Bridge, no bus lane is imposed in any scenario relating to this crossing.

Exhibit 9: Lafontaine Bridge/Tunnel - (A) Volumes and (B) Travel Times by Scenario and Direction



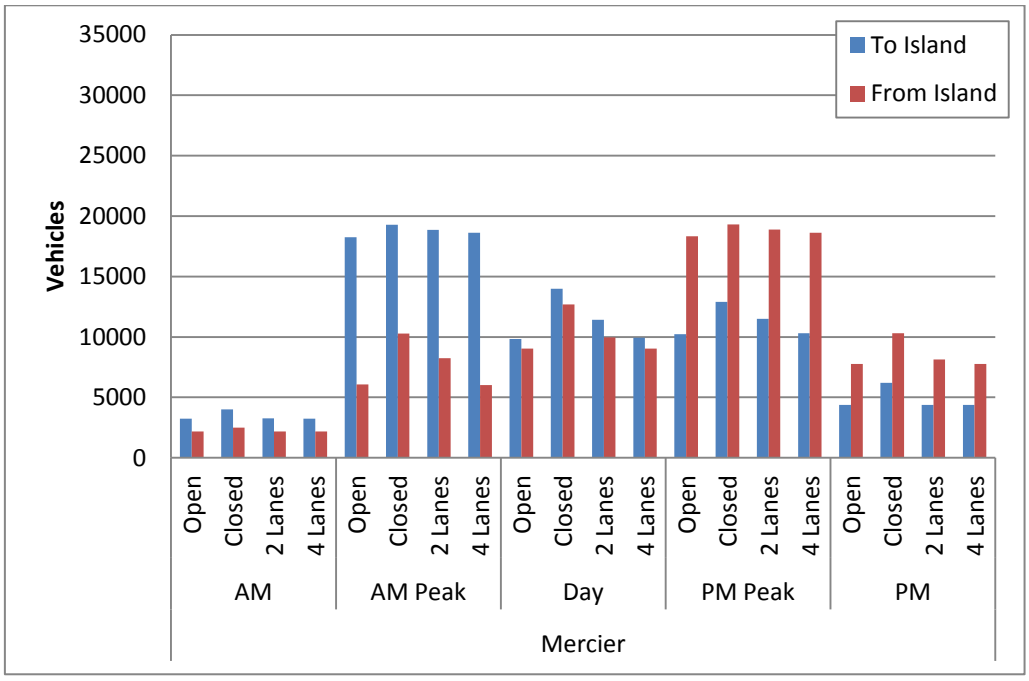
A.



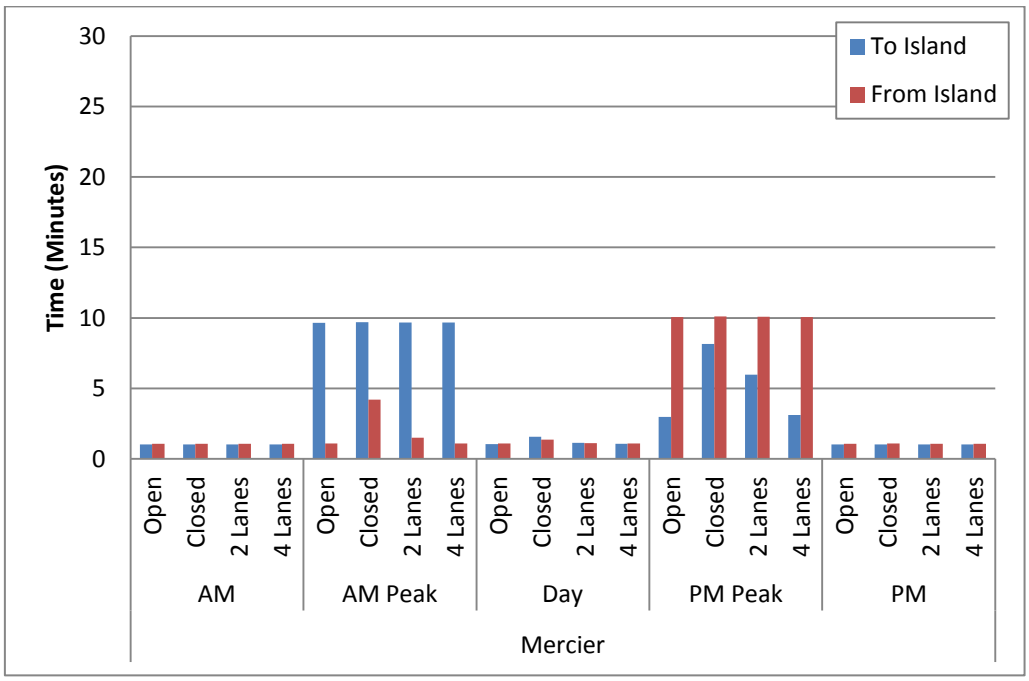
B.

The Mercier Bridge, in its pattern of results (Exhibit 10), shows the same indicators of fairly significant congestion. There is no peak direction scenario that strongly boosts the travel times any further than ten minutes. Ten minutes is about five times the free flow travel time. With respect to travel in the non-peak direction, the PM peak travel toward the island is much more significant than the AM peak travel away from the island.

Exhibit 10: Mercier Bridge - (A) Volumes and (B) Travel Times by Scenario and Direction



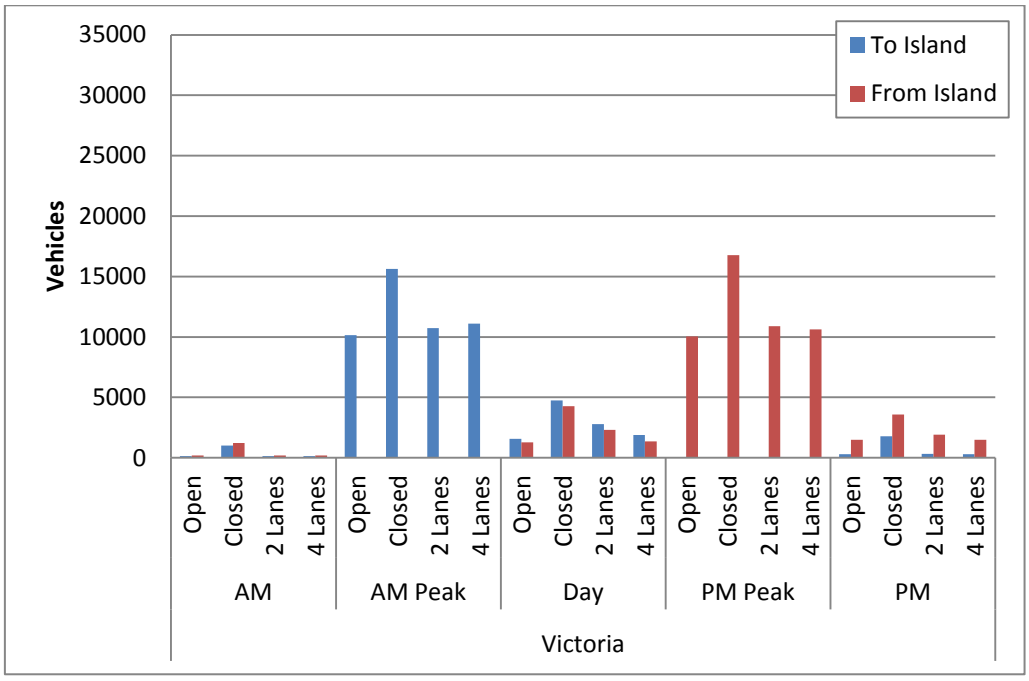
A.



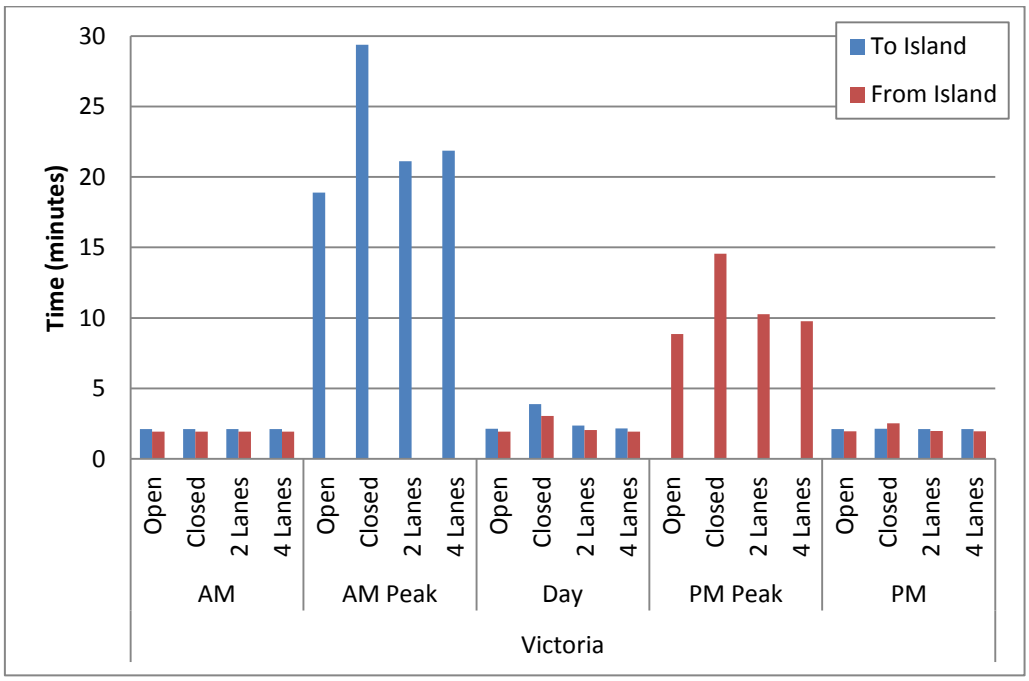
B.

The scenario patterns associated with the Victoria Bridge (Exhibit 11) are distinct in that only peak direction traffic is permitted at peak times. In the AM peak, only trips toward the island are allowed and in the PM peak it is reversed. AM peak travel times by scenario are uniformly higher than corresponding travel times in the PM peak even though the volumes are similar in both time periods. The forecast crossing times in the AM Peak if the Champlain Bridge is closed balloon to nearly 30 minutes.

Exhibit 11: Victoria Bridge - (A) Volumes and (B) Travel Times by Scenario and Direction



A.

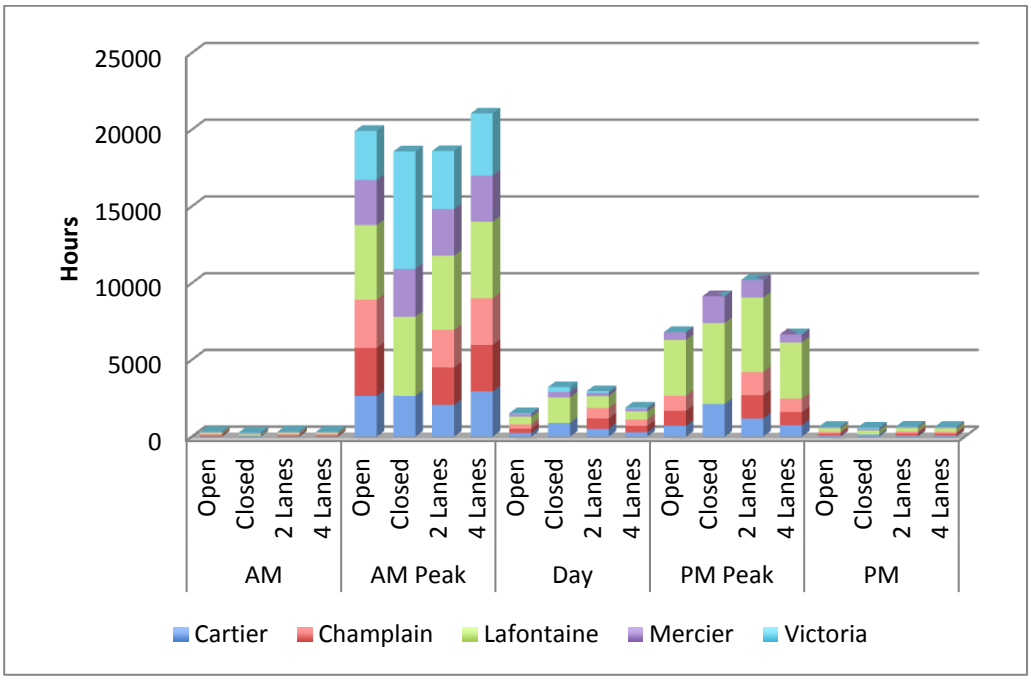


B.

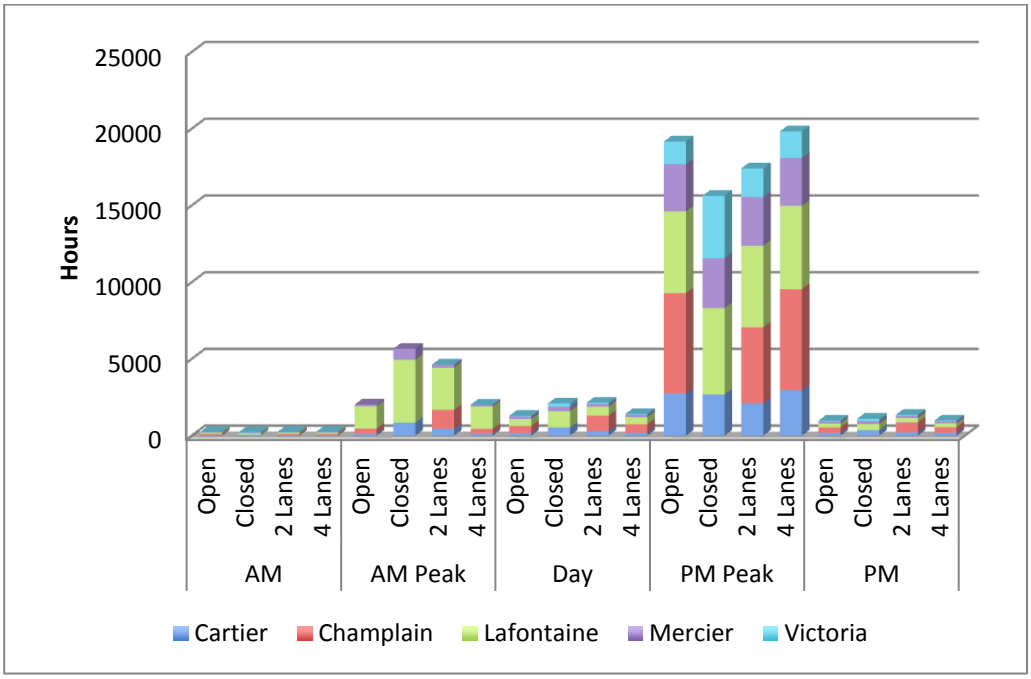
In the Appendix, some additional "bridge specific" information is supplied in the form of estimated hourly traffic counts by crossing. In Exhibits 41 to 45 the top (A) figure portrays traffic flows toward the island while the (B) figure portrays flows away from the island. Among other things, these Exhibits confirm that the Lafontaine crossing is consistently the most busy and has more uniform peaks in both directions.

Exhibit 12 paints a picture of the aggregate time and effort involved in bridge crossings by scenario. It is set up in a similar way as Exhibit 6 except that prior graphic was focused on travel volumes. Note that the closed and 2-lane AM/PM peak scenarios do not include the extra trips allocated to public transit. In general, the maximum time and effort in crossing the river is very much associated with peak directions at peak times. Consider also that changes to the Champlain Bridge are shown to have large percentage impacts on travel in the non-peak directions. There is the possibility that such percentage changes in the peak directions are being underestimated by MOTREM.

Exhibit 12: Aggregate Vehicle*Hours Crossing Bridges (A) Toward and (B) Away from Island by Scenario



A.



B.

In Exhibit 13, efforts are translated into actual vehicle minutes travelled but for entire trips rather than just bridge crossing times. In interpreting this table, the trip totals from Exhibit 4 need to be considered as the public transit trip reallocations are playing a role. With the 4-lane scenario, no public transit diversions were assumed. In almost every case, the VMT increases in comparing 4 lanes to the fully open scenario.

Exhibit 13: Aggregate Vehicle Minutes Travelled by Period, Scenario and Direction

period	scenario	total	s to n	n to s	s to s	n to n
AM Peak	open	32,525,718	5,294,890	1,458,689	2,564,417	23,207,722
	4 lanes open	32,679,810	5,449,621	1,460,629	2,570,397	23,199,163
	2 lanes open	32,100,417	4,715,270	1,681,273	2,548,339	23,155,535
	closed	32,348,889	4,699,866	1,926,526	2,600,535	23,121,962
PM Peak	open	41,505,791	2,429,174	5,851,507	3,576,409	29,648,701
	4 lanes open	41,611,103	2,441,670	5,959,644	3,579,720	29,630,069
	2 lanes open	41,134,239	2,814,006	5,213,409	3,543,114	29,563,710
	closed	41,412,491	3,036,576	5,199,095	3,609,330	29,567,490

A clearer picture emerges when the aggregate VMT are divided by the trip totals to reveal an average trip duration for the various trip types as is shown in Exhibit 14. One thing that immediately stands out is that trips involving a river crossing on average are much longer in duration than those that don't. The "s to n" and "n to s" columns show a progressive increase in average trip time as the scenario becomes more restrictive to traffic. Clearly, the time impacts would be worse without diversion to transit.

Exhibit 14: Average Trip Duration by Period, Scenario and Direction

period	scenario	total	s to n	n to s	s to s	n to n
AM Peak	open	24.01	56.81	42.39	10.79	23.45
	4 lanes open	24.12	58.47	42.44	10.81	23.44
	2 lanes open	23.91	58.47	48.85	10.72	23.40
	closed	24.21	63.13	55.98	10.94	23.37
PM Peak	open	23.65	50.19	60.62	10.70	23.24
	4 lanes open	23.71	50.44	61.74	10.71	23.23
	2 lanes open	23.62	58.14	62.53	10.60	23.18
	closed	23.85	62.73	66.85	10.79	23.18

The largest travel times are seen in the peak direction but the largest net and percentage changes are opposite to the peak direction. Specifically, in the AM Peak there is a 32% average increase to travel times away from the island if the Champlain Bridge is closed and a 15% increase if it is reduced to two lanes. In PM Peak, there is a forecast 25% increase in travel times towards the island with Champlain closed and a 15% increase if there is a reduction to two lanes.

The results suggest that trips to the island in the PM Peak will be almost as severe, in the event of Champlain restrictions, as the AM peak. Trips away from the island to the south shore will be quite severe in the AM Peak also.

Earlier estimates carried out by MTQ revealed that the impact of a bridge closure to current Champlain users would be fairly severe during AM Peak. Estimates suggested that their VKT would increase by 11% while travel time would increase by 25%. This earlier MTQ work also showed that Champlain Bridge users make relatively longer trips which account for 4.1% of regional vehicle kilometres and 4.4% of regional vehicle hours, more than double their share of trips.

3.4 Mapped Impacts by Scenario

The purpose of this section is to show a variety of mapped outcomes generated by the Champlain closed and 2-lane scenarios. Four types of maps are shown: velocity maps, travel time increase maps, travel time index maps and finally maps which illustrate changes in travel time index. Each of the maps is based on data that were taken or derived from large travel time matrices that were a by-product of all the scenarios run by MTQ. These travel time matrices captured all the travel times between all the combinations of approximately 1500 points in the CMA of Montreal. For each of the maps below, two particular points are emphasized: a downtown point to highlight the effort involved in making a trip to the downtown from any point in the CMA, and a south east point to highlight the effort to exit the CMA in the direction of the U.S. These reference points show up as turquoise coloured stars on each map.

3.4.1 Velocity Maps

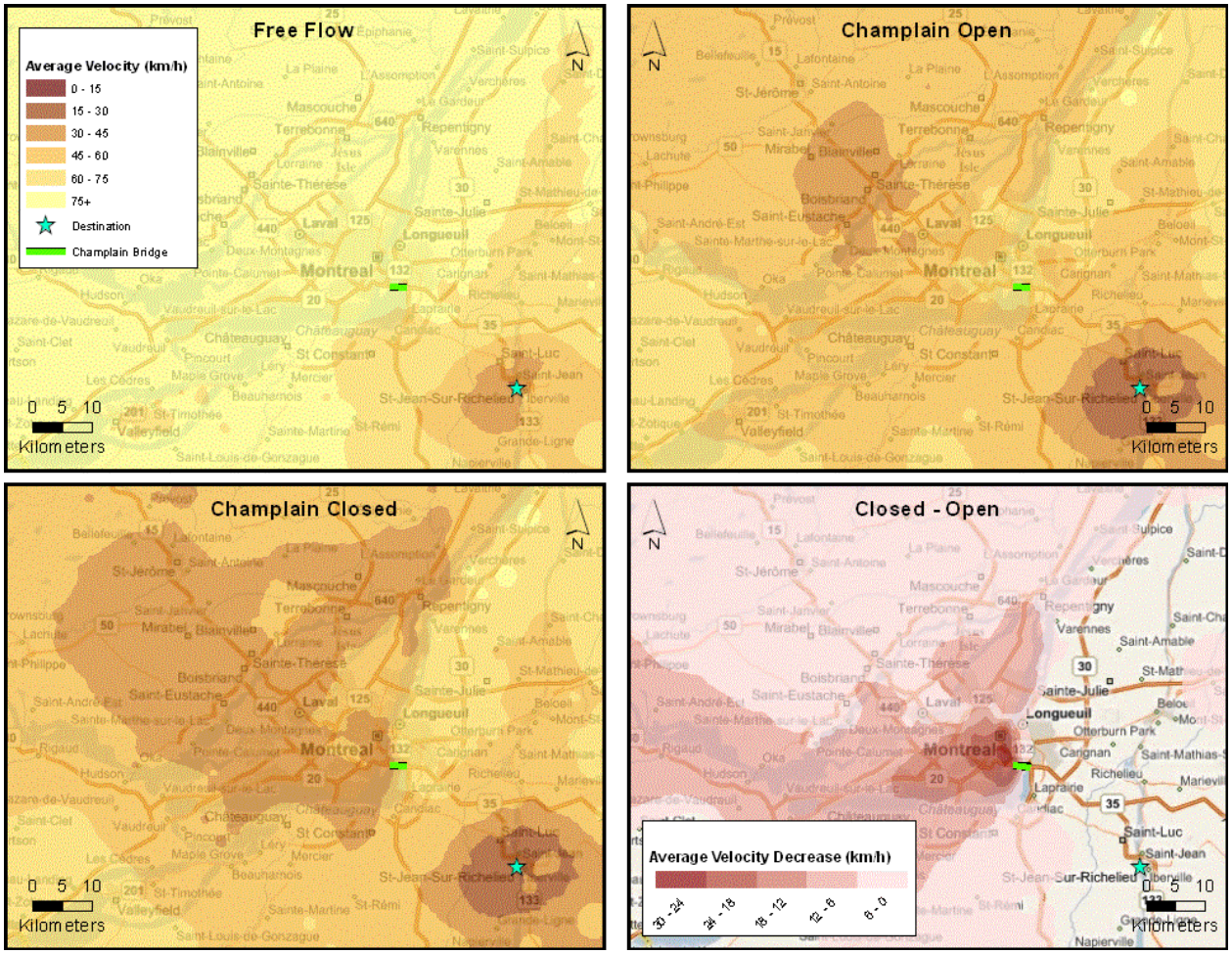
Exhibit 15 illustrates the average velocity that applies in AM peak for a trip to the downtown under varying scenarios. The first three maps are also based on a common velocity scale with six categories. The first thing to note is that the free flow map looks much more yellow than the Champlain Open or Champlain Closed scenarios. The traffic model is suggesting that there is a bigger difference between free flow and the two AM Peak scenarios than there is a between the two AM scenarios themselves. In free flow, there are large areas where the average velocity exceeds 60 km/h. In the open and closed scenarios, there are large areas where the average velocity is less than 30 km/h. In comparing the open and closed scenarios, the main points to notice are that the dark areas, mostly on the side of the south shore, get larger. The most precise picture of velocity decreases is shown on the fourth map. As a trip originates further from the Champlain Bridge on the south shore, average velocity for the trip seems to decrease more. Some trips have their speed reduced by approximately 15km/h. This is a fairly significant decline for trips that would not have a high average velocity even with the bridge open.

Exhibit 15: Average Velocity Patterns for Trips to Downtown (AM Peak)

Exhibit 16 below applies also to AM Peak but considers velocity patterns for trips against the peak direction towards the U.S. This set of maps, against the peak direction, actually portrays a more dramatic impact than was the case in Exhibit 15. In comparing the Champlain closed to open map, it is clear that the area of Montreal where average speeds would shift down to the 30 to 45 km per hour class is greatly expanded. With the Champlain Bridge closed it appears that it would be much more of a travel ordeal to get from the island to the south shore. There are significant areas where an originating trip could expect a decline in average speed of up to 30 km/h.

In the Appendix, the same two maps are shown for PM Peak (Exhibits 36 and 37). The maps suggest a similar theme where the strongest net changes forecast by the traffic model are counter to the peak direction.

Exhibit 16: Average Velocity Patterns for Trips to U.S. (AM Peak)



3.4.2 Travel Time Increases

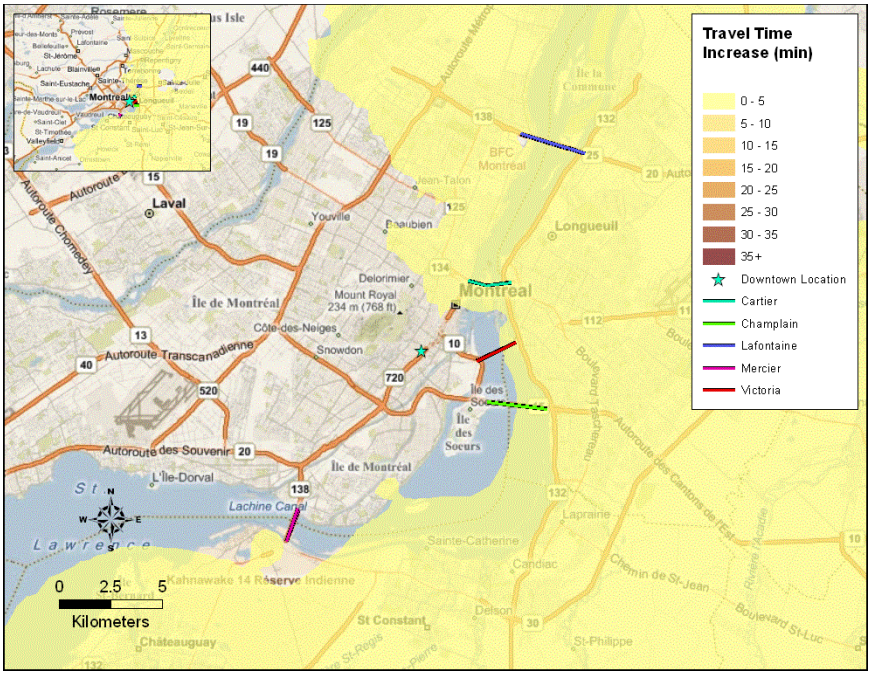
The following series of maps focus on the scenarios where the Champlain Bridge is reduced to two lanes or closed. The maps based on the 4-lane Scenario are not shown here as the impacts are more muted in comparison. These are maps of travel times increases induced by some restriction of the bridge. Areas of Montreal that are not coloured actually show no change in travel times or very minor reductions due to the bridge scenarios. The focus instead is on the areas that experience some significant travel time increase when the "open" scenario is compared to the "restricted" scenario. Each Exhibit is shown as a two map combination: the top map (A) will always relate to the AM peak period and the bottom map (B) will always relate to the PM peak period.

Exhibit 17 illustrates increases in travel time for trips to the downtown in the event that the Champlain Bridge is reduced to two lanes. Interestingly, the big increases are represented during PM peak mainly because the model interprets more leeway for added congestion to occur. Large areas on the south shore are having incremental delays of 10 to 15 minutes depending on the origin of the trip. The increases for AM peak are represented as generally less than five minutes. Note that there is some

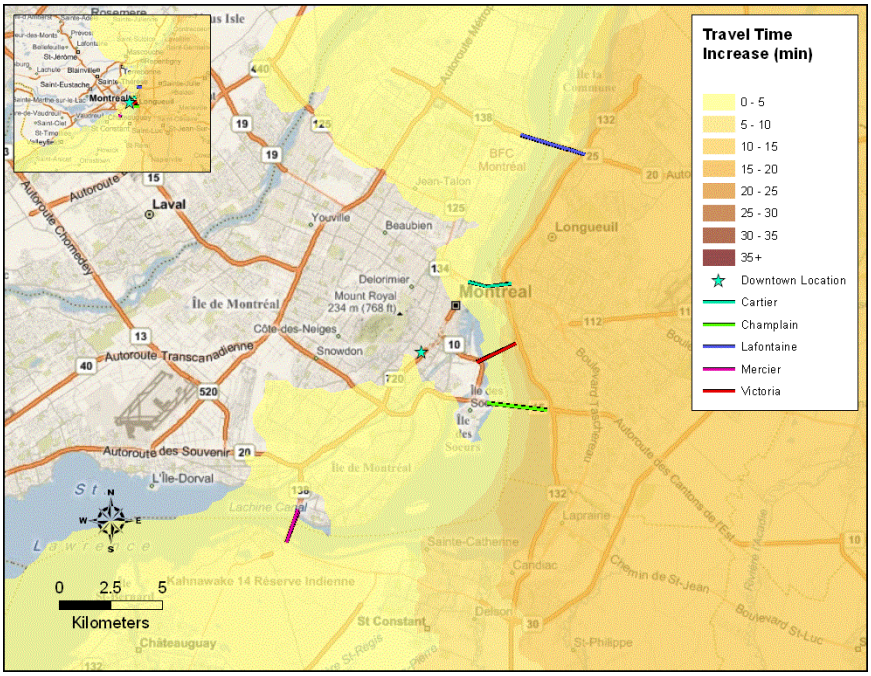
spillover of delays for trips originating on the island and which do not even utilize any bridge crossings to get to the downtown. From the pattern, it appears that the Lafontaine crossing is a preferred alternative.

Exhibit 17: Travel Time Increases to Downtown (2 Lanes Open - Open) for (A) AM and (B) PM Peaks

A.



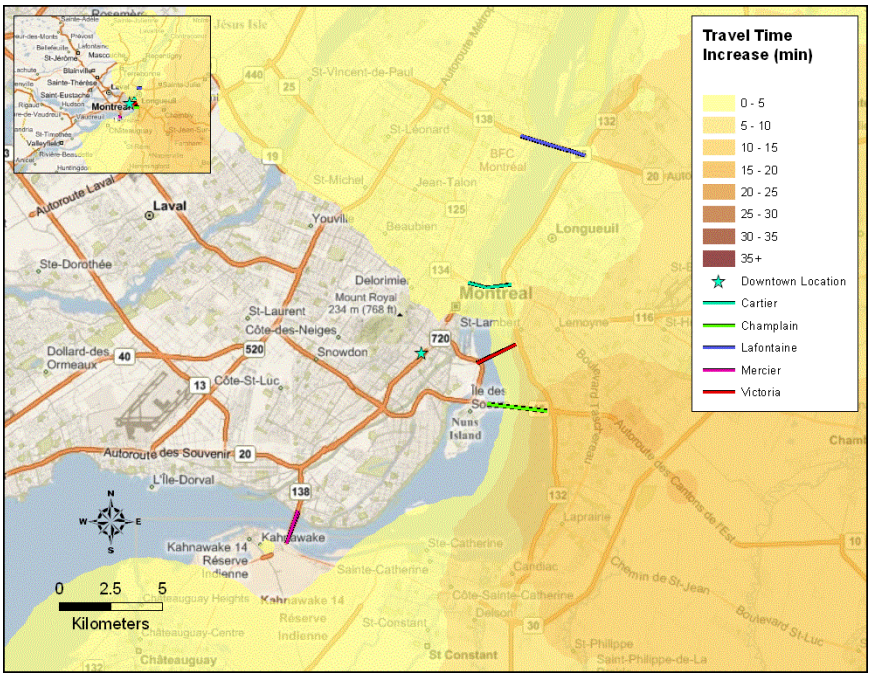
B.



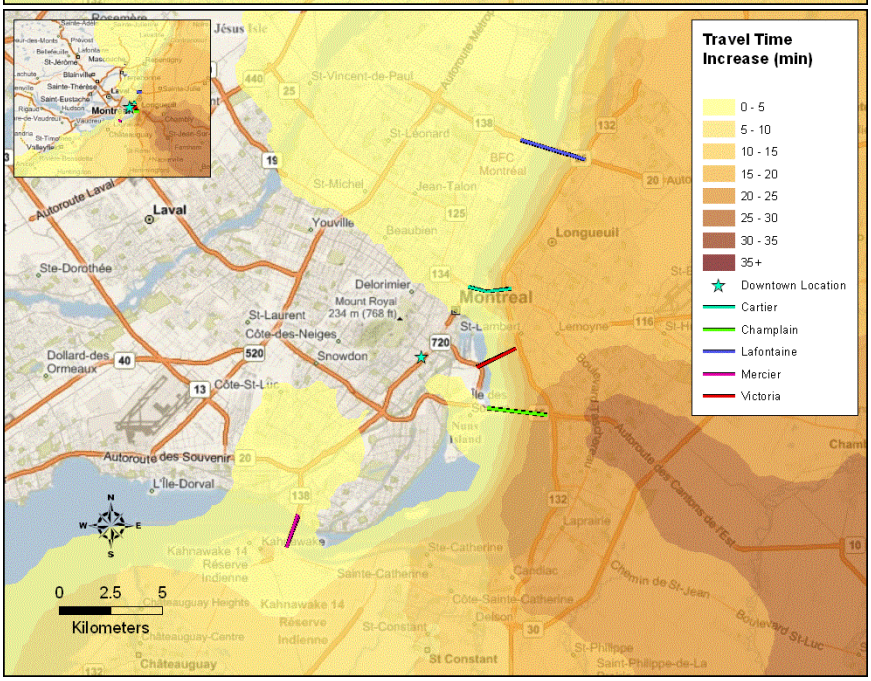
When the Champlain Bridge is closed, as is the case in Exhibit 18, the estimated increased delays are generally 10-15 minutes in the AM peak and 25-30 minutes in the PM peak with more isolated areas experiencing incremental delays of up to nearly 40 minutes. Compared to the two lane case, the area of delays on the island has increased. While the PM peak increases represent trips that should be against the peak direction of traffic, the trip durations are behaving almost as if they are in the peak direction.

Exhibit 18: Travel Time Increases to Downtown (Closed-Open) for (A) AM and (B) PM Peaks

A.



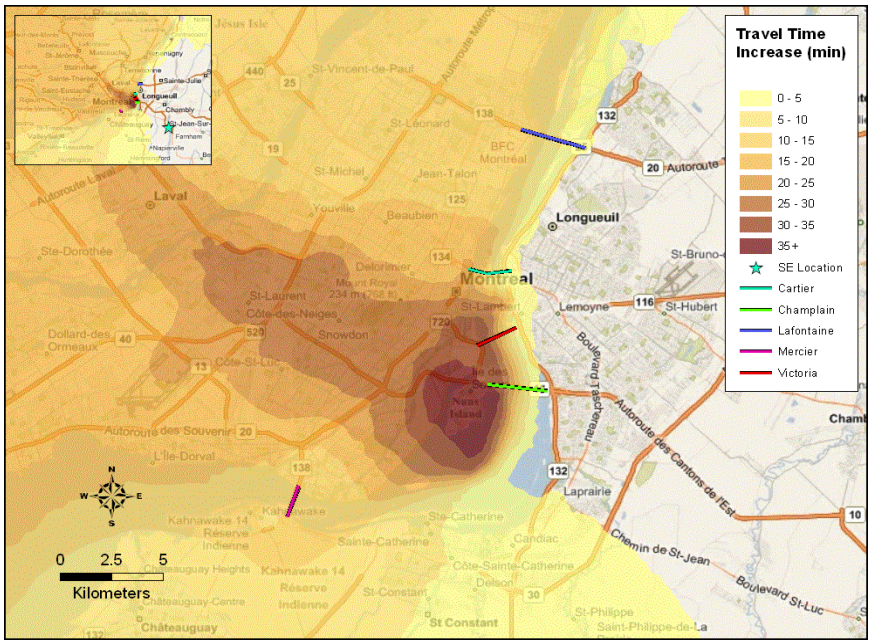
B.



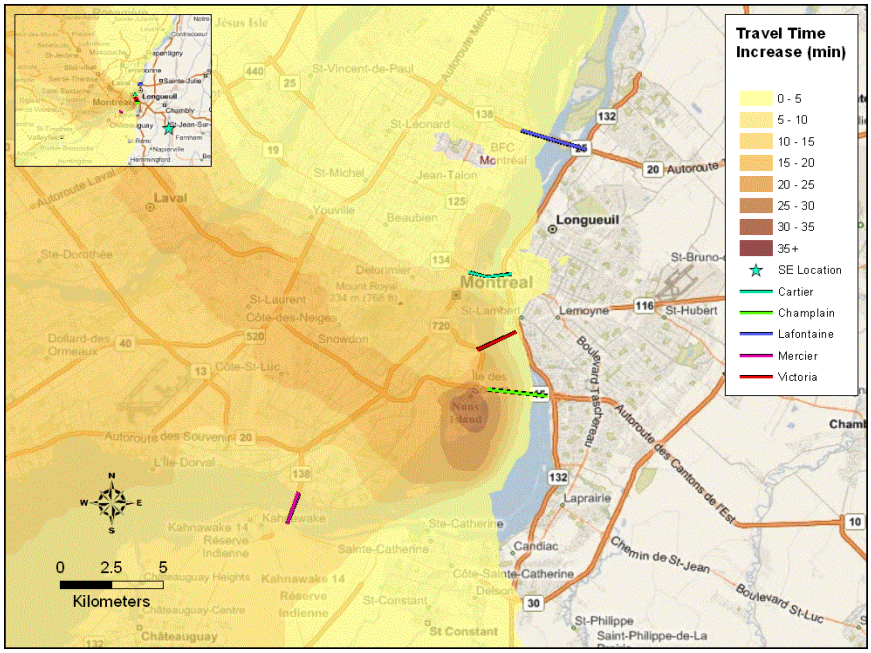
In Exhibit 19, an arbitrary location is chosen which approximates the direction required for a trip toward the U.S. Border and the impact of a closure to the bridge is considered. Most of the resulting delays are on the island but there is a large area in the area of the Mercier Bridge which experiences incremental delay. This area is larger in the AM peak. In many ways, a similar pattern is seen where the biggest net changes in travel time are for trips against the peak direction. The biggest increases are centred on Nuns Island and in the vicinity of the Champlain Bridge. From the pattern, it appears that the Mercier Bridge is the preferred alternative. In the AM peak, the delays are up to 40 minutes and in the PM peak, they are up to 25-30 minutes.

Exhibit 19: Travel Time Increases towards U.S. (Closed-Open) for (A) AM and (B) PM Peaks

A.



B.



A further series of travel time increase maps are shown in the appendix for the 2 lanes open and 4 lanes open scenario in Exhibits 38 to 40.

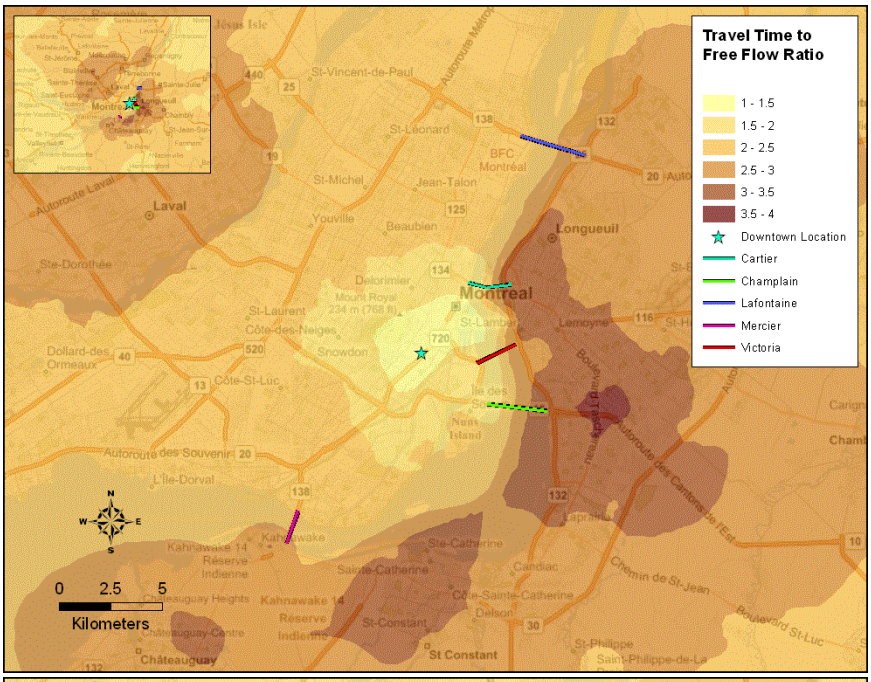
3.4.3 Travel Time Index

The travel time index is a ratio which has been popularized by the Texas Transportation Institute and which gives a measure of congestion. In particular, scenario travel time is divided by free flow travel time. The free flow travel time in this exercise has been estimated from the early AM/overnight time period during which congestion is typically a non-issue.

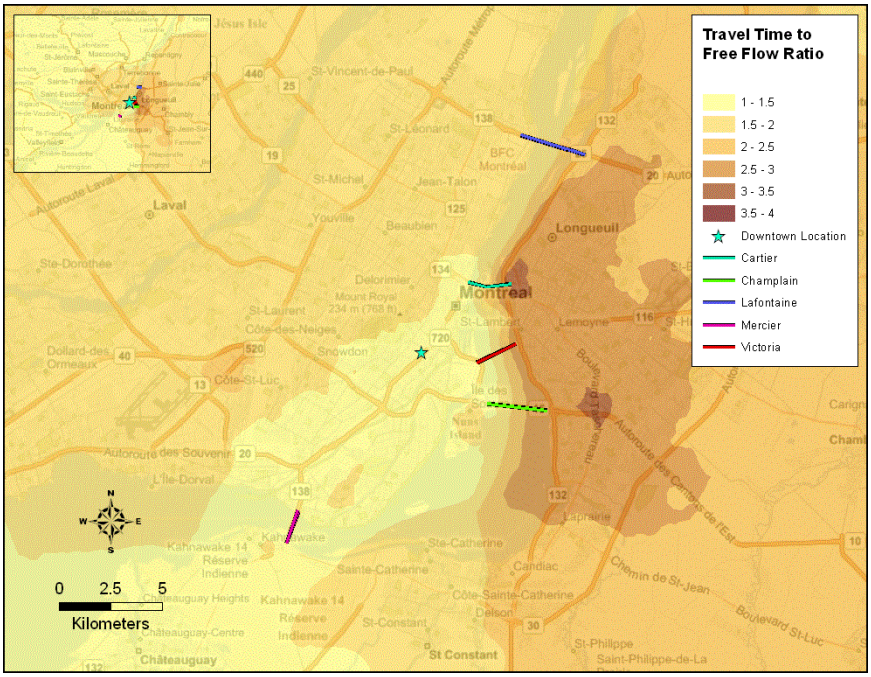
In Exhibit 20 the scenario where two lanes on the bridge are open is compared against the free flow travel state for a trip to the downtown. The traffic model portrays little difference from free-flow for trips in the vicinity of the downtown but fairly large ratios for most other areas in the city. The small inset shows fairly dark “blobs” covering a large area both to the north and the south. The darkest spots are seen in the vicinity of the Champlain Bridge where the ratios range from 3.0 to 4.0. This result suggests that a trip to the downtown would take 4 times longer in AM peak than in a free flow context. In Laval, to the north of the island, the maximum ratio is in the 2.5 to 3.0 range. In the PM peak, the ratios for a trip to the downtown are not so severe even after the fairly large increases in travel time that were noted in the previous section. On the south shore though, there are spots which achieve ratios of between 3.0 and 3.5.

Exhibit 20: Travel Time Indexes to Downtown (2 Lanes Open/Free Flow) for (A) AM and (B) PM Peaks

A.



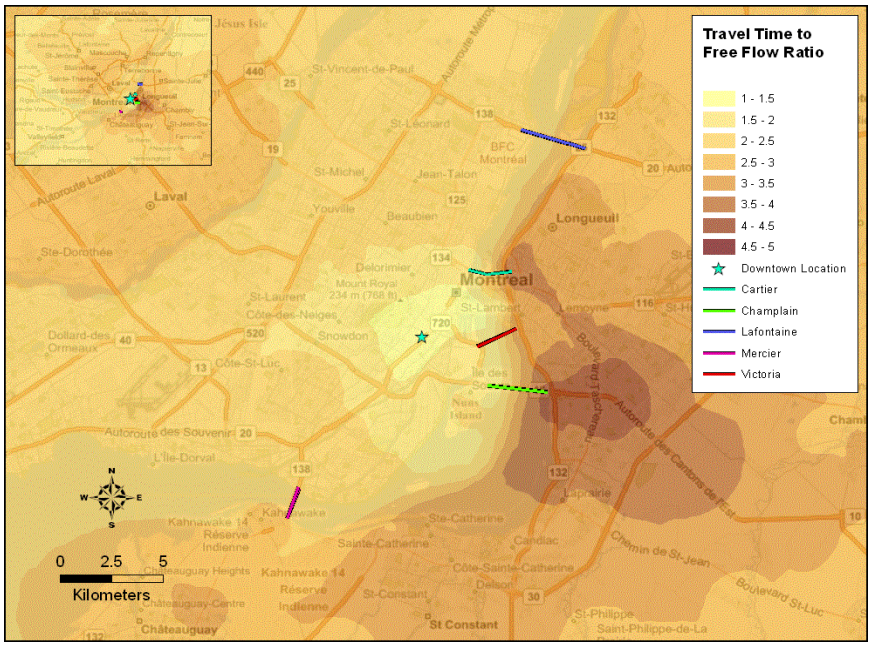
B.



In Exhibit 21, with the Champlain Bridge closed and for trips to the downtown, the patterns are intensified. In the AM peak the largest of the ratios are on the south shore near the Bridge and are generally between 4.0 and 4.5 with fairly high ratios applying most everywhere else also. For PM peak the effects are quite notable. There are fairly large areas near the Champlain Bridge which are in the range from 3.5 to 4.0 and these, of course, are associated with going against the peak direction into the downtown. Meanwhile, on the Island and into Laval, the ratios are mostly between 1.5 and 2 times the free flow results.

Exhibit 21: Travel Time Indexes to Downtown (Closed/Free Flow) for (A) AM and (B) PM Peaks

A.



B.

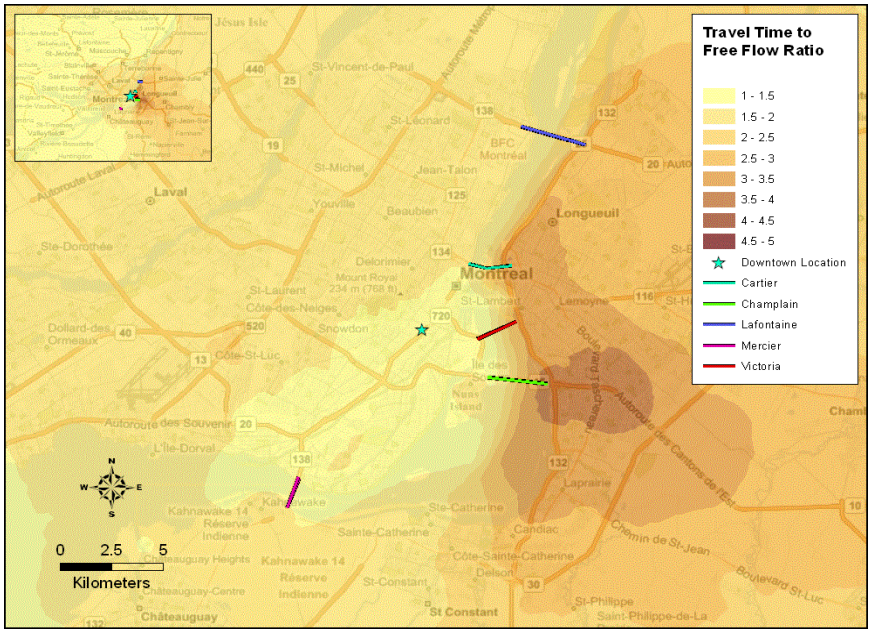
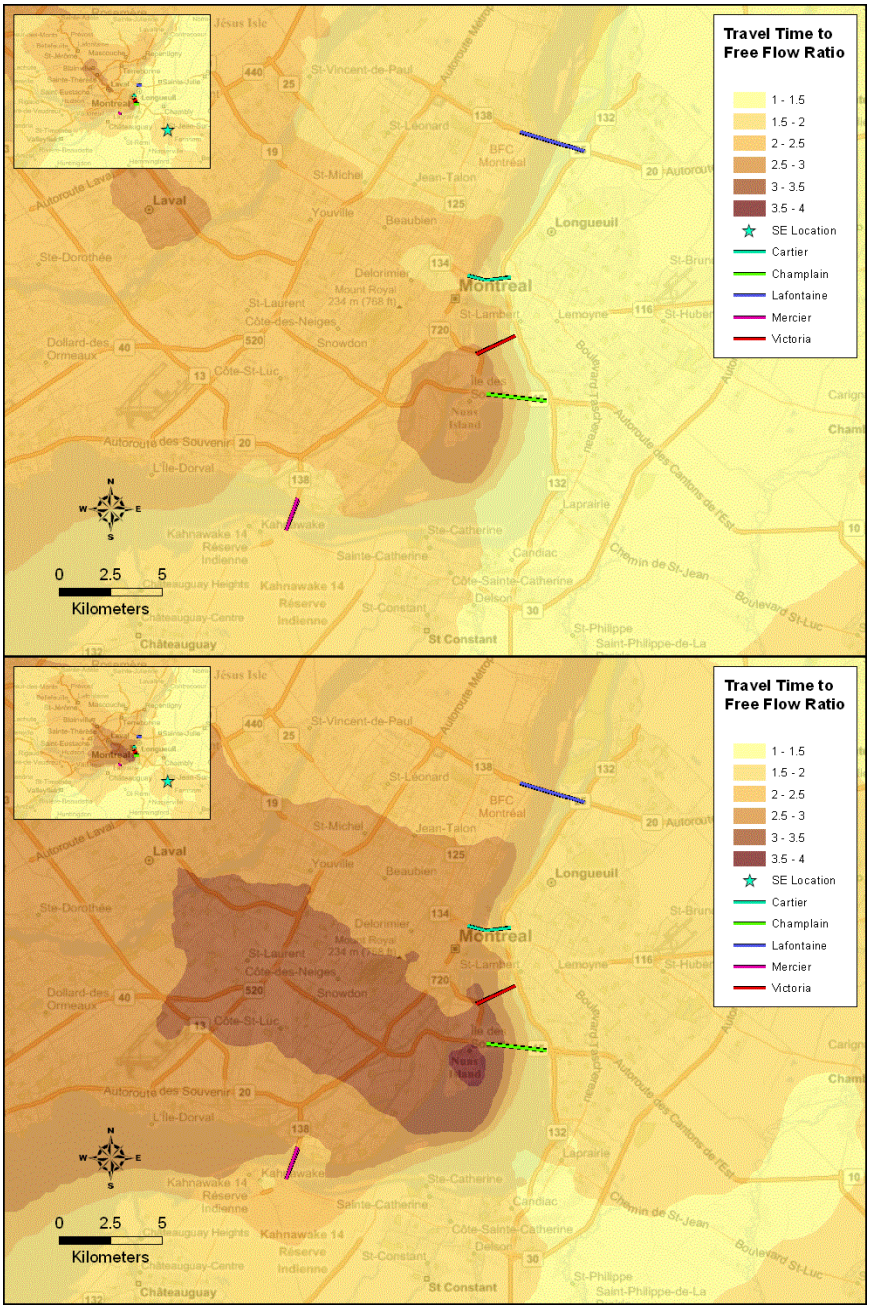


Exhibit 22 considers index behavior for trips toward the U.S. where the Champlain Bridge is closed. In the AM peak, the result is significant areas of the island where the index is between 2.0-2.5 and a smaller set of areas between 2.5 and 3.0. During the PM peak, there are many trips originating on the island which will take 3.0 to 3.5 times longer than the free-flow state and some that extend up to 4 times longer. It is important to keep in mind that a ratio of 4.0 does not imply that the closure of the Champlain Bridge increases travel times four-fold. The precise impact of the closure and other scenarios on the index is analyzed in the next section.

Exhibit 22: Travel Time Indexes Towards U.S. (Closed/Free Flow) for (A) AM and (B) PM Peak

A.

B.

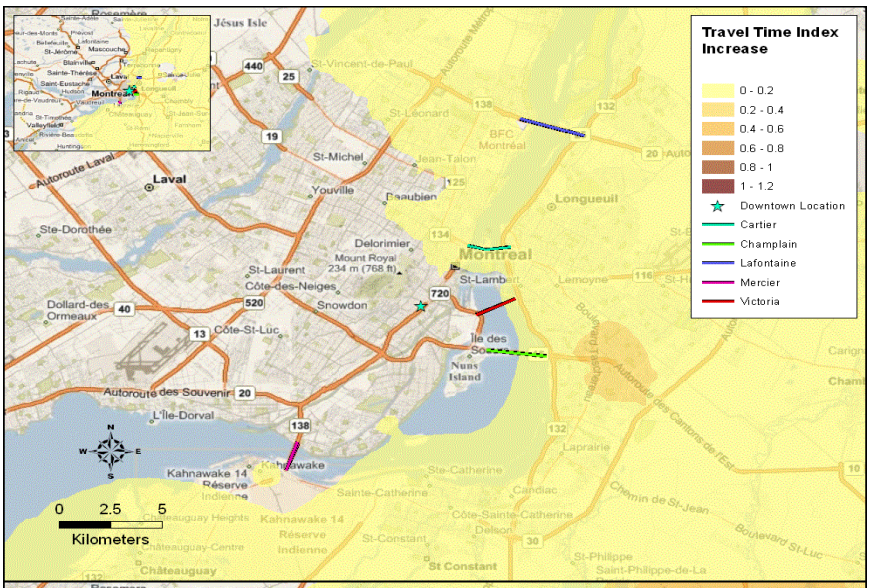


3.4.4 Increases in Travel Time Index

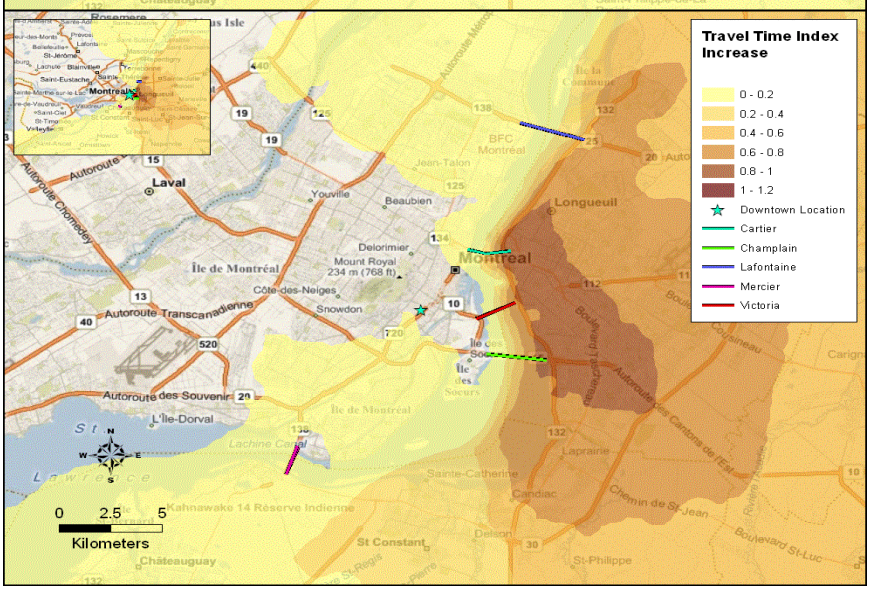
The intent in this section is to compare travel time indexes for the scenarios versus the base cases. In the AM peak, for example, travel time ratios are already high even when the Champlain Bridge is open. Restrictions on the bridge usage increase the travel time ratios but by how much? In the AM Peak, for the case where the bridge is reduced to two lanes as in Exhibit 23, most ratios increase by up to 0.2 for trips to the downtown. This is an increase of up to 20% of the free flow time. At PM peak, the highest impacts are generally between 0.8 and 1.0 which implies a near doubling of the free-flow travel times. These patterns are consistent with the maps of increased travel times that were presented earlier. The net changes are more dramatic for the PM peak but one must consider that the milder AM results are at least partially an artifact of the traffic model's capabilities.

Exhibit 23: Travel Time Index Increases to Downtown (2 Lanes Open-Open) for (A) AM and (B) PM Peaks

A.



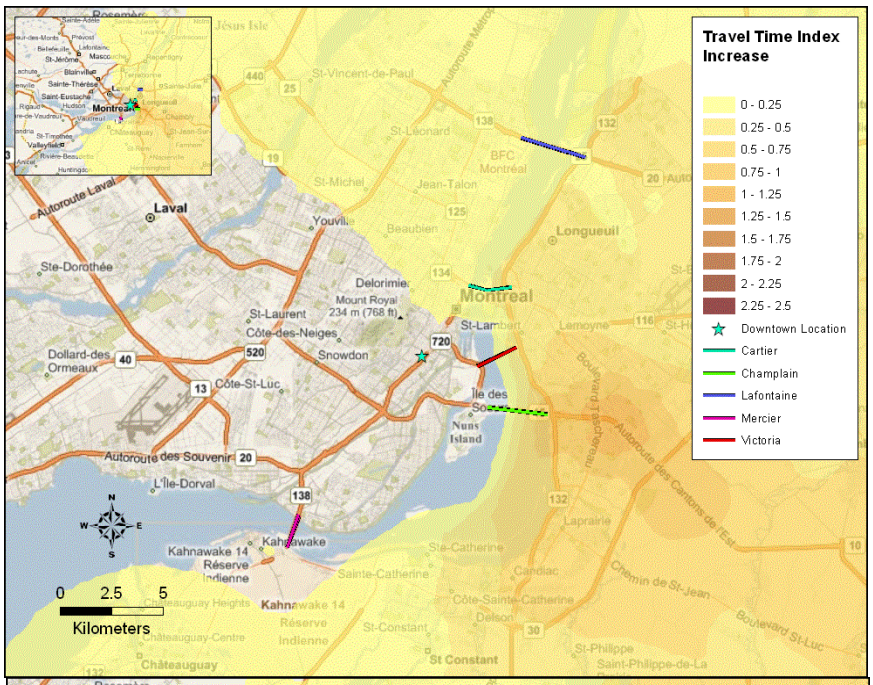
B.



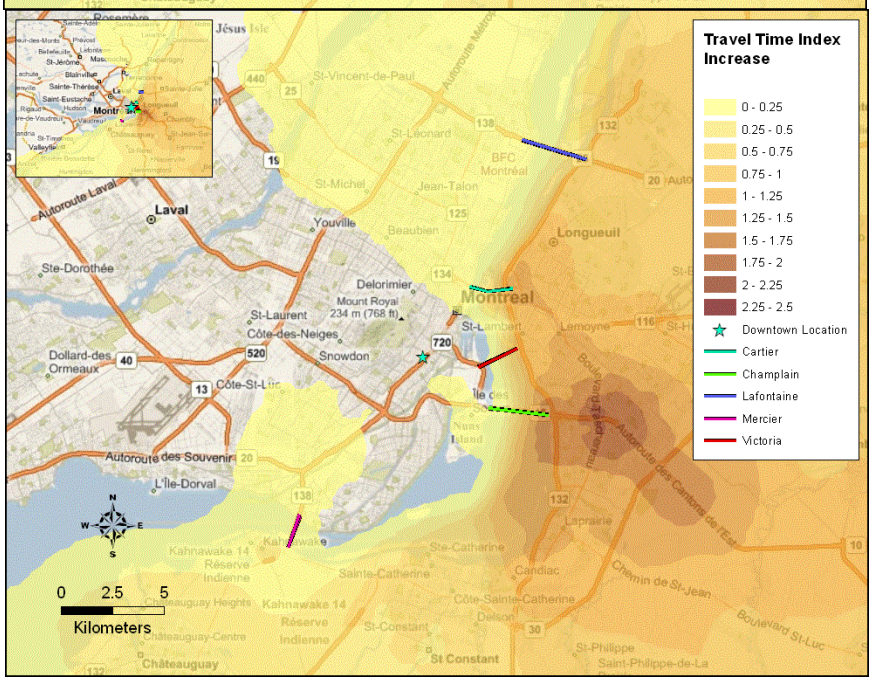
As expected, the index increases are more dramatic when the bridge is closed (Exhibit 24). For AM peak, the highest increases are between 1.0 and 1.25 which suggests more than a doubling of the free flow times strictly because of the bridge closure. During PM peak, the highest area of significant effects for a trip to the downtown has an increase in the ratio of between 1.75 and 2.0. This result is consistent with a near tripling of the free-flow travel times due to bridge closure.

Exhibit 24: Travel Time Index Increases to Downtown (Closed-Open) for (A) AM and (B) PM Peaks

A.



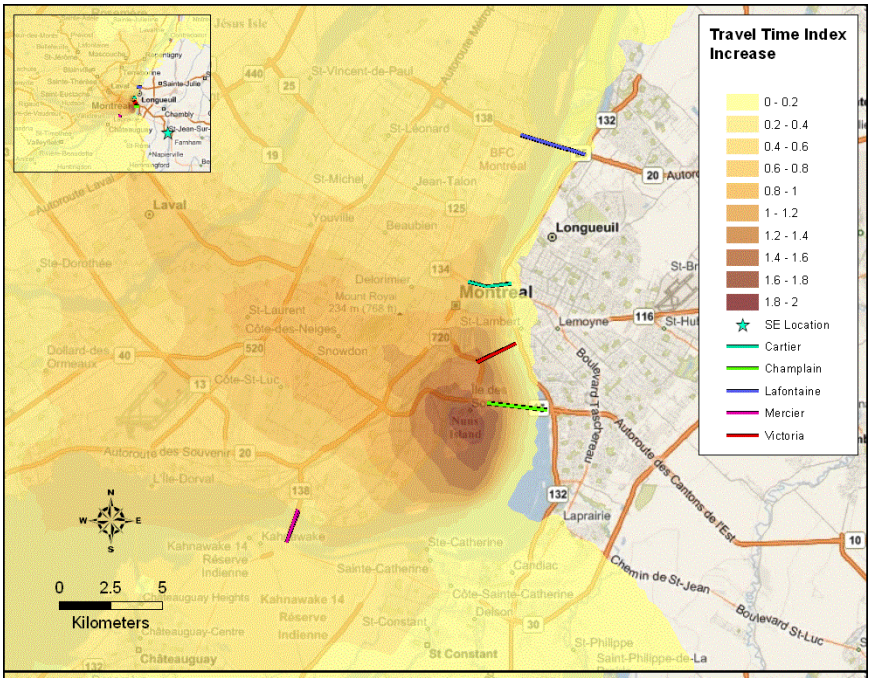
B.



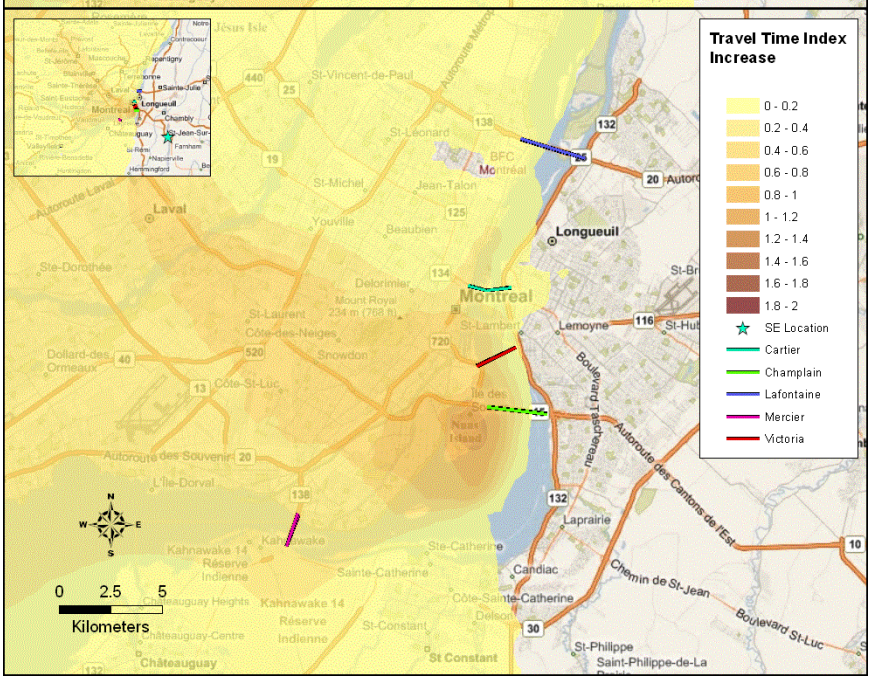
Further index increases are highlighted in Exhibit 25 for the trip towards the U.S. In general, the index changes are a bit less severe than is the case for trips to the downtown but this result might partially reflect that the trip to the destination (see inset) is further away. Bear in mind that Exhibit 17 shows significant travel time increases for this trip. Nevertheless, for both AM and PM peaks, there are significant areas where the free flow travel time would be doubled based on the effect of closing the Champlain Bridge.

Exhibit 25: Travel Time Index Increases Towards U.S. (Closed-Open) for (A) AM and (B) PM Peaks

A.



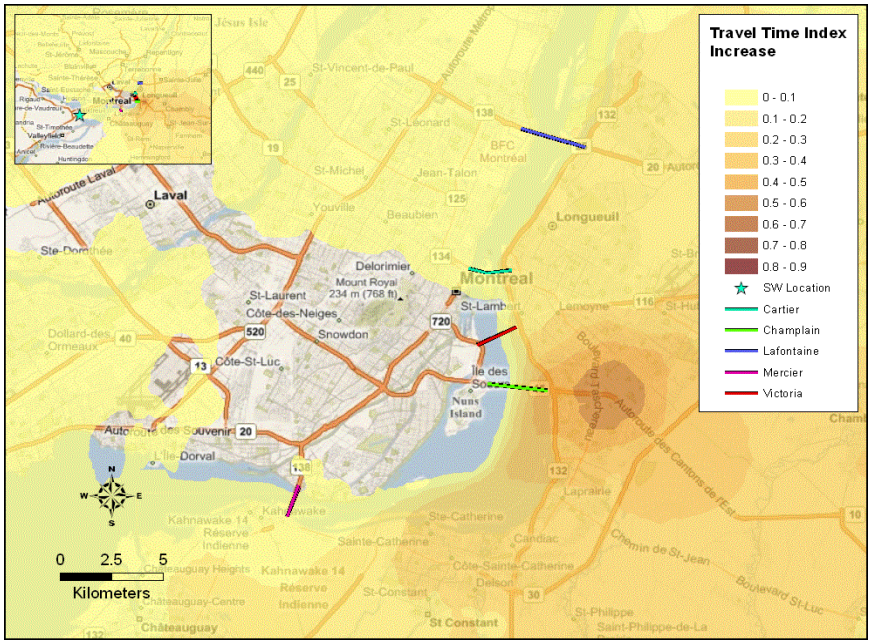
B.



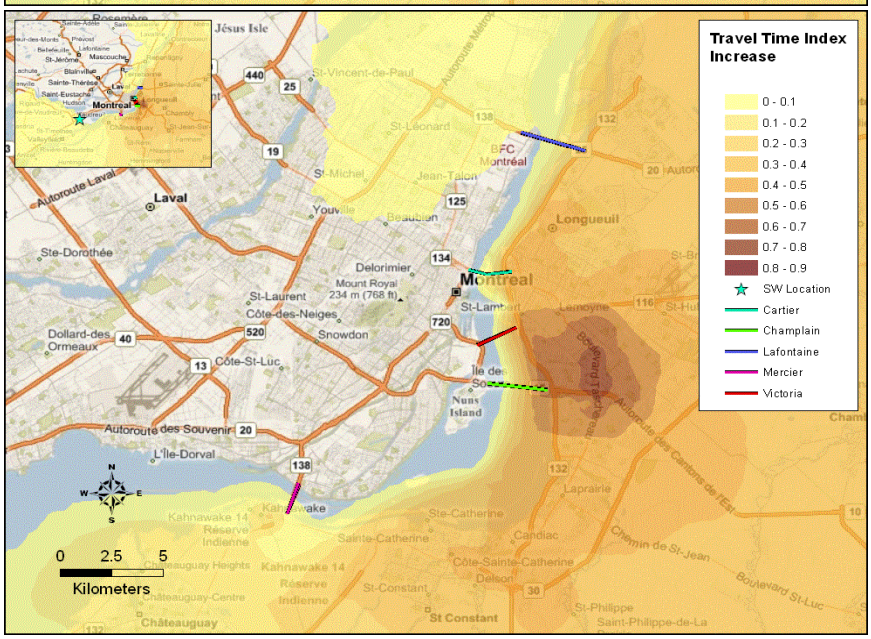
To add some variety, Exhibit 26 considers trips in the direction of Ontario. A pattern is revealed that shares similarities with trips to the downtown. The differences in indexes are not as severe again partially because the trip considered (see inset) is a longer distance. From this example, we can see that goods moving between Ontario and the U.S. via Quebec would be very much affected by closure of the Champlain Bridge.

Exhibit 26: Travel Time Index Increases Towards Ontario (Closed-Open) for (A) AM and (B) PM Peaks

A.



B.



4

Economic and Other Impacts

Input-Output (IO) modelling is an elegant, macro-economic methodology that accounts for economic linkages as well as trade relationships. IO models are widely used to understand economies and the impacts associated with changes such as the projected impacts of new economic development initiatives. The technique can also be used to simulate the impacts of disruptions or disasters and as such is an appropriate tool to study any restrictions that might be placed on the Champlain Bridge.

Data for the model outlined below is based on the 2001 input-output national economic accounts, produced and maintained by Statistics Canada. The model is commodity-based and accounts for the trading and final demand of 43 commodities, as shown in Exhibit 27. In this analysis, we focus on the Multiregional Input-Output Model (MRIO) which introduces a detailed geographical perspective into the overall framework. See Miller and Blair (2009) for further expansion on what is described below.

While the results portrayed below represent various economic impacts, they should not be interpreted as "predictions". Rather, they are a range of potential outcomes some of which are more likely than others. The results give a sense of the potential dollar importance of the Champlain Bridge to the economies of Montreal and Quebec.

4.1 Model Description

The Multiregional Input-Output model, in matrix notation, is given by:

$$\boldsymbol{x} = [\boldsymbol{I} - \boldsymbol{CA}]^{-1}\boldsymbol{C}\boldsymbol{f}$$

where ***x*** is a vector of economic outputs by commodity and region and is thus of dimension r*c by 1, R represents the number of regions and c represents the number of commodities. In this application, there are 14 regions and 43 commodities. The matrix ***I*** is an identity matrix which is r*c by r*c. It is entirely zeros except for the diagonal elements which are all set to 1.0. The C matrix is r*c by r*c also and it incorporates some detailed information about trade. In particular, for each commodity, there is an r by r matrix which details the trade of the given commodity, in dollar terms, between the various regions. This information is purely geographical and for one commodity at a time; it provides no detail on how a certain commodity from a given region is used as an input to make another commodity in a second region.

The A matrix, on the other hand, helps to provide some of this information. Again, it is an r*c by r*c large matrix and it is built on a set of region-specific technical coefficient matrices. Each region-specific matrix is c by c and provides a recipe for how commodities are used as intermediate inputs into the development of other commodities. The combination ***CA*** in the expression above does the job of simulating what ingredients are used and from what region. For every combination of commodity and region, the question relating to inputs of “from where” and “what” is answered in terms of generating a dollars worth of output. Finally, the term f is known as the final demand vector and is an r*c by 1 vector. It represents the dollar requirements of end users for each of the commodities and in each of the regions. End users can be represented by households in the form of consumption, governments or foreign entities via exports. The combination ***Cf*** at the end of the expression is basically a geographically allocated final demand and turns out to be an r*c column vector which details the total final demand served by each sector in each region. Note that a given region is likely to serve some of its own final demand for a given commodity as well as some final demand of other regions and that this idea is captured here.

In the current analysis, R=14 and is essentially related to the number of provinces and territories. The one deviation from this statement is that Quebec is divided into the Census Metropolitan Area (CMA) of Montreal and then all other parts of Quebec that are left over. The former and the latter are quite similar in terms of the value of economic activity. A variety of inferences and assumptions are required to make this division of Quebec possible. In particular, detailed sectoral employment data have been collected for the Montreal CMA and the rest of Quebec. These are associated as well as possible with the 43 commodities to provide an approximate split of how economic flows might breakdown between the two regions. Insight gained from these employment data is applied to generate some intra-Quebec trade and technical coefficients.

Exhibit 27: Commodities Considered in MRIO Model

ID	Commodity
1	Grains
2	Other Agricultural Products
3	Forestry Products
4	Fish, seafood and trapping products
5	Metal ores and concentrates
6	Mineral fuels
7	Non-metallic minerals
8	Services incidental to mining
9	Meat, fish and dairy products
10	Fruits, vegetables and other food products, feeds
11	Soft drinks and alcoholic beverages
12	Tobacco and tobacco products
13	Leather, rubber and plastic products
14	Textile products
15	Hosiery, clothing and accessories
16	Lumber and wood products
17	Furniture and fixtures
18	Wood pulp, paper and paper products
19	Printing and publishing
20	Primary metal products
21	Other metal products
22	Machinery and equipment
23	Motor vehicles, other transport equipment and part
24	Electrical, electronic and communications products
25	Non-metallic mineral products
26	Petroleum and coal products
27	Chemicals, pharmaceuticals and chemical products
28	Other manufactured products
29	Repair construction
30	Transportation and storage
31	Communications services
32	Other utilities
33	Wholesaling margins
34	Retailing margins
35	Other finance, insurance and real estate services
36	Business and computer services
37	Private education services
38	Health and social services
39	Accommodation services and meals
40	Other services
41	Transportation margins
42	Operating, office, cafeteria and laboratory supplies
43	Travel and entertainment, advertising and promotic

4.2 Scenario Implementation

A distinction will be made below between short term impacts and longer term impacts. For example, the 4-lanes open scenario is best associated with preventative maintenance and repair. The associated duration is likely best measured in weeks. The 2-lanes open scenario is a more serious, likely unplanned closure but will be modelled in a similar way with an anticipated disruption of weeks. On the other hand, a complete closure is likely to result only from a natural disaster and could lead to the crossing being closed for several years. In the current MRIO analysis, this will be modeled as an event with longer term implications that might adjust the overall competitiveness of the Montreal region slightly downward. For this, estimated impacts will be reported in annual terms.

The list of 43 commodities in Exhibit 27 provides some guidance for the scenarios. While many types of scenarios are possible, in this analysis the focus is on direct negative impacts on the manufacturing sector and resulting indirect effects on other sectors and regions. Manufacturing is an important sector which is very much associated with driving the economy and is quite dependent on efficient movement of goods. In particular, in the scenarios that are reported on below, some coefficient and final demand reductions on commodities 11 through 28 (see Exhibit 27) are assumed and their impacts traced through the Canadian economic system.

In terms of how scenarios are implemented, adjustments are made to the CA matrix and to the Cf matrix. The former is 602 by 602 and the latter is 602*1 where R*C=602. The last 43 rows in either matrix deal with outputs from the CMA of Montreal with each row representing a different commodity. By reducing the coefficients associated with some or all of the columns in these rows, it is possible to simulate a decline in the ability of Montreal to produce its output relative to what the other regions are producing. In the CA matrix, the bottom right 43*43 quadrant deals with inter-commodity flows within the CMA of Montreal itself. It is possible to maintain those coefficients so that only inter-regional changes are considered or the same patterns can be represented internal to the CMA. By the same token, the last 43 rows in the Cf column vector describe total final demand that is served from Montreal. In the same way that scaling of coefficients can simulate a decline in Montreal's ability to service the need for intermediate inputs, a decline in the ability to cater to final demand in all regions is possible.

Exhibit 28: Relative Importance of Montreal CMA by Commodity

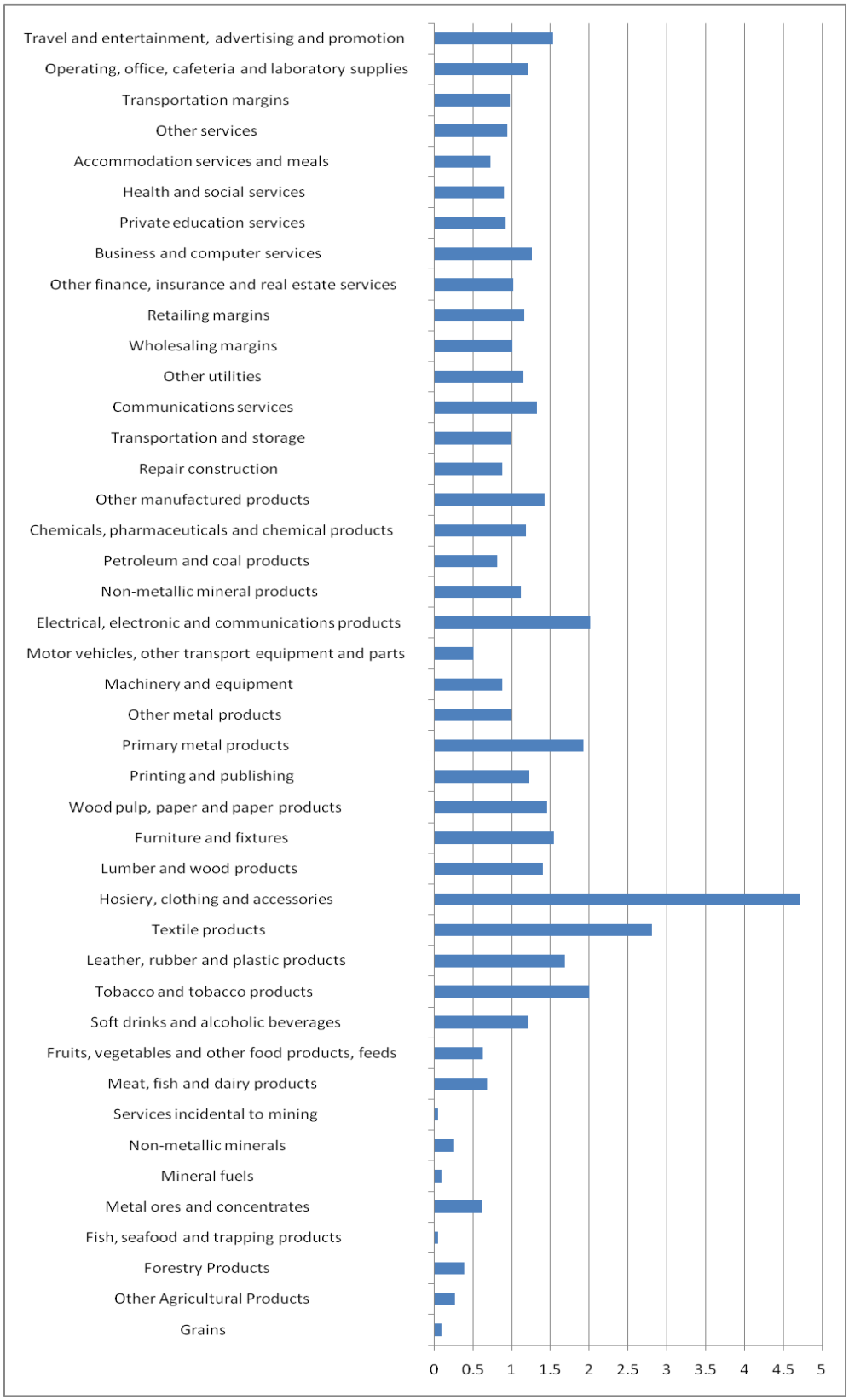
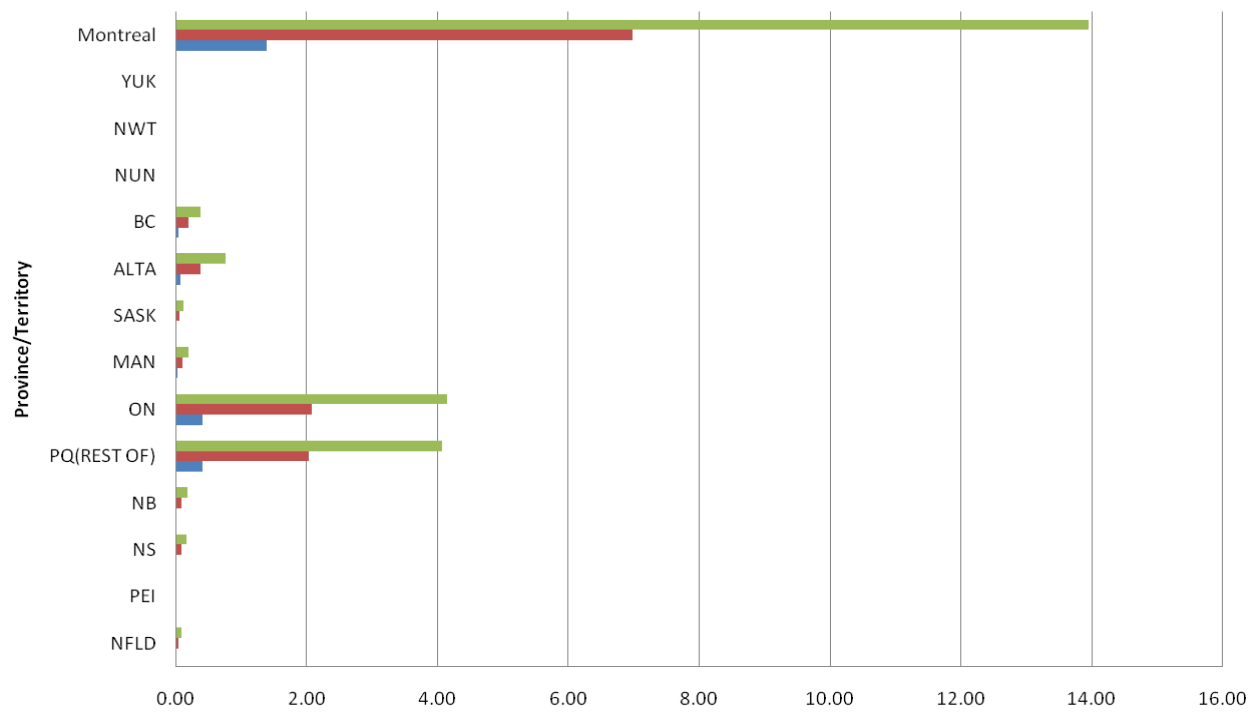


Exhibit 28 provides a profile of the Montreal economy in terms of its outputs by commodity. Numbers larger than 1.0 indicate that Montreal specializes in that commodity relative to all the rest of Canada. From this graph it is clear that hosiery, clothing and textiles is a strong area of specialty. Other specialties include electronics and tobacco among others. On the other hand, it is clear that many of the commodities associated with primary industries such as grains or fish are not strongly represented in Montreal.

4.3 Shorter Term Impact Scenarios

The shorter term scenarios relate to those circumstances where the Champlain Bridge might be reduced to either two or four lanes. These types of circumstances would be brought about by required maintenance/repairs to keep the bridge safe. In either case, it is assumed that the condition would apply for weeks as opposed to months or years so dollar impacts considered below are expressed on a per week basis. In the shorter term scenarios, there is little doubt that extra congestion and delays generate economic costs. Firms involved cope but cannot do too much in the short run to mitigate against the effects.

Exhibit 29: Weekly Short-term Declines in Output by Region



	NFLD	PEI	NS	NB	PQ(REST OF)	ON	MAN	SASK	ALTA	BC	NUN	NWT	YUK	Montreal
1%	0.08	0.01	0.17	0.19	4.08	4.14	0.20	0.12	0.77	0.38	0.00	0.01	0.00	13.95
0.50%	0.04	0.01	0.08	0.09	2.04	2.07	0.10	0.06	0.38	0.19	0.00	0.00	0.00	6.98
0.10%	0.01	0.00	0.02	0.02	0.41	0.41	0.02	0.01	0.08	0.04	0.00	0.00	0.00	1.40

Weekly Declines in Output ($ Millions)

Exhibit 29, illustrates potential regional weekly impacts from disruptions caused by lane reductions of the Champlain Bridge. Three distinct scenarios are considered which are associated, at most, by a temporary one percent reduction in output of the Montreal manufacturing sector. The other two scenarios portrayed are a 1/2 percent reduction and a 1/10th percent reduction For the Montreal CMA, the output reductions range from approximately $1.4M to $14M per week depending on the scenario. For the nation as a whole, the output reductions range from $2.4M to $24M per week for these same scenarios. Keep in mind that the only direct declines are in the Montreal CMA and that the additional declines are from indirect impacts on supply chains. The proportional regional impacts are clarified in Exhibit 30 which shows how output declines are dispersed throughout the regions. In all cases, the output of the Montreal CMA is most affected with the rest of Quebec being affected at a level similar to Ontario. This proportional pattern does not vary by scenario.

Exhibit 30: Percentage Distribution of Weekly Output Declines by Region

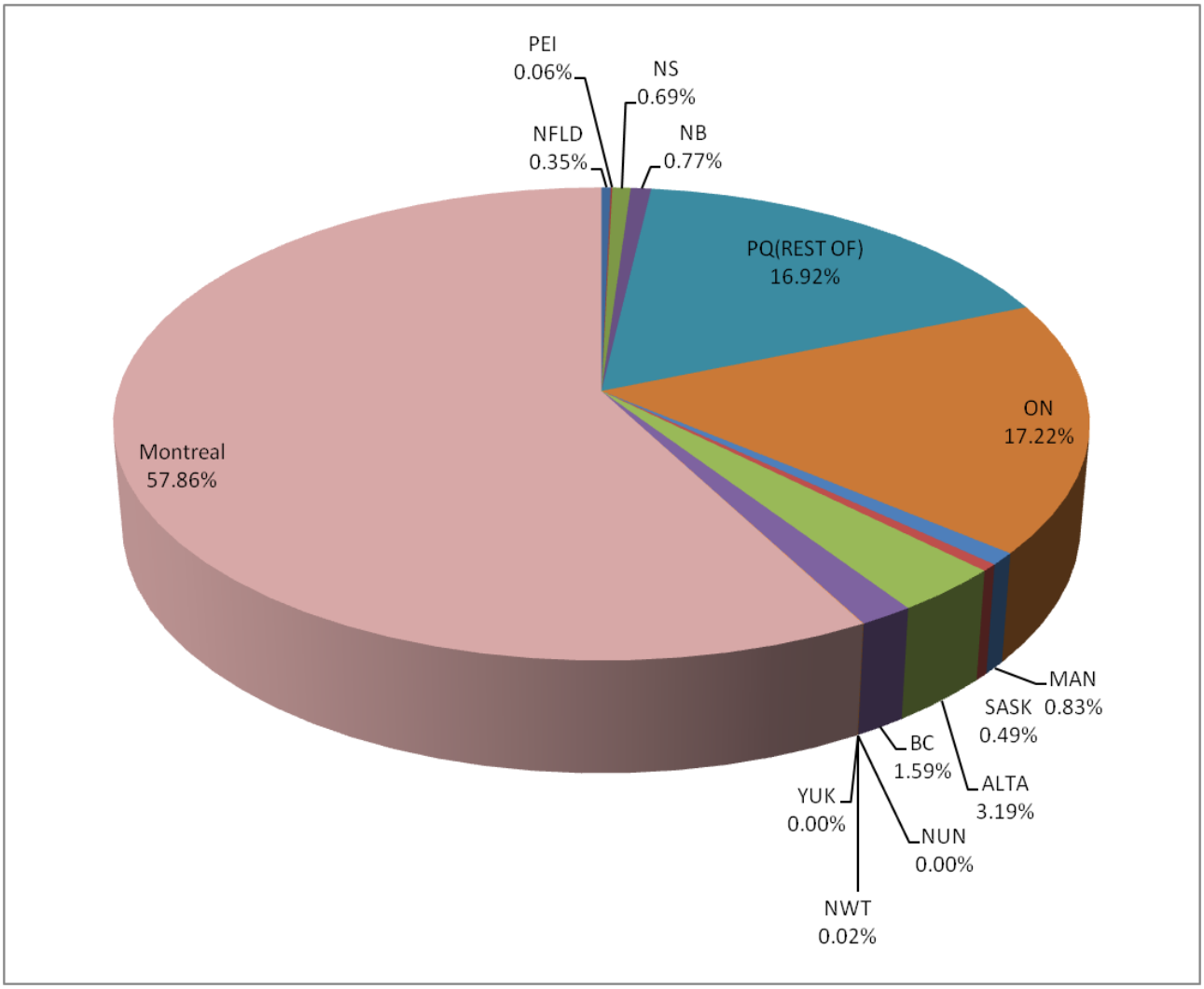
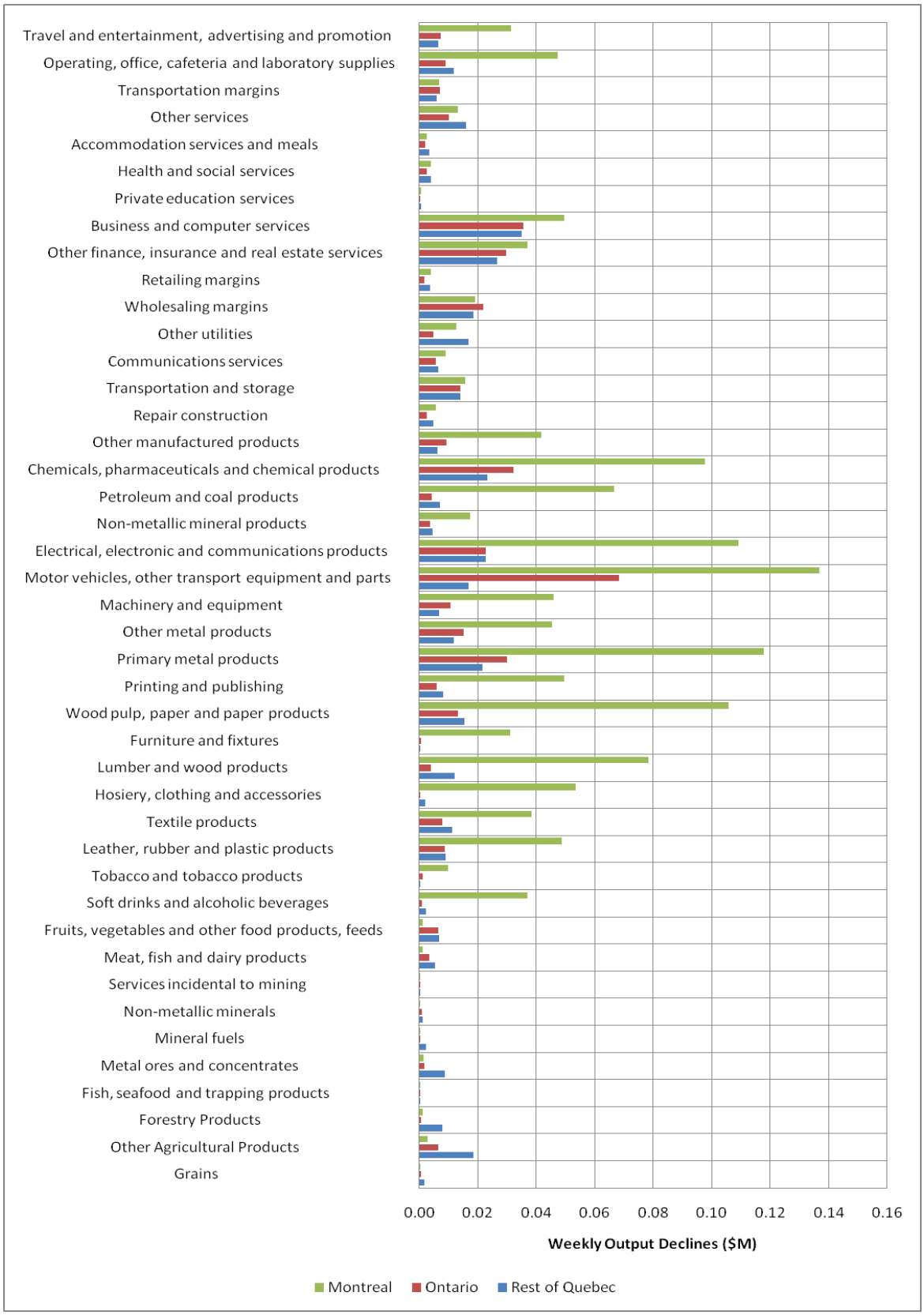


Exhibit 31: Weekly Output Declines by Commodity and Region (4 lanes open)



These reductions of manufacturing output in Montreal can be decomposed. Further analysis revealed that if only intra-CMA supply chains were disrupted that the output declines across the scenarios would range from $0.4M to about $4M. Conversely, if local supply chains remained intact and inter-regional ones were disrupted; the impacts would range from approximately $1M to $10M depending on the scenario. These results highlight that a substantial percentage of manufactured Montreal outputs is purchased locally but that the bulk are intended to satisfy markets in other regions.

Exhibit 31 illustrates how the weekly output declines are allocated among the commodity types and also the three main affected regions: Montreal CMA, rest of Quebec and Ontario. Not surprisingly, the most affected commodities are associated with manufacturing and, in Montreal at least, are the ones that had associated I/O coefficients reduced. These cover the range of commodities starting with "Other manufactured products" and extending down the list to "Soft Drinks and Alcoholic Beverages."

With a uniform percentage decline across the manufacturing commodities in Montreal, it is the "motor vehicles and other transport equipment and parts" group that suffers the most to the tune of nearly $140K per week. "Chemicals, pharmaceuticals and chemical products", "electrical, electronic and communication products", "primary metal products" and "wood, pulp and paper products" are all facing output declines in Montreal in the general vicinity of 100K per week.

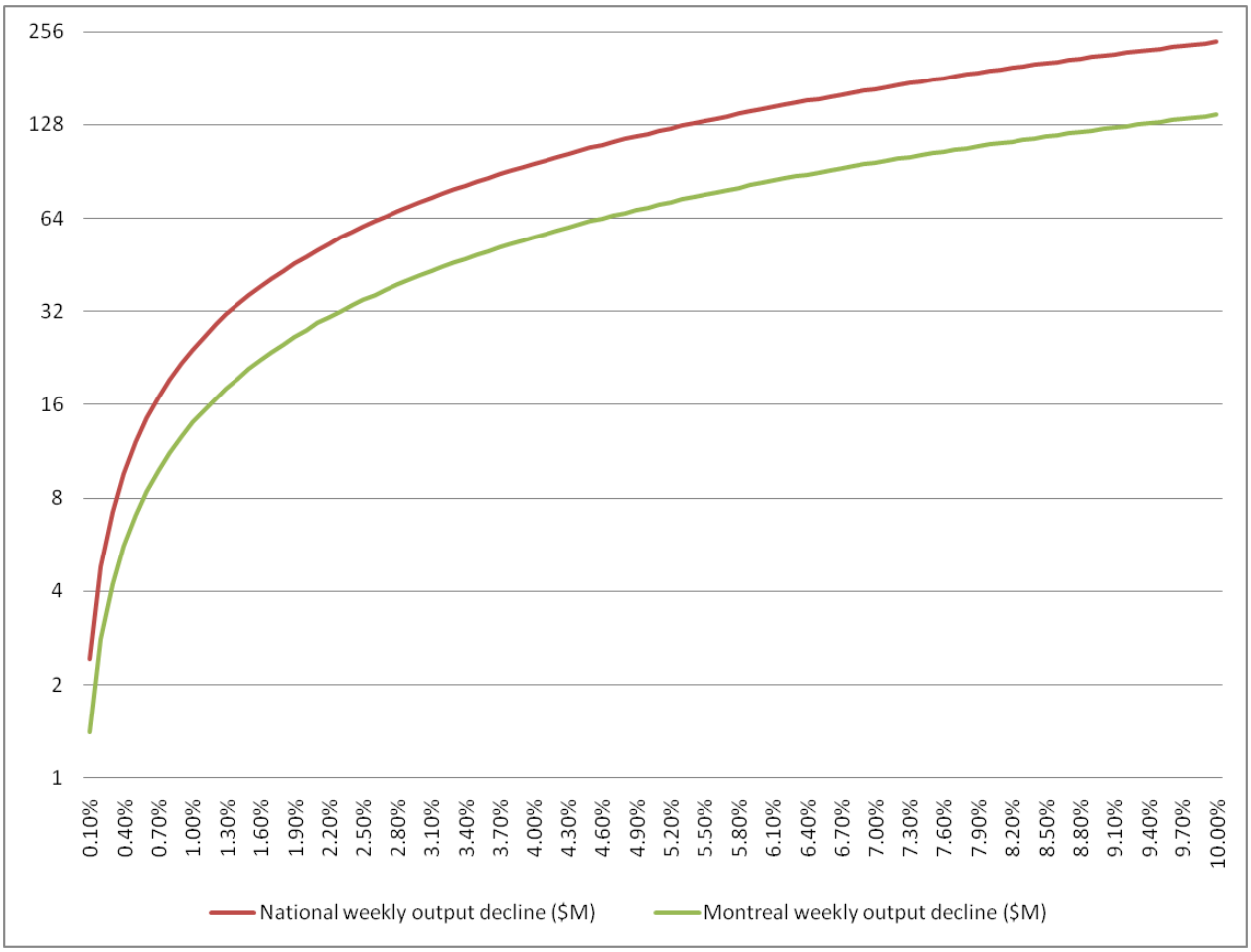
Even though there were no direct changes to the other commodities, there are still some significant indirect impacts that are captured in Exhibit 31. In particular, the so-called "service" commodities are shown to take a significant hit from disruptions to manufacturing. "Business and Computer Services" is quite largely impacted along with "operating, office, cafeteria and laboratory supplies". In Montreal, the former would be impacted by about $50K per week and the latter by a bit less. For many of the more "primary" commodities, the impacts are less with no commodity being impacted in Montreal by more than $20K per week.

A final avenue to explore is how the other two regions proportionally respond to the changes in the output of commodities in Montreal. It is evident, for example, that Ontario is proportionally much more negatively affected in motor vehicles than it is for wood, pulp and paper products. It appears that Ontario is much more integrated to Montreal in the former commodity than the latter. In fact, there is evidence of considerable integration in manufacturing between these three regions in the sense that the indirect manufacturing effects that are felt in Ontario and the rest of Quebec exceed the dollar impacts of non-manufacturing sectors in the Montreal CMA itself.

With respect to the particular impacts associated with only two or four lanes open on the Champlain Bridge, the two lanes open scenario would be the one to most likely associated with the $6.98M and $13.95M impacts identified in Exhibit 29. The impact is likely to be a multiple of the four lanes open scenario as congestion impacts are much more pronounced. These scenarios might suggest a range of $5M to $15M per week. The most likely scenario for four lanes open is the $1.4M impact identified in Exhibit 29 which suggests a probable range of impacts in the order of $1 to $3 million dollars per week that the Champlain Bridge restrictions are in place.

In Exhibit 32, a set of Montreal and national outcomes are considered over a very wide range of scenarios. This graphic shows the pattern of output decline but most scenarios covered here would likely fall into the far-fetched category for these particular Champlain restrictions. Both the national and Montreal output decline curves are in millions of dollars and show the biggest percentage impacts for the initial one or two percent reductions in Montreal manufacturing.

Exhibit 32: Weekly Output Decline Scenarios due to Manufacturing Disruption in Montreal CMA



4.4 Longer Term Impact Scenarios

The longer term impact scenarios relate to the fairly extreme circumstance where the Champlain Bridge is closed to traffic. This might be expected to occur as a result of a seismic event.

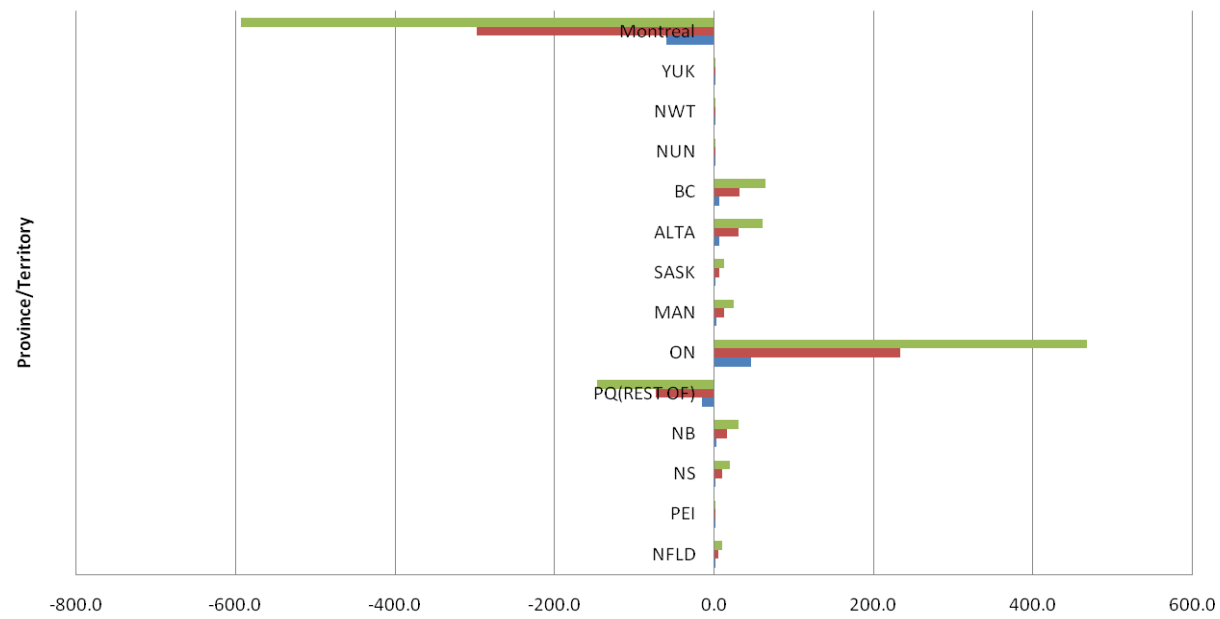
To represent longer-term impacts and adjustments, a reallocation process is assumed because firms have a chance to adjust to circumstances. The crossing could potentially be out of use for several years and firms will know it. In the modelling sense, reductions in coefficients reflecting the commodity-by-commodity contributions of Montreal to other regions are made up by increases in the coefficients of other regions. An assumption is made that other supplying regions "pick up the slack" in that

commodity to the extent that they are already active in providing it to the given region. For a given commodity, the impact of a change in the CMA is portrayed as at least partially depending on how important Montreal is in the production of that commodity. If Montreal is prominent, then an X percent decline will create more reallocative potential, all things being equal. As will be seen, Ontario is often in a position to benefit from any reallocation of production away from Quebec.

It is important to note that this reallocation process is nothing more than a controlled experiment of a type. An attempt is being made to isolate the impact of a Champlain Bridge closure and a subsequent shift of investment and production while holding everything else constant. In reality, congestion issues in other regions could deteriorate badly or even worse than Montreal. No attempt is being made to predict such outcomes. Instead the assumption is made that Montreal is the only place where congestion is getting materially worse and for a very specific reason.

The treatment of the "Rest of Quebec" region in this analysis deserves some mention. On the grounds that this region is the most tightly integrated into the economy of the Montreal region, the idea was to treat the "Rest of Quebec" in a neutral manner. In other words, coefficients did not get reduced as was the case in Montreal but neither could they benefit from a reallocation away from Montreal as other regions did. The net result of these assumptions is that the rest of Quebec is generally seen as suffering some negative economic impacts from a Champlain Bridge closure as might well be expected.

Exhibit 33: Annual Regional Impacts of Champlain Bridge Closure by Scenario



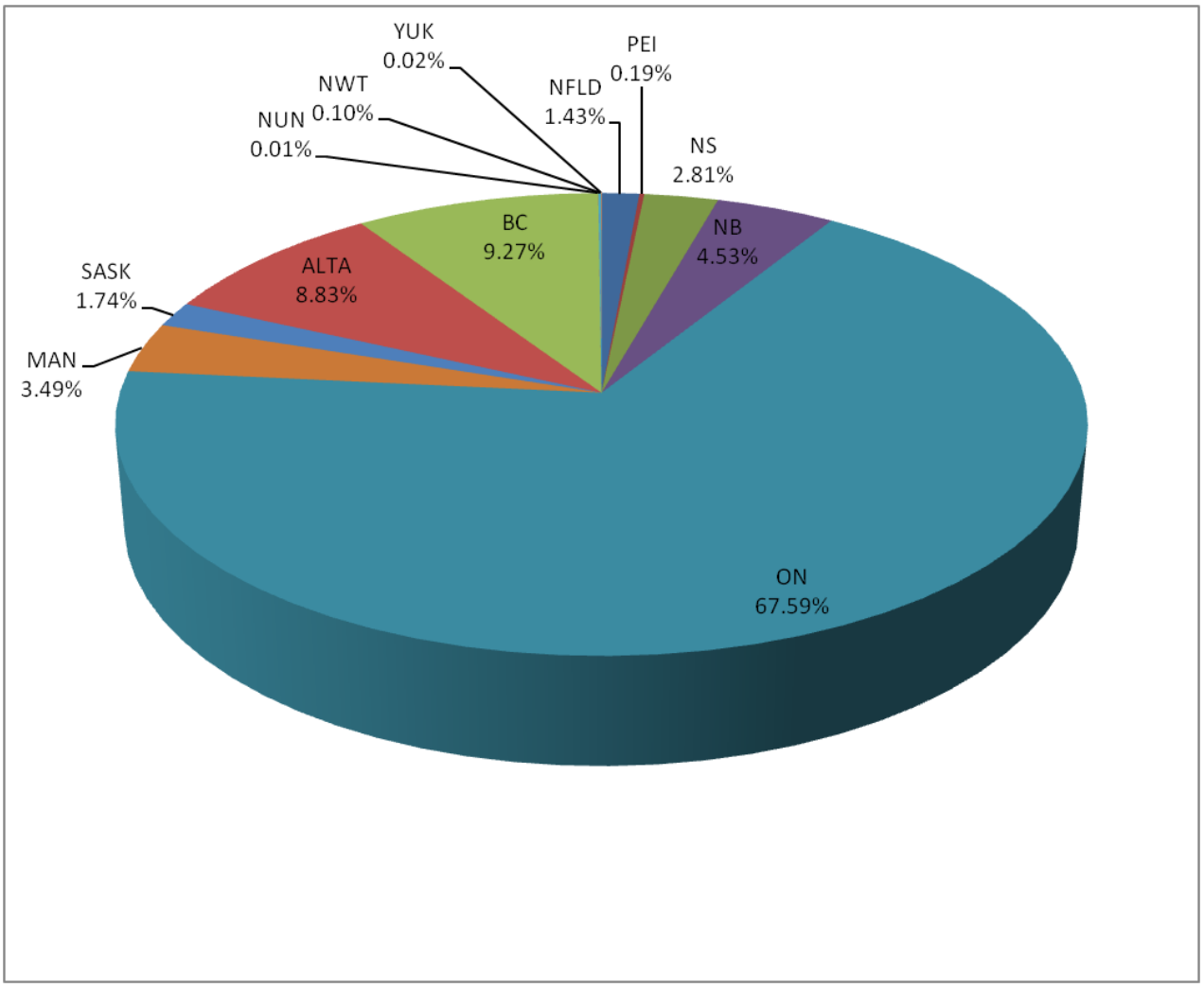
	NFLD	PEI	NS	NB	PQ(REST OF)	ON	MAN	SASK	ALTA	BC	NUN	NWT	YUK	Montreal
1%	9.9	1.3	19.4	31.3	-146.7	467.3	24.2	12.0	61.1	64.1	0.0	0.7	0.1	-593.7
0.5%	4.9	0.6	9.7	15.7	-73.5	233.8	12.1	6.0	30.6	32.1	0.0	0.3	0.1	-297.1
0.1%	1.0	0.1	1.9	3.1	-14.7	46.8	2.4	1.2	6.1	6.4	0.0	0.1	0.0	-59.5

Annual Changes in Output ($ Millions)

In considering the results shown in Exhibit 33, the first thing to note is that there are positive as well as negative impacts. This result is in contrast to the short term results where firms were represented as not having any time to adjust. In the long-term context, there is sufficient time and the pattern represented is one where other regions benefit at the expense of Montreal and the rest of Quebec. It should be noted that there is nothing implemented in the scenarios that would offer any particular advantage to Ontario over other competing regions. The reductions in Montreal-specific coefficients are simply re-allocated in proportion to how other regions already compete in that specific context.

In the most severe scenario, Montreal would suffer an annual output decline of $594M dollars from the closure of the Champlain Bridge for several years and the rest of Quebec would endure an annual decline of $147M. The net output decline for the nation though is estimated at $50M under this scenario implying that the other regions would be quite successful in making up most of the slack.

Exhibit 34: Distribution of Long Term Output Gains by Region



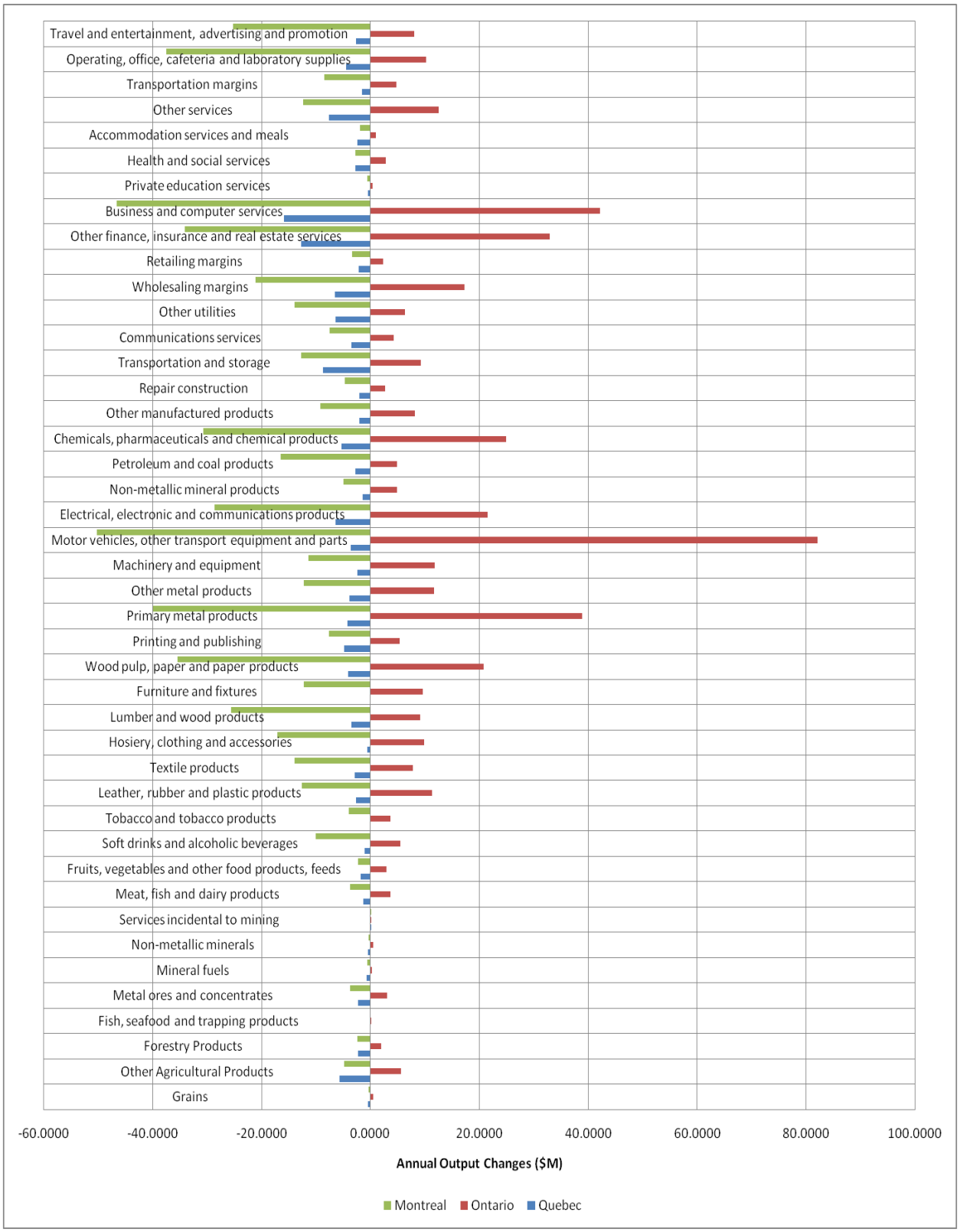
While the impacts may seem severe on the surface it is important to note that the total GDP for the CMA of Montreal is estimated at approximately $123 Billion in 2002 dollars (Lefebvre et al., 2010). Considering that the Champlain Bridge is an absolutely critical link for a very large metropolitan economy, even the “severe” scenario considered here could prove conservative over a period of several years without access to the crossing and with the potential crippling impact on the efficient movement of goods. A potential $594M decline in output would still represent only a miniscule piece of the overall economy. Another point to consider is that these scenarios cannot account for investment that never arrives in Montreal because it is discouraged by congestion issues that are perceived to drive up the cost of doing business.

Exhibit 34 illustrates how gains are allocated among the benefitting regions. As can be seen, more than two-thirds of the gains are shown to accrue to Ontario while Alberta and BC collectively fall somewhat short of acquiring 20% of the gains. It is worth mentioning that one element we are not directly accounting for in the model is the possibility that U.S. regions might stand to benefit from difficulties in the Montreal CMA. This could be viewed as a question for future work since there is little doubt that firms are capable of making cross-boundary moves in the event that better opportunities are available. Mostly, this aspect is not implemented here because it is beyond the scope of the present study and because an integrated MRIO data set for Canada and the US is not available to the best of our knowledge.

Finally, Exhibit 35, illustrates patterns, by the major regions and commodity, for the 1% scenario illustrated in Exhibit 33 which results in $594 million in lost output to the CMA of Montreal. Exhibit 35 is a similar formatted graphic as Exhibit 31 in the short term case. The short term case illustrates systematic output declines across the board while the current graphic illustrates the strong gains that Ontario might be expected to make. The biggest potential gains for Ontario would be in "motor vehicles, other transport equipment and parts", "business and computer services", "primary metal products" and "other finance, insurance and real estate". It is interesting to note that only two of those commodities are from the subset of commodities directly impacted in Montreal.

Ontario benefits also from output shifts that are likely to occur from the Rest of Quebec which suffers from being in such close integration with the CMA of Montreal. For the most part, the Ontario increases by commodity are less than the losses from Montreal and Quebec. The "motor vehicles, other transport equipment and parts" commodity-sector is a very interesting case because Ontario appears to benefit more than the two Quebec regions lose. The interactions between commodities which would cause this to happen are complex and so it can be best summarized as indicating that Ontario is particularly well positioned to benefit in that particular industrial segment. This is not surprising given the province's strong involvement in the auto industry.

Exhibit 35: Annual Output Changes by Commodity and Major Region (Bridge Closed)



Conclusions

This analysis has focused on the strategic importance of the Champlain Bridge to the Montreal CMA and the wider regional economy. Primarily, this report has viewed restrictions on the Champlain Bridge from an economic perspective with a particular emphasis on potential impacts to firms and their ability to carry on business efficiently. Excess congestion in a metropolitan area, of the type that would be induced by Champlain Bridge restrictions, has the effect of disabling many of the advantages that cause firms to locate in such areas in the first place. For example, excess congestion effectively reduces the area from which a firm can draw on people resources and this has the impact of driving up costs. Excess congestion interferes with "just-in-time" operations which have become increasingly prevalent.

The Montreal CMA is an approximately $123 Billion economy and the Champlain Bridge is a critical transportation link on which this large metropolitan economy depends. The bridge carries approximately 145,000 vehicles per day and supports a dedicated bus service that provides an estimated 40,000 person*trips per day. The Bridge is the best situated by far to handle vehicular cross-border trade in the vicinity with the United States and also facilitates a key linkage with Ontario.

In partnership with Transport Quebec, traffic simulation results were generated for a series of Champlain Bridge scenarios. Impacts all over the Montreal metropolitan areas were studied at different

times of the day for scenarios where the Champlain Bridge was open, reduced to four lanes, reduced to two lanes or closed. Some of the key observations that emerged from this analysis were as follows:

- Restrictions on the Champlain Bridge will expand the intensity and length of the AM and PM peak travel periods. While goods movement is already very much hampered during the peaks, the expansion of the durations of the peaks will disrupt the ability to move goods and provide services during what should be the non-peak hours. This time from 9AM to 4PM is very important for intra-urban commercial movements.
- The Lafontaine Bridge/Tunnel Crossing stands out in the scenarios as one of the key crossings for picking up slack from a Champlain Bridge closure. It is critical to note that vehicles carrying hazardous material are prohibited from using this crossing. Thus one of the key alternative routes would not be available to a significant proportion of commercial vehicle movements.
- Restrictions to the Champlain Bridge would mean that peak period trips against the peak direction would behave much more as if they were in the peak direction (e.g. trips to the island from the south shore during PM peak).
- Peak direction movements over the crossing were shown to slow down further from already slow levels although there is a reasonable likelihood that the traffic analysis software may have underestimated some of the peak direction declines in speed.
- In the event that the Champlain Bridge was closed or reduced to two lanes, the dedicated bus service would most likely need to shift to the Jacques-Cartier Bridge which would negatively impact vehicular traffic flows on that crossing and then the others via a chain reaction. In addition, the lack of reserve capacity on other bridges would likely enforce a shift of trips to public transit or a rescheduling or consolidation of trips into fewer vehicles. Bus flows on the bridge counter to the flow of traffic would reduce safety.

Economic impacts from restrictions on usage of the Champlain Bridge were assessed through a Multi-Regional Input-Output Model. A short-term impact analysis focused on the impacts associated with a reduction of the Champlain Bridge to four lanes and two lanes. It was assumed that such restrictions on capacity would be shorter in duration and would be best measured in terms of weekly costs. Short-term disruptions in goods movement supply chains originating in the manufacturing centre of the Montreal CMA were traced throughout the economy.

For the reduction of the Champlain Bridge to four lanes, it was estimated that the most likely scenario would suggest an output loss of $1.4 million per week that the restrictions were in place. A reduction to two lanes would be far more serious and would be associated with a most likely scenario of $6.98 million per week.

A longer-term analysis focused on the potential impacts of a closure of the Champlain Bridge. This was deemed to most likely be the potential result of a seismic event with a potential period of five to seven years where the crossing would be unavailable. Analytically, one of the key differences from the short term impact analysis was the assumption that over the longer term, there is the potential for firms to adjust to problems being encountered in one region by shifting production to another. As with the short-term analysis, a multi-regional input-output model was utilized, but in a somewhat different

manner. In the most serious scenario considered, Montreal would suffer an annual output decline of $594 million and the rest of Quebec would endure an annual decline of $147 million. A potentially more likely scenario forecasts a Montreal decline of approximately $300 million annually and a rest of Quebec decline of nearly $75 million.

Overall, it has to be considered that a loss of capacity between the main island of Montreal and the South Shore has the potential to reduce and slow down travel, hinder business investment and even change the location of business activities. While the impact analysis focused on what could be lost from economic activity that is currently present in the Montreal area, it is critical to note that it cannot account for firms that are discouraged from investing in the region due to congestion issues magnified by Champlain Bridge restrictions. In a worst case scenario, the Champlain Bridge crossing could be unavailable for several years. The serious congestion effects that this would produce could be a real issue in discouraging prospective investment quite apart to the damage that might be done to existing productive capacity.

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Glossary of Terms

Arterial - In the traffic context, this refers to major intra-metropolitan traffic routes which typically have speed limits in the range of 60-70 km/h and which are punctuated by multiple controlled intersections.

CMA - Census Metropolitan Area - A geographic term introduced by Statistics Canada and intended to capture the true extent of a metropolitan region. A given CMA may encompass multiple municipalities.

Final Demand - Usually sector/commodity specific and refers to the dollar amounts consumed by "end-users." In an input-output framework, these end-users are distinct from intermediate users who purchase inputs for further processing such as a subsequent industrial process.

Free-flow - In traffic terms, free-flow travel refers to uncongested travel which is able to reach the speeds of the posted speed limits.

Link-level traffic analysis - A traffic analysis that provides detailed predictions and results (e.g. volume, speed) at the level of individual road segments.

MOTREM - a traffic analysis model maintained and run by Transport Quebec for the purposes of doing detailed traffic simulations within the metropolitan area of Montreal.

MRIO - multi-regional input-output model - An economic impact model which simultaneously represents economic inter-connections between regions and sectors/commodities. The dollar impacts of changes

in a certain region/sector combination can be traced throughout the entire economy in terms of economic output.

MTQ - Transport Quebec - The main provincial transportation agency in Quebec.

Peak direction - Refers to the direction of travel in which the majority of traffic is going. In the morning peak period, this direction would typically be toward the downtown and in the afternoon peak period, this direction would more typically be toward the suburbs.

Reserve Capacity - The difference between the largest number of vehicles that a road segment could accommodate during a given period of time and the number of vehicles it actually carries in that time period.

VMT/VKT - Vehicle Minutes Travelled and Vehicle Kilometres Travelled - Quantities that are usually used in an aggregate sense to describe the total amount of vehicular travel in some region in terms of time and distance.

Technical Coefficient - A proportional quantity which describes how many cents of a sector's output is required to produce a dollar's worth of output in some other sector. The concept applies in a commodity-based input-output framework also.

8

Appendix

Exhibit 36: Average Velocity Patterns for Trips to Downtown (PM Peak)

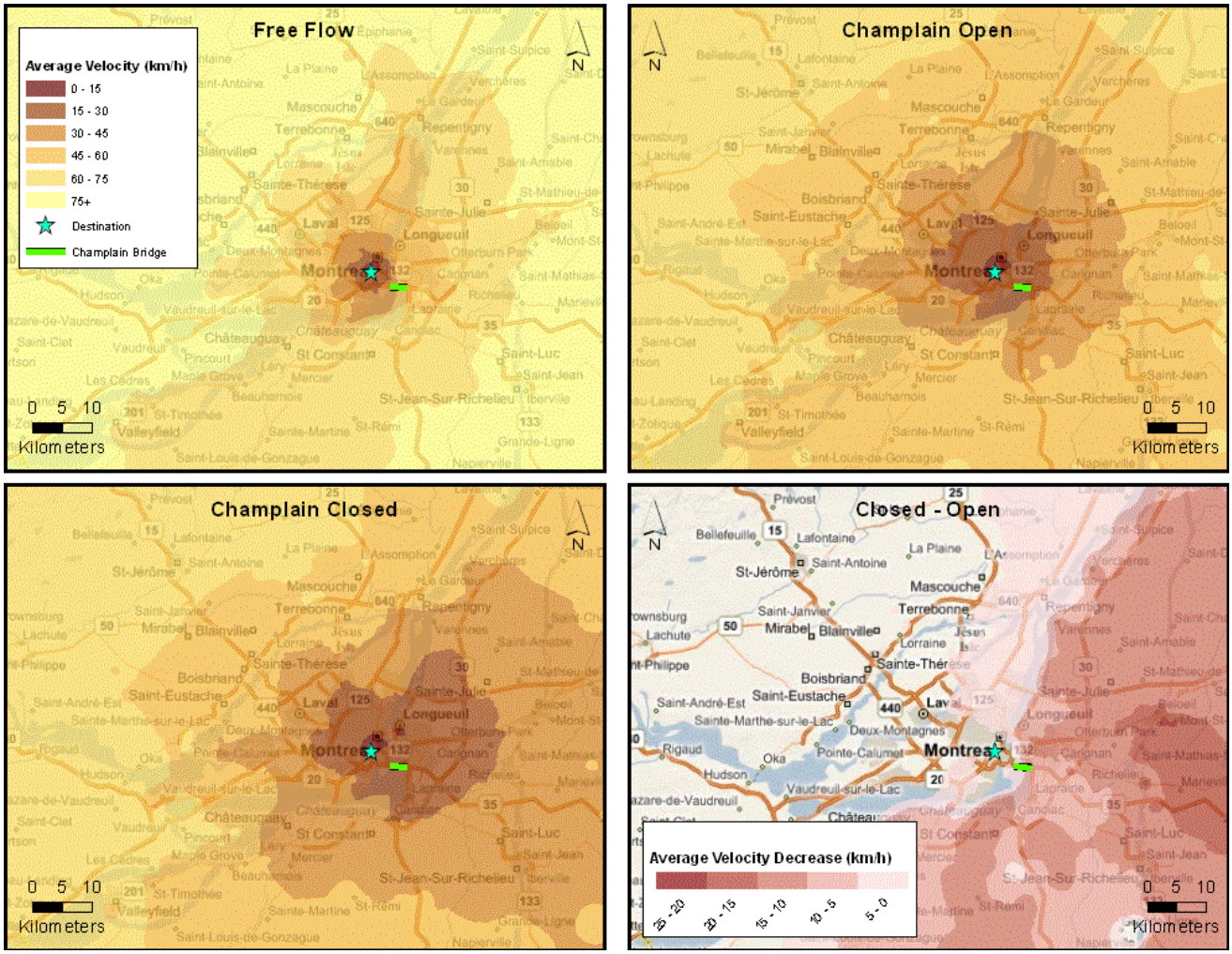


Exhibit 37: Average Velocity Patterns for Trips to U.S. (PM Peak)

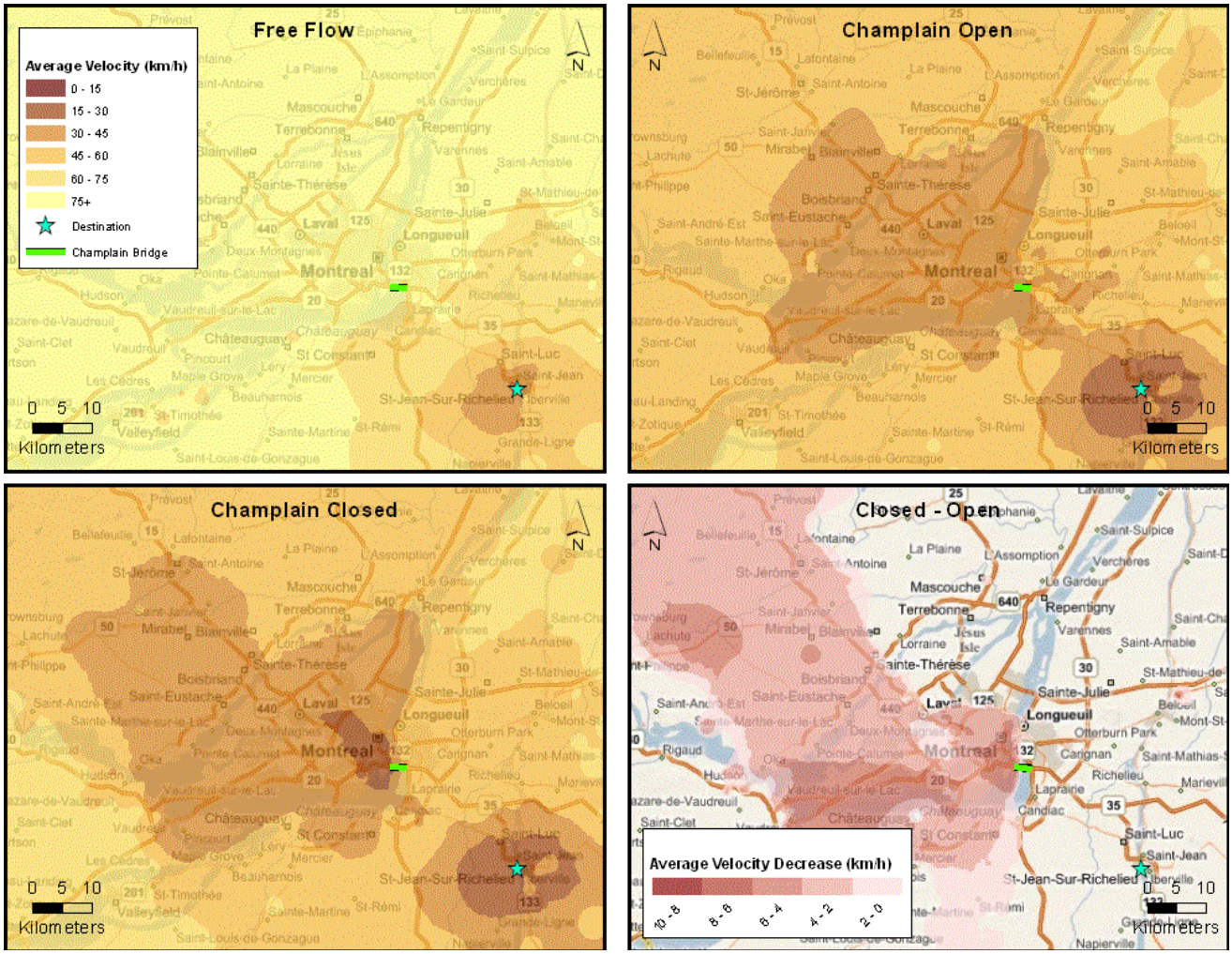
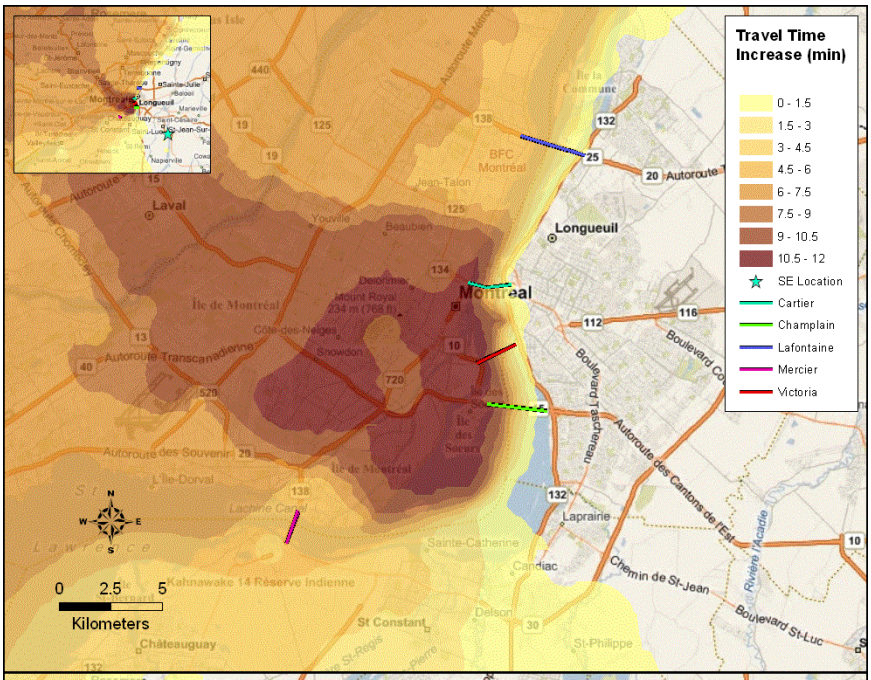


Exhibit 38: Travel Time Increases toward U.S. (2 Lanes Open - Open) for (A) AM and (B) PM Peaks

A.



B.

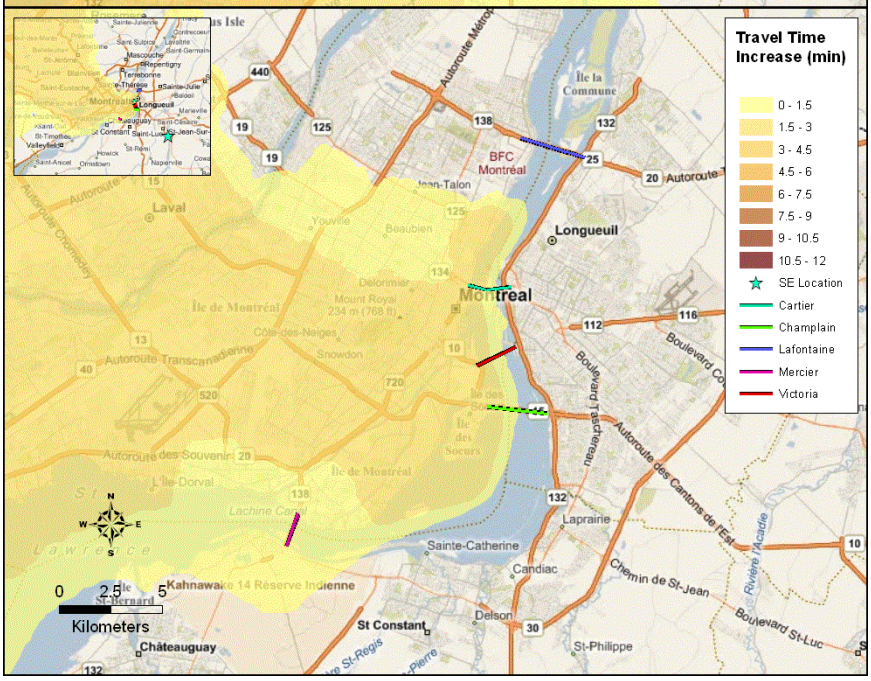
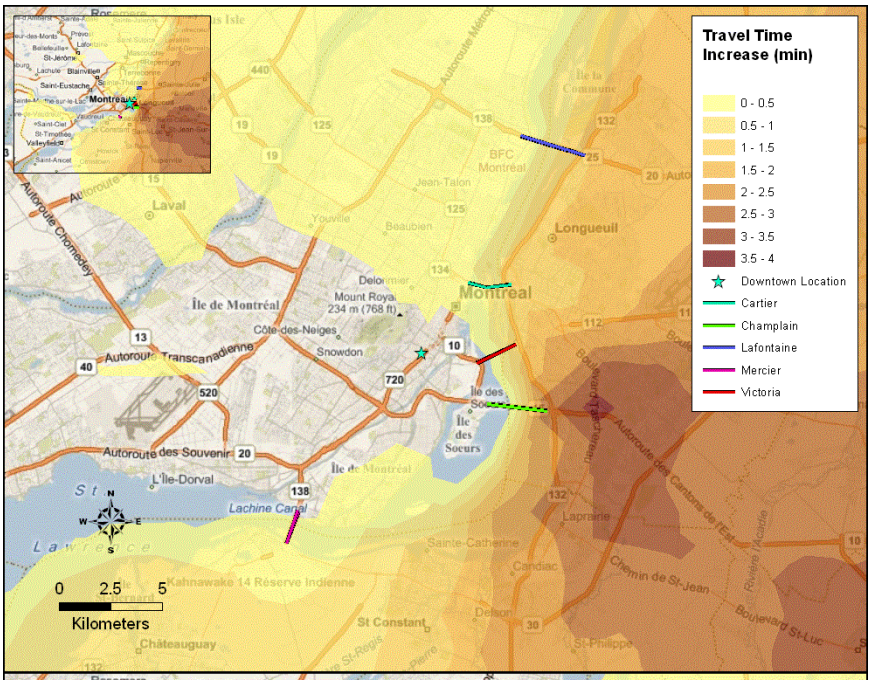


Exhibit 39: Travel Time Increases to Downtown (4 Lanes Open - Open) for (A) AM and (B) PM Peaks

A.



B.

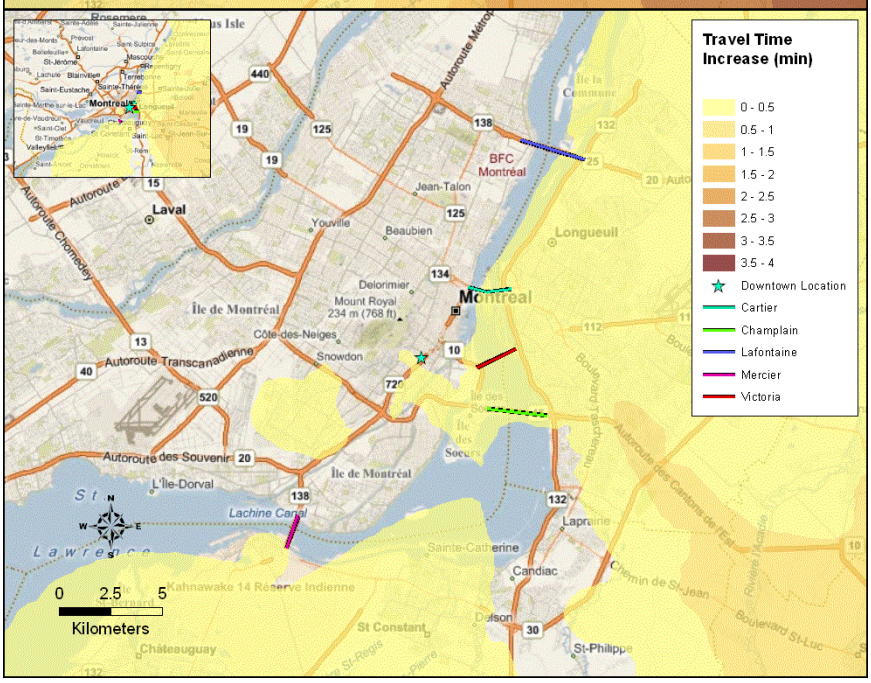
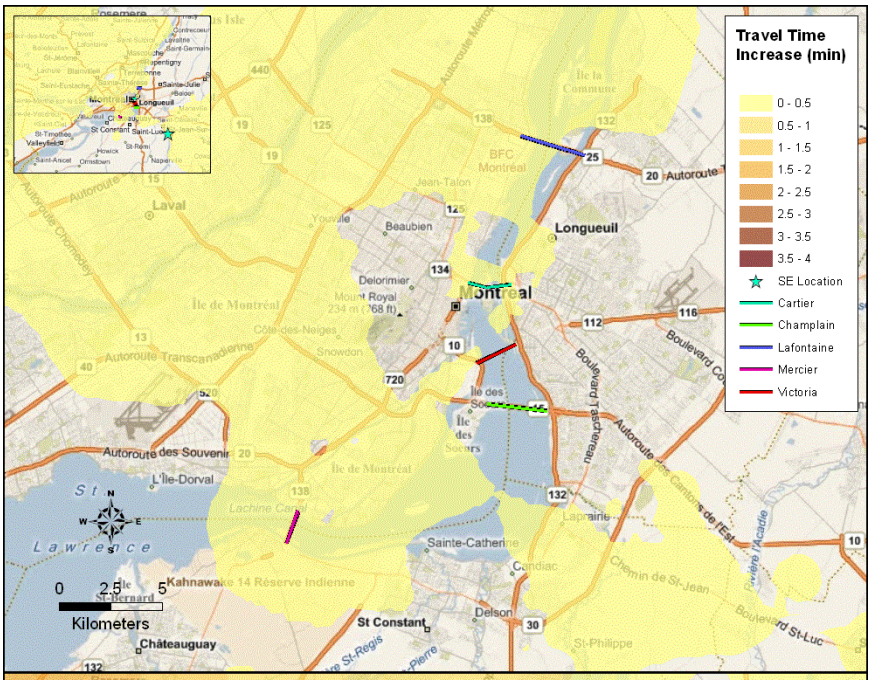
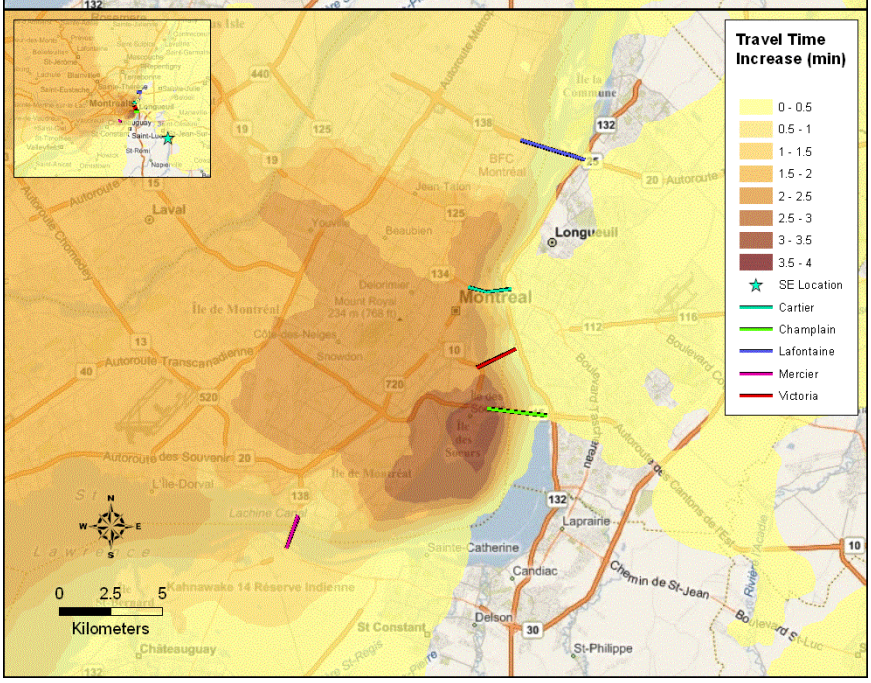


Exhibit 40: Travel Time Increases toward U.S. (4 Lanes Open - Open) for (A) AM and (B) PM Peaks

A.

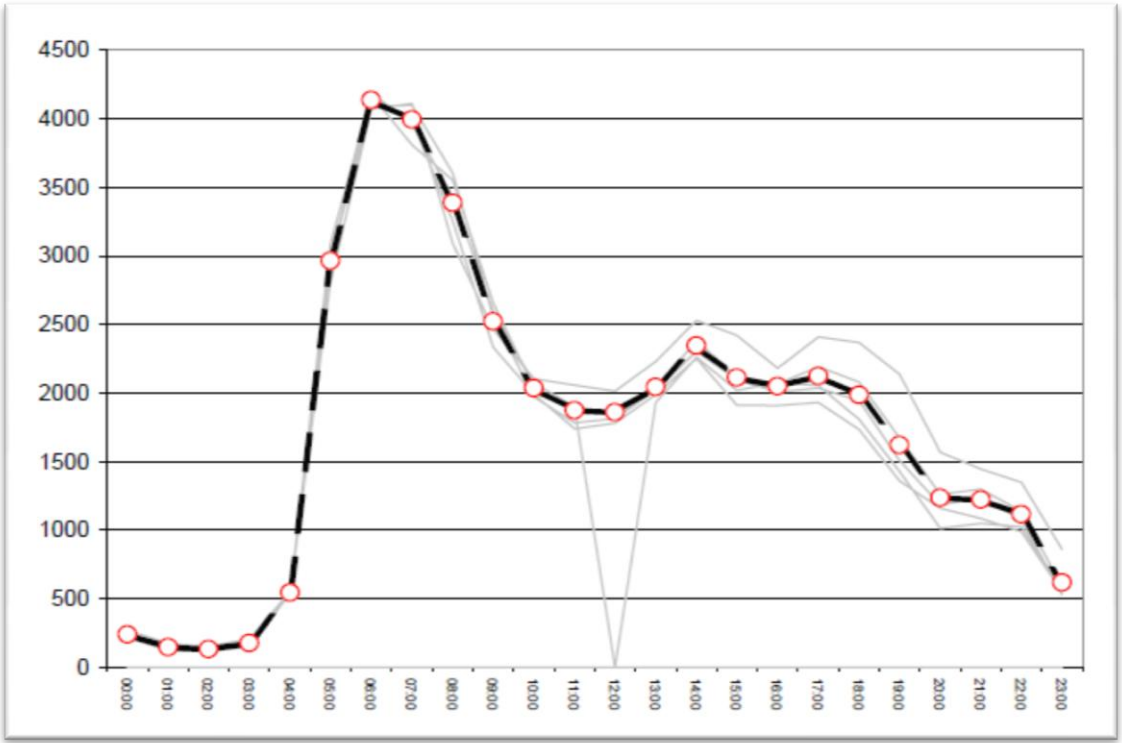


B.

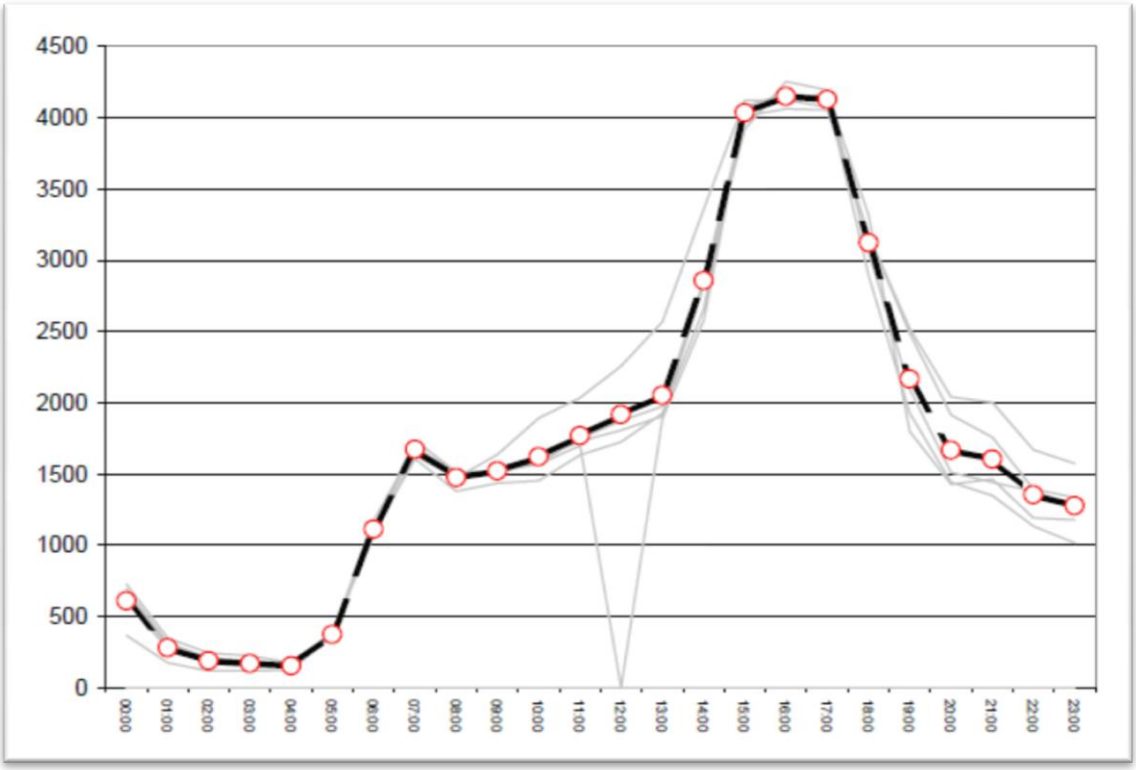


Exhibits 41 to 45 are from information provided by Transport Quebec:

Exhibit 41: Mercier Bridge Traffic Counts (A) to Island and (B) from Island

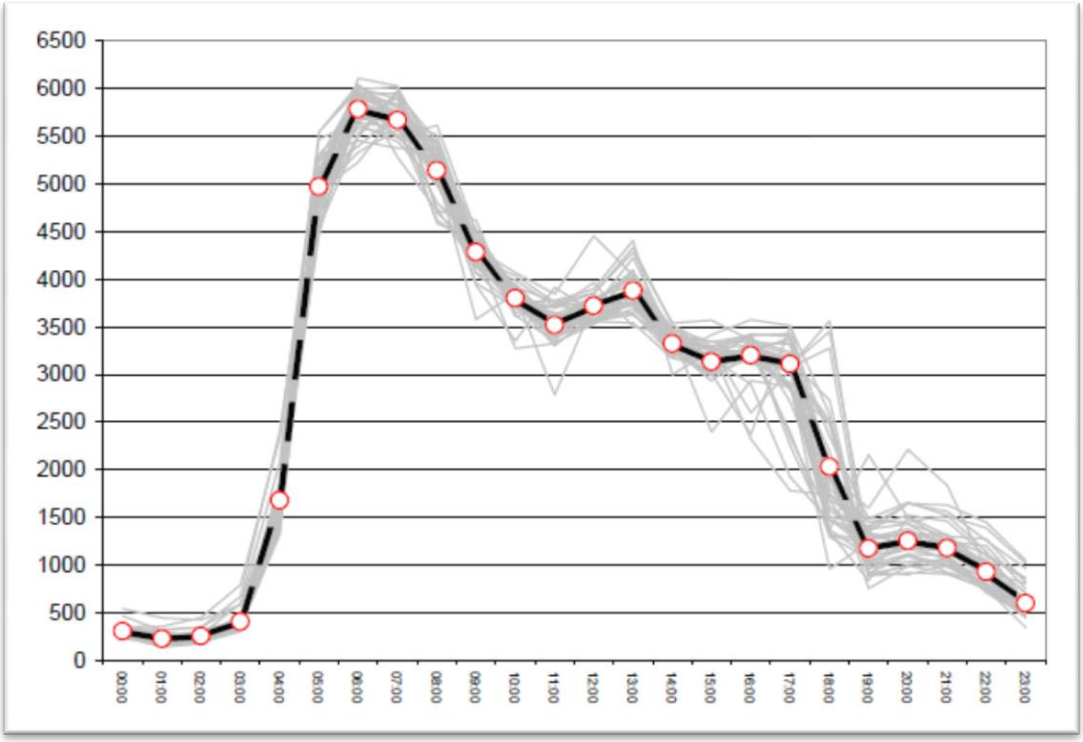


A.

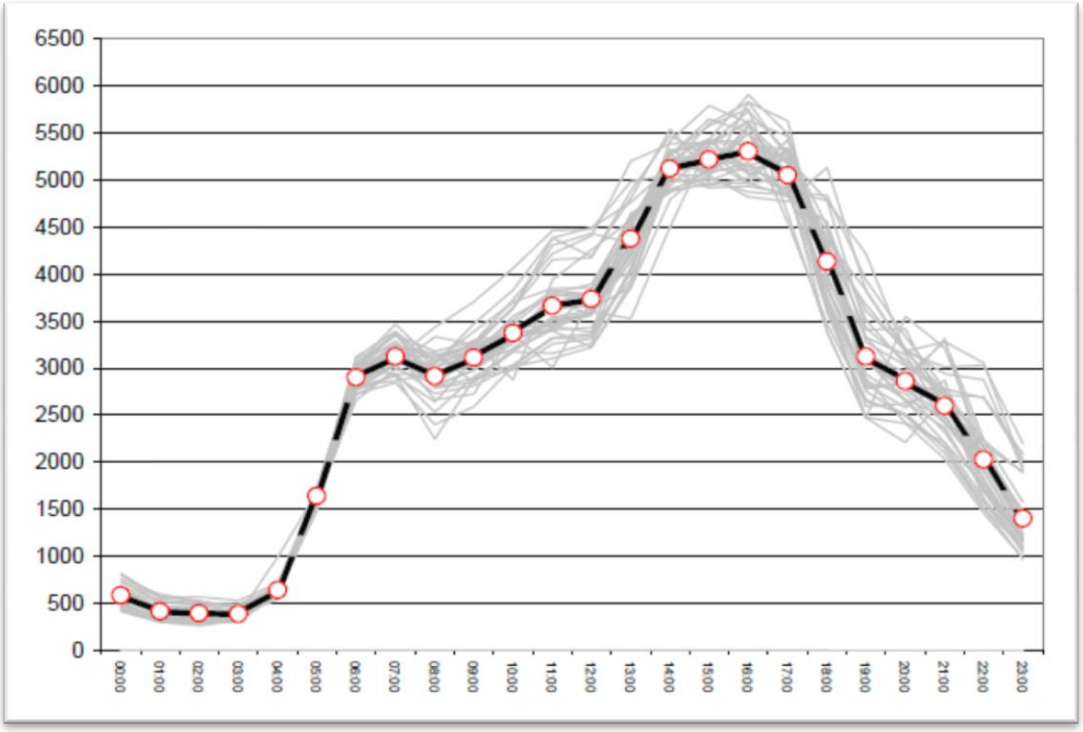


B.

Exhibit 42: Champlain Bridge Traffic Counts (A) to Island and (B) from Island

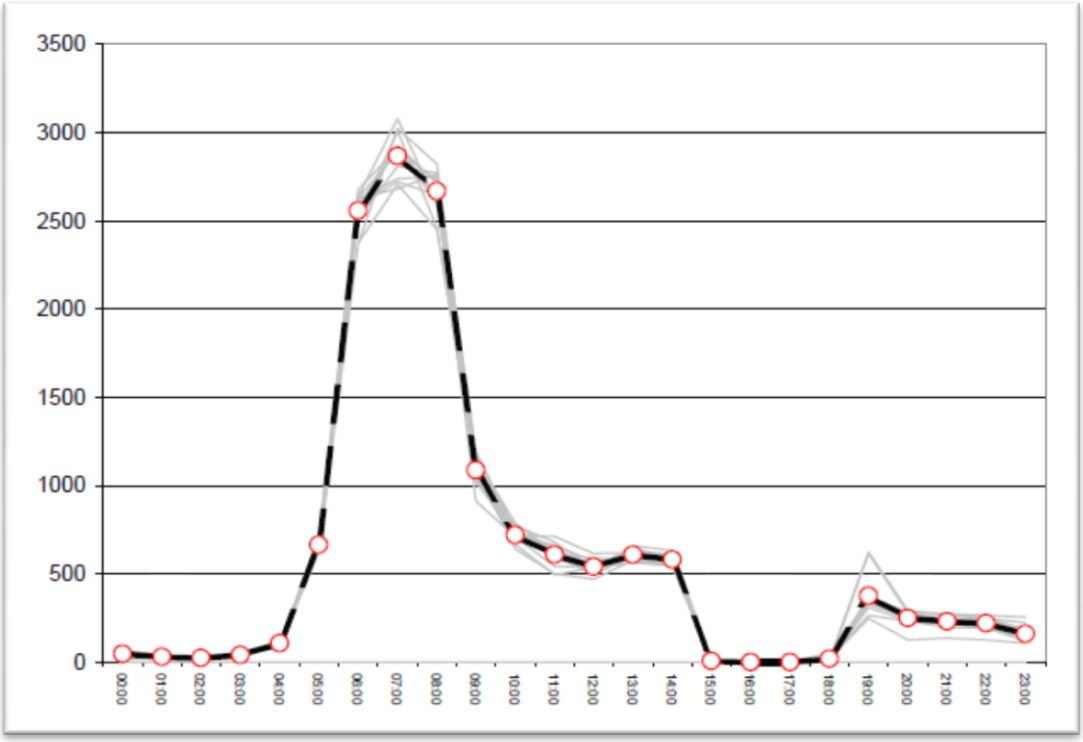


A.

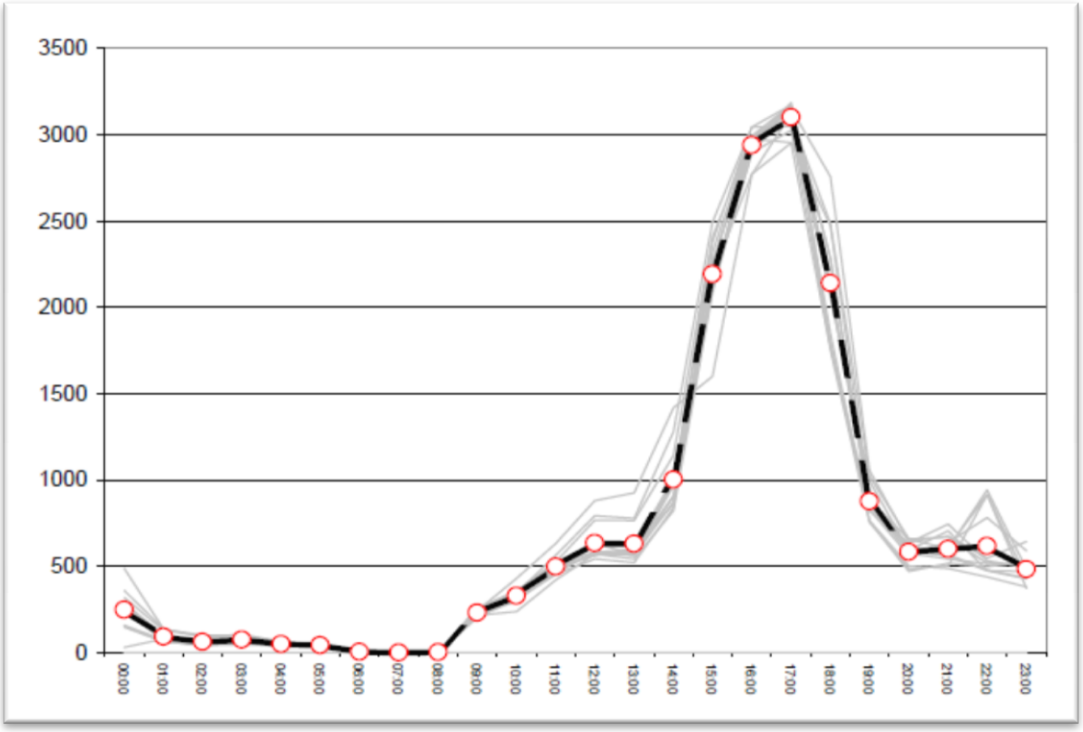


B.

Exhibit 43: Victoria Bridge Traffic Counts (A) to Island and (B) from Island

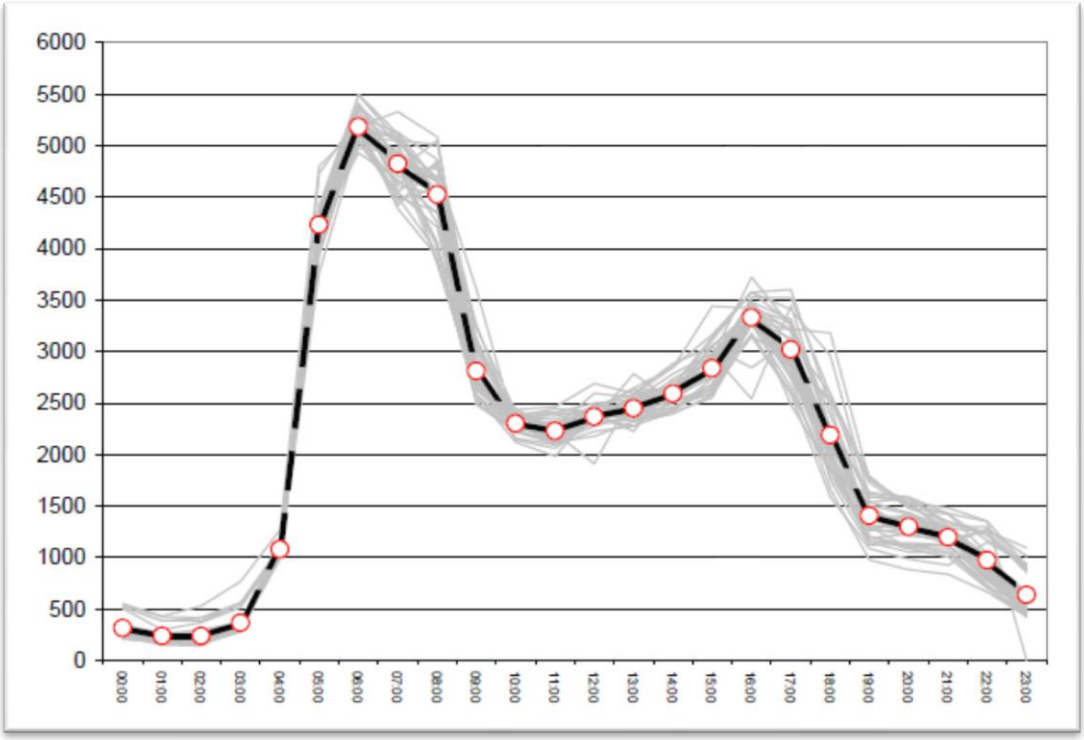


A.

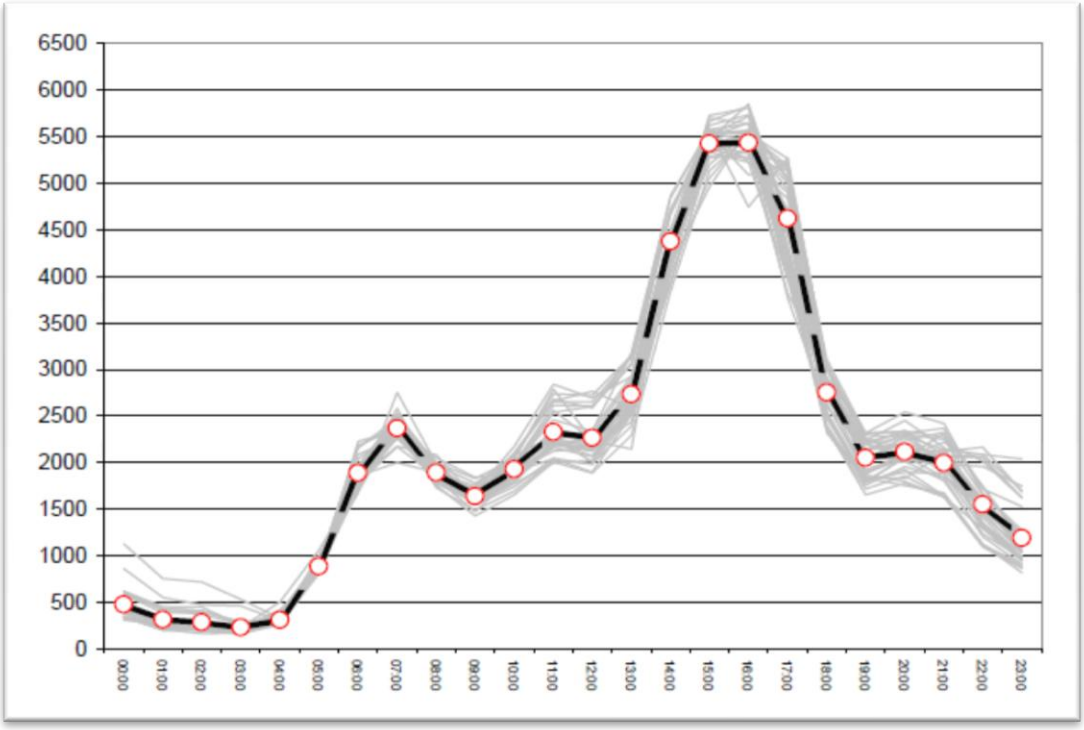


B.

Exhibit 44: Jacques Cartier Bridge Traffic Counts (A) to Island and (B) from Island

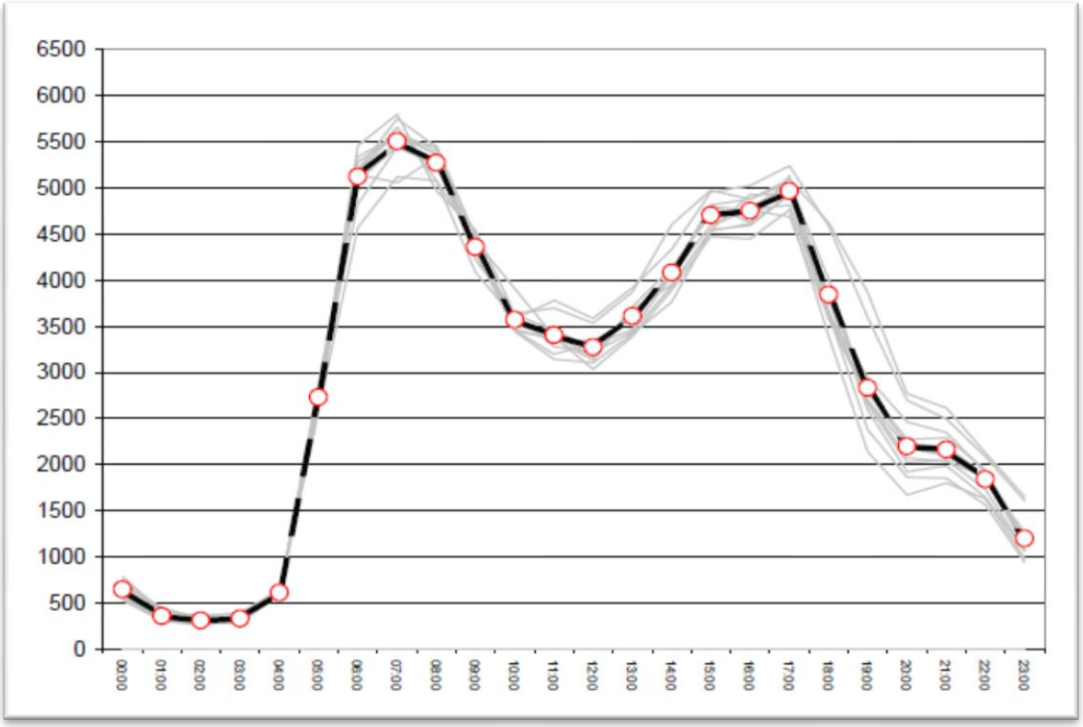


A.



B.

Exhibit 45: Lafontaine Bridge/Tunnel Traffic Counts (A) to Island and (B) from Island



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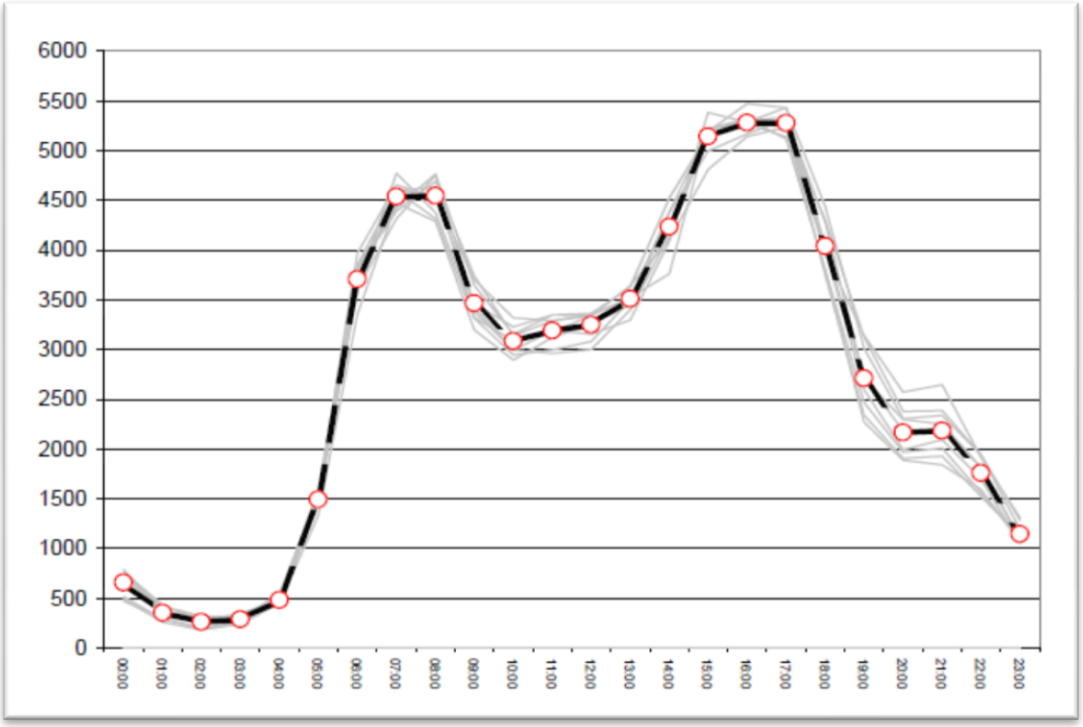

B.