The Potential for Premium-intermodal Services to Reduce Freight CO_2 Emissions in the Quebec City - Windsor Corridor: A Stated Preference Application

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ABSTRACT

The Quebec City-Windsor corridor (the Corridor) is the busiest and most important trade and transportation corridor in Canada. The transportation sector is the second largest greenhouse gas (GHG) emission category in the country. This paper develops estimates of the potential for CO_2 emission reductions in the freight transportation sector through the use of premium-intermodal services between the main Corridor destinations.

CO_2 reduction estimates are arrived at using a Stated Choice methodology. The basis of the analysis is a recently administered stated-preference carrier-choice survey of shippers in the Corridor. Survey data were used to develop mode share models for five different categories of shipments between eighteen city-pairs. A railyard-catchment approach was taken to arrive at estimates of contestable intercity truck traffic using a subset of the Ontario Ministry of Transportation's Commercial Vehicle Survey. CO_2 emissions were based on current truck traffic estimates, and emissions factors obtained from MOBILE6.2C. The results show that premium-intermodal has the potential to capture a significant share of traffic between the main Corridor destinations with potential CO_2 emissions reductions considered to be in the range of nil to 0.4 Mt.

INTRODUCTION

Canada, like many countries, is searching for ways to decrease its greenhouse gas (GHG) emissions. Because transportation is such a large contributor to GHGs (the second largest emission category after "Stationary Sources"(*1*)), it is also seen as a category where significant GHG reductions are possible. One method often considered to reduce GHG emissions by freight transportation is to increase the proportion of freight transported by rail instead of road.

This paper presents estimates of potential CO_2 reductions through using premium-intermodal services between the main destinations of the Quebec City - Windsor Corridor in Canada. The estimates are made on the basis of mode share models developed from a stated preference data set of shippers surveyed in this important corridor. The mode share models are applied, under various scenarios, to estimate the potential for current truck traffic in the Corridor to be transported intermodally. The potential to reduce CO_2 emissions is then calculated based on these intermodal market-share scenarios.

The paper begins with some background information on transportation sector emissions in Canada, the study region and a brief description of the stated preference survey. For a more thorough description of the study and survey, see (*2*). Afterwards, the main results of the survey, including a short description of the mode share models, are presented. A description of the trucking data, as well as the important assumptions used in the market-share and emissions simulations is followed by a presentation of the results of the simulation scenarios and some concluding remarks.

FREIGHT CO_2 EMISSIONS IN CANADA

The transportation sector is the second largest GHG-contributing source in Canada, producing around a quarter of all emissions. Freight's GHG contribution stands at around 10% of overall Canadian emissions, with road freight making up more than half of these emissions and rail freight around 10%. At the same time road freight's contribution to emissions is increasing while rail's contribution has been declining. Measured in tonne-kilometres (t-km), road climbed from 24% to 37% of freight mode share between 1990 and 2003 (*3*). Also road transportation is thirteen times less GHG efficient than rail, with road GHG emission intensity in 2000 being 264 grams CO_2 equivalent per tonne-kilometre shipped, compared to 20 for rail (*1*).

THE QUEBEC CITY – WINDSOR CORRIDOR

The Quebec City-Windsor corridor is the strip (more or less 100-kilometre-wide) that hugs the Canada-United States border for roughly 1,100 kilometres between Quebec City, Quebec and Windsor, Ontario (see FIGURE 1).

Quebec and Ontario are the two most populous provinces of Canada containing roughly half its population. The Corridor is home to 85 percent of the population of Quebec and Ontario, and the location of 3 of the 4 largest Canadian cities. It is also the industrial heartland of the country (*5*). Due to this concentration of industry and population, it is the busiest and most important trade and transportation corridor in Canada.

The Montreal-Toronto section forms the busiest segment of the Corridor. Along this corridor, road has a much higher mode-share than for the country as a whole, with almost 65% in 1997 relative to 35% for rail. In the country as a whole, road mode share increased in the corridor from 61% in 1990 to 65% in 1997 (*6*). Because of the corridor's importance for freight transportation and the dominant role of trucking, understanding the potential to increase rail's mode-share here has important implications for the country as a whole.

PREMIUM-INTERMODAL

The focus of this research was intermodal transportation that could compete directly with truck-only freight transportation in the Corridor. The intermodal configuration referred to as 'premium-TOFC' (trailer-on-freight-car) was the only one found to meet these criteria. Premium-TOFC refers to railway service configurations that prioritize on-time reliability (through scheduled services and reduced loading and unloading times), minimize damage risk (by using smooth-ride technologies), and provide schedules that allow carriers to provide the same service to their clients as by their truck-only services (*7,8*).

The service is referred to as *TOFC* because it involves carrying regular truck trailers as opposed to reinforced marine or domestic containers. Both Canadian National Railway (CN) and Canadian Pacific Railway (CP) introduced premium-TOFC services in the Corridor at the end of the 1990s. These services were offered between various combinations of the main Corridor destinations (Chicago, Montreal, Toronto and Windsor), but have been for the most part abandoned by CN, while CP continues to offer its service between Montreal and Toronto. As a result, the CP service called Expressway was used as the 'model' configuration during the study and survey development. Expressway service includes two trains from Montreal to Toronto and two trains from Toronto to Montreal per day. Expressway trains have been engineered so that a trailer can be loaded or unloaded in as little as 15 minutes. At the same time, the specially engineered train cars provide load stability comparable to standard trucks trailers.

While premium-TOFC was used as the model of a service that could compete directly with trucks, the study should not be seen as a study of the potential of only premium-TOFC services, but rather as a study of the potential for premium-*intermodal* services.

SURVEY AND MODEL RESULTS

The Carrier Choice Survey

In order to estimate the potential for premium-intermodal services between the main destinations of the Quebec City - Windsor Corridor, a stated preference carrier choice survey of end-shippers was administered. End-shipper is the term used in the study to describe a shipper that hires carriers for all of their shipments. The decision to use intermodal services will generally be that of the carrier, since it is the carrier that organizes the movements of consignments from end-shipper to receiver. Although one might expect end-shippers to be indifferent to how their shipments are shipped as long as they arrive in good condition and on time, carrier decisions about whether or not to use intermodal services will ultimately be constrained by shipper preferences. In effect, the end-shipper can be seen as the true backstop for the demand for intermodal services.

As a result, while many previous mode choice studies, e.g. (*9*), have surveyed both end-shippers and own-account shippers, this study focused exclusively on end-shippers. In particular, it was designed to establish whether a carrier's use of intermodal services would affect the end-shipper's choice of carrier. To save space, only a cursory description of the survey is provided here - a more complete description of the survey can be found in (*2*).

The survey itself took the form of what is called in the literature a 'contextual stated preference' or CSP survey, e.g.(*10*). In fact, there were two surveys one in English and the other in French, reflecting the primary mother tongues of respondents. The surveys had two parts. The first described the purpose of the survey and how the survey was meant to be completed. In addition, some information believed to be relevant in post analysis was sought, e.g. the proportion of the firm's shipments that were 'by-appointment'), and whether the shipper employed carriers using intermodal services.

The second part of the survey was the actual CSP, involving 18 questions for each respondent. For each question, the respondent was asked to make a choice between three alternative carriers in the context of a particular shipment, whose details were described. The information given to the respondent was the origin and destination, when the shipment was to arrive, whether it was 'by-appointment,' whether it was of high or low value, whether it was fragile or perishable, and its size (truckload or LTL). Information on value and fragility was not provided explicitly, but through the type of commodity that was being shipped. For example, televisions were the shipment used to represent high value, fragile goods.

With respect to carrier attributes, five were provided: cost, on-time reliability, damage risk, security risk and whether the carrier would send the shipment by rail for a portion of the journey. Whereas in previous mode choice studies (*11*,*12*,*9*), mode has been included explicitly by asking respondents to choose between alternative modal configurations for their shipments, in this survey, mode was considered a carrier attribute. Unlike many SP freight surveys, time required for shipping was considered a shipment's attribute, not a carrier's. This is because discussions with shippers established that shipping times in the Corridor are standardized, e.g. a Montreal to Toronto shipment is 'overnight'. As a result, shipping time is not a basis upon which carriers are chosen as all carriers can offer the same overnight shipping. This is not the case for shipments between city pairs separated by longer distances. For example, a shipment between Toronto and Vancouver can require between 3 and 7 days. Because of this difference, a study that included longer-haul shipments between city-pairs for which travel times are not standard would require a different survey – i.e. one that included shipment travel time as a carrier characteristic. Unfortunately, it was outside of scope of this research to be able to field two surveys, and so only one survey for trips between destinations in the Corridor was used.

A list of end-shippers including manufacturers, wholesalers, retailers and third party logistics companies (3PLs) was provided to a telephone survey company to contact and recruit respondents for the web-based survey. The list of companies came from the Dun & Bradstreet Million Dollar Database of companies in Ontario and Quebec. The survey was administered between mid-August and early December 2005. All companies in the list sent to the marketing firm were contacted (7,004). Of these, 680 agreed to participate. In the end, completed results were obtained for 392 respondents.

Model Results

Overall simulation results were based on the application of five random-effects mixed-logits (see (*2*) for a description of this type of model) to five subsets of the data obtained from the survey. Determination of the data subgroups to be modeled separately took place in three stages.

The first stage was to establish potential subgroups. In all, seventy-two different shipment categories were presented to the respondents in the contextual part of the surveys. The different categories were defined by shipment fragility, value, size, time-sensitivity and distance. An example of one of the these shipment types used in the survey was a by-appointment shipment of a pallet of televisions to be shipped from Montreal to Chicago and delivered at 10 AM in two days' time. This was an example of a long haul, small, high-value, fragile, by-appointment shipment. As such, there were originally considered to be 72 potential shipment sub groups, which might need to be modeled separately.

These 72 categories were reduced to 24 by incorporating distance-interaction variables with the carrier attributes. That is, instead of having separate groups for short-, medium- and long-haul shipments, shipment distance was interacted with each of the carrier attributes. As a result, instead of having 72 separate groups to begin with, there were only 24, each containing as variables the carrier attributes, as well as variables that were the product of each of the carrier attributes and shipment distance. In addition to the effect of shipment types on carrier choice, there was also an interest in seeing whether 3PLs had different utility functions for carriers than other shippers. As a result, 48 subgroups were tested for whether or not they should be modeled separately. That is, the 24 subgroups were further subdivided into 48 subgroups: 24 for 3PLs and 24 for the other end-shippers.

In the second stage, a test was conducted to see which of the different subgroups could be considered as statistically different from the others, and hence not modeled together. This also made it possible to determine which subgroups weren't different from others and therefore could be modeled together.

In order to do this a version of the so-called Chow test (see for example (13)). The Chow test is an F-test of the joint insignificance of multiple variables identified with subsets of a population. The coefficients of these subset specific variables are allowed to vary independently from the coefficients used for the rest of the observations. These coefficients are allowed to vary independently from the rest by 'interacting' the explanatory variables with a dummy variable identifying the subset of observations of interest. If all the explanatory variables of the model are interacted with the dummy variable identifying the subgroup, this amounts to testing whether the subgroup is statistically significantly different from the other observations. More precisely, it is testing whether, by allowing each of the explanatory variables to be estimated separately for the subgroup, there is a statistically significant increase in the explanatory power of the model. An example of using this method would be to test for the joint insignificance of variables interacted with a dummy variable indicating whether each respondent was a woman. If the test turned out to be statistically significant (i.e. the null hypothesis was rejected), it would amount to saying that there is a statistically significant increase in explanatory power by estimating a model for women independently from men, and therefore that separate models ought to be estimated for women and men. As this is a discrete choice analysis involving maximum likelihood estimation, instead of using an F-test the appropriate test is a likelihood-ratio test.

The procedure is relatively straightforward if there are only two subgroups of observations in a dataset, as in the case of testing for differences between men and women. It becomes more complicated as the number of subgroups increases. For example, suppose there are three subgroups in a dataset (groups 1, 2 and 3). Also suppose the explanatory variables were interacted with groups 2 and 3 separately, i.e. one set of explanatory variables interacted with a dummy variable for group 2 and another set with a dummy variable for group 3. A significant Chow test, jointly testing the variables interacted with group 2 would imply that the group 2 observations ought to be estimated separately from group 1. This would not, though, provide any information on whether group 2 should or should not be modeled with group 3. In order to establish this, it would be necessary to estimate a model with group 2 as the base category and to test for the joint insignificance of group 3 variables.

As there were 48 different shipment-shipper categories, the initial idea was to test for differences between these 48 different subgroups. Very early in the analysis, it became clear there were far too few observations for each of the 24 shipment types by 3PLs to be able to test whether there were differences by shipment type and shipper group. As a result, the number of a priori subgroups was reduced to 24 shipment types.

An initial aggregate model (see column 2, TABLE 1) was developed, testing down iteratively from a more to a less elaborate model, with insignificant variables being removed in each iteration. Because the purpose of developing this model was to test for different utility functions by subgroups of shipment types, information on shipment type was not included in the explanatory variables of this aggregate model. For example, whereas in the global model presented above, by-appointment shipments were interacted with on-time reliability, this was not done in this model so that differences between the subgroups could be tested.

A dummy variable for each of the 24 subgroups was then interacted with each of these variables and included in each of the models, except in those models where the given subgroup was the base subgroup. As one example, a dummy variable for the second subgroup (fragile, truckload, high-value, by-appointment shipments) was interacted with each of the variables, except in the second model where group 2 was the base group. For each of the models, Chow-tests for the joint insignificance of the variables interacted with a particular subgroup were calculated.

Each of the 23 models included 264 variables and as a result, over 6,000 coefficients in total were estimated and 276 Chow-tests calculated. Because of the large number of regression coefficients estimated and LR-tests calculated, there is bound to be a considerable number of type-I errors. Hence , a statistical significance level of 1% instead of the usual 5% was used for the Chow-tests as recommended by Kennedy (14).

The third stage of sub-group determination was to examine which groups (according to the LR-tests) described above should not be modeled together. This information, in combination with examination of the groups themselves, allowed determination of groups that were intuitively acceptable, and which did not need to be modeled separately. For example, by-appointment and not by-appointment high-value perishable goods tested significantly different from most other categories. At the same time, by-appointment and non-by-appointment high-value perishable goods did not test significantly different from each other so they were included in their own subgroup. This process eventually resulted in the determination of five subgroups.

Models with the variables used in the aggregate model were tested for each of the subgroups and the final models were arrived at by testing down from the aggregate model to the more specific models presented. The global model and those for the five subgroups are presented in TABLE 1. The most notable thing about the submodels is that they generally include only the five (and sometimes only 4) carrier attributes. One reason for the small number of coefficients is that each of the subgroups had only a fraction of the observations of the global model, thus resulting in the insignificance of many variables. The submodels themselves meet *a priori* expectations.

High-value shipments by appointment tend to be less sensitive to price and more sensitive to on-time reliability than the other four groups. Perishable goods are also particularly sensitive to on-time reliability. The seemingly low (in absolute value) shipping cost coefficient for low-value, not by-appointment goods is Explained by the fact that when the coefficient for the interaction between distance and cost is taken into consideration, it results in a coefficient of -4.592 for the shortest shipping route considered in the survey. As such, it is in fact the most cost-sensitive category. It is also the least sensitive to on-time reliability.

With respect to the intermodal coefficient, it is relatively stable across the subgroups, except for the high-value not by-appointment, non-perishable subgroup. For this subgroup the intermodal coefficient is only -0.56. No explanation for the low (in absolute terms) value of this coefficient could be found.

MARKET-SHARE AND EMISSIONS SIMULATION: DATA, BACKGROUND AND ASSUMPTIONS

Before these models could be used to estimate emissions, three different types of information were required. Namely, estimates of contestable truck trips; shipper, shipment and carrier attributes; and emissions factors for truck-only as well as intermodal trips.

Contestable Truck Trips

Truck trips believed to be contestable, given the service offerings of current premium-intermodal services on the corridor were: truckload (TL), overnight, for-hire truck trips between major destinations with appropriate railway infrastructure in the Corridor. While current service offerings are only competitive in the truckload market, in some of the simulation exercises below, less-than-truckload (LTL) trips are also included as being contestable under the assumption of appropriate changes to premium-intermodal shipping schedules. Only for-hire trips were included because only end-shippers using for-hire carriers were surveyed.

The ability to conduct such an analysis relied on the ability to establish the universe of total truck trips traveling the Corridor. Luckily, the Ontario Ministry of Transportation (MTO) provided a sub-sample of its Commercial Vehicle Survey (CVS) updated to the year 2002. The database from the MTO provided considerable information on trip (e.g. geocoded origins and destinations, distance between origin and destination), shipment (by 4-digit SCTG category), vehicle (e.g. configuration) and carrier (e.g. for-hire or private) characteristics. The geographical, shipment and carrier characteristics, as will be described below, were the most important for the current analysis.

Quebec City, Montreal, Toronto, Windsor-Detroit and Chicago were included as the major destinations. Ottawa was left out due to lack of sufficient rail infrastructure. Trips between all of the destinations were included except for trips between Montreal and Quebec City since shipments between these destinations are generally sameday and not overnight.

The association of origins and destinations to these cities was determined using a ‘railyard catchment’ analysis. That is, trip-ends were associated with a particular city if they fell within 50 km of an intermodal railyard in that city. Trips between cities, then, were actually trips between railyard catchments. The number of trips between railyard catchments was adjusted to account for the fact that the two Class-I carriers operating on the Corridor would be unlikely to share traffic. For example, it is very unlikely that a trailer would leave from a CP railyard in the origin city and arrive at a CN railyard in the destination city. As a result, a trip that had its origin in a CP railyard catchment and its destination in a CN railyard catchment, which was not a CP railyard catchment would not be considered a contestable trip.

From these truck trips, private and LTL trips were removed. The former were readily removed as the database identified them. Removing LTL trips was a bit more involved since there was no variable uniquely identifying trips as LTL. Trips with more than one destination were considered as LTL trips and removed.

One final adjustment was made to arrive at the final number of contestable truck trips. This involved adjusting the number of trips between Montreal and Toronto upwards. This was necessary because some of the trailer traffic between these two cities has already been successfully contested by CP which currently offers a premium-intermodal service between them. The number of trailers carried is believed to be significant. However, for competitive reasons, it was not possible to get information from CP on the number of trailers carried by Expressway. Using information on scheduled service capacity, two different assumptions about capacity-utilization (one of 50% and the other of 100%) were used to upwardly adjust the total trailer trips for this route. These two assumptions resulted in premium-intermodal trip estimate of 10% and 20% of current trips.

Shipper, Shipment and Carrier Attributes in the Simulations

Carrier attribute values used in the simulations were based on shipper interviews. In all, one hundred and fifty calls were made resulting in thirty interviews. These short interviews (2 to 5 minutes) involved asking shippers about the performance, in terms of their service attributes, of their carriers for both TL and LTL shipments. Respondents were also asked whether any of their carriers used premium-TOFC services and if so, how they performed in terms of service attributes. Of the thirty shippers interviewed, nine had used carriers who had used premium-TOFC services. The attribute values obtained from the respondents were averaged and used as the attribute values for the truck-only and intermodal services in the simulations.

The degree to which Expressway services may be more or less expensive for a carrier is unclear since this information is of a particularly competitive nature. Nevertheless, discussions with Expressway staff led to the conclusion that the cost of a shipment for an end-shipper would be the same whether or not the carrier used Expressway or provided a truck-only service. Therefore the costs used in the exercise were the same for both types of carriage, and were based on TL prices between the cities of interest.

Some of the models required information on whether or not the shipper was located between the two Expressway railyards. This was incorporated by using the proportion of shippers in the entire shipper population located between the two railyards. Shipper location was determined by geocoding the postal codes of firms as recorded in the Dun & Bradstreet database.

Naturally, applying the subgroup models required the identification of truck trips with the different types of shipments. The CVS contained information on shipment contents (by 4-digit SCTG code) as well as by value. As a result, relevant shipment codes were classified as being perishable or not and shipment values were used to classify shipments as high- or low-value. While the CVS did not contain information identifying shipments as by-appointment, the first part of the survey asked respondents to estimate the proportion of their shipments that were by-appointment. The average value of the answers to this question was used to divide shipments between by-appointment and not by-appointment.

Emissions Factors

Once estimates of truck trips were developed, emissions could be estimated - both for the existing truck trips and for current trips had they traveled intermodally. This essentially involved multiplying the distance of the trip by the appropriate (truck or train) emission factor. Emissions estimates were made solely for the Canadian portion of trips since the focus of the research was Canadian transportation emissions. The CVS data included the distance of each of the trips (including distance of the trip covered in Canada), so calculating the emissions for each of the trips simply involved multiplying this distance by the trucking emission factor (see below).

Estimates for what the emissions would have been, had the trip gone intermodally were estimated by calculating the straight-line distance between the trip-start and origin railyard and between the destination railyard and the trip-end. These distances were then multiplied by the truck emissions factor. For the rail part of the journey, rail distances were compiled using the Canadian Trackside Guide 2003 (*15*) and emissions calculated as the product of the rail distance by the rail emission factor.

The Truck Emission Factor

MOBILE6.2C was used to produce the truck-only CO_2 emissions factor in the analysis. MOBILE6.2C is the name given to the Canadian adaptation of the US Environmental Protection Agency's MOBILE6.2. Although, MOBILE6.2C is used internally at Environment Canada for mobile source emissions modeling (although not for CO_2), it has not been officially released by Environment Canada. Nevertheless access was provided to the program for the current project. The descriptions of MOBILE6 and MOBILE6.2C come predominantly from (*16*) and (*17*), respectively.

For the purposes of this research, one vehicle emission rate was sought to represent emissions from intercity heavy-duty trucks operating in the Corridor. The final emission factor amounted to a weighted average of the emissions factors for each vehicle type (MOBILE6 classes 7, 8a and 8b for gas and diesel trucks) in each of four regions defining the Corridor. The weighting used was the proportion of vehicle kilometers traveled by truck class, per region. The resulting CO_2 emission factor used was 978 g/km.

The Train Emission Factor

Information on train fuel economy obtained from CP was used to derive rail emission factors. Naturally, derivation of a per-trailer emission factor requires knowledge of the number of trailers carried per train. CP could not release the number of trailers actually carried, but provided total capacity (105 railcars for two trains per day from Montreal to Toronto and two trains per day from Toronto to Montreal - 420 trailer capacity per day). They also provided fuel consumption per train trip (2000 litres over 340 miles). Since we did not know how many trailers were actually carried, one high and one low capacity utilization assumption were made. The high capacity assumption was that Expressway was operating at full capacity. The full capacity assumption implied a per-trailer emission rate of about 10% of truck-only emissions. The low capacity utilization assumption assumed capacity utilization of 50%, thereby implying a per-truck emission factor of 20% of truck-only emissions. The emission factor was updated dynamically in the simulations when the capacity-utilization factor changed. The resulting emission factors were 189 and 94 g/km per trailer for the low and high capacity utilization assumptions, respectively. That is, between 10% and 20% of truck emissions.

MARKET-SHARE AND EMISSIONS SIMULATIONS

Emissions simulations involved first the estimation of the current number of truck-km. Truck-km were then multiplied by the truck emissions factor to arrive at overall CO_2 emissions. In the case of trips between Montreal and Toronto, the intermodal emissions factor was used to estimate CO_2 emissions of current trailers traveling by premium-intermodal services. This resulted in the current emissions reported in the column labeled "Annual KG CO_2" in TABLE 2. Market-share estimates by shipment subgroup were then made by applying the appropriate model to the appropriate truck trips to develop market-share potential estimates in truck-km. The appropriate emissions factors were then applied to truck-km estimates to arrive at overall simulated emission estimates. That is, the truck-only emissions factor was applied to truck-only km and the intermodal emissions factor was applied to intermodal truck-km. The sum of the simulated emissions from truck-only and intermodal traffic were then compared with "current" emissions, or those emissions labeled as "Annual KG CO_2". The sum of the simulated emissions are always lower than current emissions because in the simulations, a proportion of current traffic is assumed to be transported intermodally. Since the intermodal traffic emits less, the total emissions of the truck and intermodal traffic together is lower than for the current situation. An example of a simulation can be seen in TABLE 2.

TABLE 2 results are from a simulation where premium-intermodal services is presumed to be available for all city pairs in the Corridor and CP's current service between Montreal and Toronto is assumed to have the higher of the two market shares. The third column shows estimated annual emissions in 2002 associated with truck and premium-intermodal traffic between the city-pairs considered. At around 0.70 Mt of CO_2, this represents roughly 2% of total road freight GHG emissions in Canada. This figure may seem surprisingly small, given the importance of these cities in terms of overall road transportation. But it should be remembered that the many truck trips to and from each of these cities that include origins or destinations not among the five cities have been left out of the analysis. Columns 4 and 5 show what emissions would be were premium-intermodal to reach its estimated potential (around 20% market share) for all the city pairs. Taken as a whole, estimated reductions for this scenario are 0.06 MT CO_2 per year.

Altogether 18 different scenarios were simulated for this study. Each of the different scenarios was defined by assumptions about four different parameters. Those parameters were: current market-share; intermodal service offerings (both geographic and logistic); cost differentials (as a proxy for differential taxes); and intermodal carrier attribute performance, and shipper perception of intermodal carriers.

The current market-share assumption was explained above. The second set of assumptions is about intermodal service offerings. There are two dimensions along which intermodal service offerings are varied. The first is with respect to what city pairs are included among the service offerings. The current extent of Expressway service makes up one set of scenarios, and the other set includes all eight city pairs considered – these scenarios are referred to as the “extended service” scenarios.

Service offerings are also varied along a logistical dimension. As mentioned above, current Expressway service offerings are only suitable for TL shipping. Some of the simulation scenarios include LTL trips as contestable traffic, under the assumption that premium-intermodal services could take a form where LTL shipping could realistically be attracted.

Under certain scenarios, the costs for truck-only carriers is allowed to be greater than for intermodal carriers. This is a proxy for what would happen should there be taxes levied against trucks to encourage a shift to intermodal freight transportation.

Finally, in some scenarios, intermodal carrier attributes are allowed to vary. In one set of simulations, the carrier attributes of truck-only and intermodal carriers are set to be the same. This amounts to asking what would happen if intermodal carriers could provide the same performance as truck-only carriers. Some of the scenarios also include changes in the magnitude of the intermodal coefficient. One set of scenarios assumes that the intermodal coefficient is half of its estimated value, whereas others assume that it is 0. These assumptions amount to asking how market-share would change if shippers were less mistrustful of rail for their shipments.

With this description of the parameter assumptions used in the different simulation scenarios, the results of all the different simulations are now presented. The overall purpose of each of the simulations was to ask how CO_2 emissions would change if premium-intermodal services were able to reach their estimated market-share potential. TABLE 3and TABLE 4 summarize the results for all of the simulations.

Two main conclusions can be drawn from this summary of the results. The first concerns the effect of the intermodal coefficient on overall results relative to cost. In particular a 20% increase in cost for truck-only carriers could not overcome the combined disadvantages of perceived inferior intermodal attribute performance and shipper bias against intermodal carriers. However, when comparing the simulation where truck-only carriers are 20% more expensive with the "Intermodal Coefficient = 0" simulation in each table, we see that the results are very close. This suggests that a 20% increase in cost comes very close to overcoming shipper bias against intermodal shipping - a potentially interesting policy implication. Second, and most importantly for this research, is the ultimate best-case scenario emissions reduction result - i.e. the potential reduction of 0.43 MT.

Discussion of the Results

After this relatively thorough analysis of the results, what can be said about the potential for premium-intermodal services in the Corridor to reduce CO_2 emissions in Canada? This is not a feasibility analysis, so it is beyond the scope of the research to judge to what extent the different assumptions made in the different simulations are likely to be realistically achievable either for technical or for economic reasons. This research simply asks the question, what would happen if these assumptions were to hold. Under these assumptions, the maximum estimated CO_2 emission reductions are in the range of 0.43 MT per year.

This represents a significant proportion (more than 50% of current CO_2 emissions) of the truck trips considered to be contestable in this analysis. The fact that such a large proportional reduction seems at least possible provides some hope for the potential of intermodal services to contribute to meaningful CO_2 reductions. Recognizing that the potential for CO_2 reductions through the use of intermodal transportation is even greater for trips longer than 800 kms (see for example US EPA (*18*)), a complete analysis of potential reductions on other longer-haul city pairs (e.g. Toronto - Vancouver, Vancouver - Calgary) would surely provide even more impressive reductions potential from intermodal transportation. Unfortunately, such a wider-ranging analysis was outside of the scope of this research.

REFERENCES CITED

1. Environment Canada. Canada's Greenhouse Gas Inventory - Factsheet #3 - Transportation. Environment Canada, http://www.ec.gc.ca/pdb/ghg/inventory_report/1990_00_factsheet/fs3_e.cfm. Accessed: 4-20-2004.

2. Patterson, Zachary; Ewing, Gordon O.; and Haider, Murtaza. Shipper Preferences Suggest Strong Mistrust of Rail: The First SP Carrier Choice Survey in the Quebec City - Windsor Corridor. Recommended for publication in the Transportation Research Record and for presentation at the 2007 Meeting of the Transportation Research Board.

3. Transport Canada. *Transportation in Canada 2004*. Transport Canada, 2005.

4. Government of Canada. *Climate Change Plan for Canada*. Government of Canada, 2002.

5. Environment Canada. *Making Transportation Sustainable: A Case Study of the Quebec Windsor Corridor*. En40-660/2002E. Environment Canada, 2002.

6. Delcan; KPMG; and A.K.Socio-Technical Consultants. *Assessment of Modal Integration & Modal Shift Opportunities*. KPMG, 1999.

7. Canadian National Railway. *1999 Annual Report*. Canadian National Railway, 2000.

8. Canadian Pacific Railway. Truck Trailers (Expressway). Canadian Pacific Railway, Accessed: 4-22-2004.

9. Vellay, Carine and de Jong, Gerard. *Analyse conjointe SP/RP du choix du mode transport de marchandises dans la Région Nord - Pas-de-Calais*. RAND, Santa Monica, CA, 2003.

10. Wigan, Marcus; Rockliffe, Nigel; Thoresen, Thorolf; and Tsolakis, Dimitris. Valuing Long-haul and Metropolitan Freight Travel Time and Reliability. *Journal of Transportation and Statistics*, Vol. 3, No.3, 2000, pp. 83-89.

11. Shinghal, N. and Fowkes, T. Freight Mode Choice and Adaptive Stated Preferences. *Transportation Research Part E: Logistics and Transportation Review*, Vol. 38, No.5, 2002, pp. 367-378.

12. Norojono, O. and Young, W. A Stated Preference Freight Mode Choice Model. *Transportation Planning and Policy*, Vol. 26, No.2, 2003, pp. 195-212.

13. Greene, William H. *Econometric Analysis*. Prentice-Hall, Inc., Upper Saddle River, NJ, 2000. Vol. Fourth Edition.

14. Kennedy, Peter. *A Guide to Econometrics*. MIT Press, Cambridge, Massachusetts, 1998. Vol. 4th Edition.

15. The Bytown Railway Society. The Canadian Trackside Guide. 2003. Vol. 2003,

16. United States Environmental Protection Agency. *User's Guide to MOBILE6.1 and MOBILE6.2: Mobile Source Emission Factor Model*. EPA420-R-03-010. United States Environmental Protection Agency: Office of Transportation and Air Quality, 2003.

17. Taylor, Brett. *The Development of the MOBILE6.2C Model*. M6C-06-E. Environment Canada, 2005.

18. US Environmental Protection Agency. A Glance at Clean Freight Strategies: Intermodal Transport. US EPA, Washington, DC, 2004.

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TABLE 1 Global and Subgroup Models

	All Observations	High-value, By-appointment, Not Perishable*	High-value, Perishable	Low-value, By-appointment	High-value, Not By-appointment, Not Perishable**	Low-value Not By-appointment*
Variable						
Cost(ln)	-2.520	-2.687	-4.00286	-4.375	-4.292	-2.392
Cost(ln)*Distance	-0.002					-0.004
On-time Reliability	0.143	0.133	0.181	0.143	0.083	0.089
On-time Reliability*Distance	0.000					
On-time Reliability*Employees	0.000					
Damage Risk	-0.436	-0.494	-0.265	-0.454	-0.549	-0.424
Security Risk	-0.113					
Intermodal	-0.790	-0.730	-0.719	-0.818	-0.560	-0.754
Intermodal*Distance	0.000					
Intermodal*Ontario Shipper	-0.252					
Intermodal*Shipper btw Railheads	-0.218		-0.507		-0.468	
ASC1	0.495	0.437	0.574	0.371	0.408	0.566
ASC2	0.521	0.461	0.558	0.415	0.502	0.614
Delta1	0.642	0.709	0.666	0.475	0.017	0.345
Delta2	0.588	0.195	0.456	0.520	0.398	0.159
Log Likelihood	-5839	-970	-893	-1522	-969	-1444
Adjusted rho-square:	0.247	0.220	0.319	0.256	0.203	0.239
Observations	7074	1141	1206	1873	1117	1737
*Delta2 not statistically significant						
*Delta1 and Delta2 not statistically significant						
NB - All other variables statistically significant at the 5% level						

TABLE 2 Extended Service - High Expressway Market-share

			Simulated Annual KG CO_2	
Origin	**Destination**	**Annual KG CO_2**	**Truck Only**	**Intermodal**
Chicago	Montreal	6,920,251	5,580,956	244,094
Chicago	Quebec	485,111	391,457	17,069
Chicago	Toronto	23,166,676	18,641,888	824,668
Chicago	Windsor	61,558	49,674	2,166
Montreal	Chicago	10,146,298	8,193,294	355,946
Montreal	Toronto	171,750,466	163,466,431	7,169,366
Montreal	Windsor	12,889,671	10,392,834	455,062
Quebec	Chicago	797,438	647,066	27,406
Quebec	Toronto	17,810,229	14,392,975	622,813
Quebec	Windsor	1,328,888	1,072,337	46,758
Toronto	Chicago	16,692,750	13,472,216	586,960
Toronto	Montreal	179,176,225	170,626,107	7,462,556
Toronto	Quebec	13,646,061	11,003,749	481,576
Toronto	Windsor	126,140,450	101,621,979	4,468,626
Windsor	Chicago	382,110	308,341	13,445
Windsor	Montreal	7,861,888	6,333,455	278,565
Windsor	Quebec	1,476,536	1,191,481	51,953
Windsor	Toronto	116,674,413	93,990,710	4,134,230
Total		707,407,021	621,376,950	27,243,258
				648,620,208
Difference Mt CO_2				0.059
% Change relative to current emissions				-0.08

TABLE 3 Emissions Simulation Summary - High Current Expressway Market-share

	Reductions in CO_2 (MT) per Year	
Assumptions	**MTL - TO**	**Extended Service**
Current situation	-0.005	0.059
Trucks 10% dearer	0.018	0.104
Trucks 20% dearer	0.042	0.154
Intermodal Coefficient (50% of estimated value)	0.016	0.101
Intermodal Coefficient=0	0.040	0.152
Attribute Values the Same (Intermodal Coefficient (50%))	0.060	0.192
Attribute Values the Same (Intermodal Coefficient =0)	0.089	0.252
Attribute Values the Same (Intermodal Coefficient =0) and LTL	0.116	0.296
Attribute Values the Same (Intermodal Coefficient =0), LTL and Trucks 20% more costly	0.184	0.434

TABLE 4 Emissions Simulation Summary - Low Current Expressway Market-share

	Reductions in CO_2 (MT) per Year	
Assumptions	**MTL - TO**	**Extended Service**
Current situation	0.019	0.074
Trucks 10% dearer	0.036	0.112
Trucks 20% dearer	0.056	0.154
Intermodal Coefficient (50% of estimated value)	0.035	0.110
Intermodal Coefficient=0	0.054	0.152
Attribute Values the Same (Intermodal Coefficient (50%))	0.070	0.185
Attribute Values the Same (Intermodal Coefficient =0)	0.093	0.236
Attribute Values the Same (Intermodal Coefficient =0) and LTL	0.116	0.277
Attribute Values the Same (Intermodal Coefficient =0), LTL and Trucks 20% dearer	0.171	0.393

FIGURE 1 The Quebec City - Windsor Corridor