MINISTÈRE DES TRANSPORTS DU QUÉBEC
MINISTRY OF TRANSPORTATION OF ONTARIO
TRANSPORT CANADA

Updated Feasibility Study of a High Speed Rail Service
in the Quebec City – Windsor Corridor

Deliverable No. 13 – Final Report:

Final Report

February 14, 2011

N/Ref.: P020563-1300-001-EN-01

Ministère des Transports du Québec
Ministry of Transportation of Ontario
Transport Canada

Updated Feasibility Study of a High Speed Rail Service in the Quebec City – Windsor Corridor
Deliverable No. 13 – Final Report

Project Manager:

Bernard-André Genest, ing., P. Eng., Ph. D.
(Start – September 2010)

Stéphane Robert, Eng.
(September 2010 – End)

Prepared by:

Alain Drouin, CA, CBV, CF.
KPMG: Partner
Ecotrain: Group Leader – Policies Implimentation and Financial/ Economic Analysis

i.A.

Ottmar Grein
DB International: High Speed Rail Senior Consultant
Ecotrain: Group Leader – Systems and Operations

Paul Nimigon, B.E.S.
MMM Group Limited: Vice President – Rail Transportation (Partner)
Ecotrain: Group Leader – Impacts Analyses

Anne Reyner
Wilbur Smith Associates: Senior Transport Analyst
Ecotrain: Group Leader – Demand Forecasting

Jean-Claude Therrien, Eng., M.S.E.
Dessau: Vice-President Transportation Expertise and Innovations
Ecotrain: Group Leader - Infrastructure

Verified by:

Claude Archambault, P.Eng., M.Eng.
Dessau: Manager - Transportation Major Projects

Approved by:

Stéphane Robert, Eng.
Dessau: Project Manager - Infrastructure
Ecotrain: Contract Manager

EcoTrain
1060 University St., Suite 600
Montreal (Quebec) Canada H3B 4V3
Telephone : 514.281.1010
Fax : 514.281.1060
E-Mail : info@dessau.com
Web site: www.dessau.com

TABLE OF CONTENTS

TABLES

FIGURES

LIST OF ABBREVIATIONS

The following definitions apply throughout this document unless indicated otherwise:

AACE	American Association of Civil Engineers
ACEC	Association of Consulting Engineers of Canada
AADT	Average Annual Daily Traffic
AC	Alternative Current
AFP	Alternative Financial Proposal
AMT	Agence métropolitaine de Transport (Montreal Metropolitan Transportation Agency)
APU	Auxiliary Power Unit
ARL	Air-Rail Link (between Union Station and Toronto-Pearson Airport)
ATC	Automatic Train Control
ATP	Automatic Train Protection
AV	Alta Velocità (High Speed Train in Italy)
AVE	Alta Velocidad Española (High Speed Train in Spain)
CAC	Criteria Air Contaminant
CAD	Canadian Dollar
CBA	Canadian Bus Association
CBD	Central Business District
CMHC	Canada Mortgage and Housing Corporation
CN	Canadian National Railway

CP	Canadian Pacific Railway
C4SE	Centre for Spatial Economics
DBI	Deutsche Bahn International
DBFM	Design-Build-Finance-Maintain
DC	Direct Current
EA	Environmental Assessment
ERTMS	European Rail Track Management System
ETCS	European Train Control System (component of ERTMS)
EU	European Union
FRA	Federal Rail Administration (USA)
GHG	Greenhouse Gases
GO	Government of Ontario
HSR	High Speed Rail
ICE	InterCity Express (High Speed Train in Germany)
IEA	Individual Environmental Assessment
IRR	Internal Rate of Return
IT	Information Technology
LP	Licence Plate (survey)
MTO	Ministry of Transportation of Ontario
MTQ	Ministère des Transports du Québec (Ministry of Transportation of Quebec)

NACC	National Airlines Council of Canada
NPV	Net Present Value
OCC	Operation Control Centre
OCS	Overhead Catenary System
OD	Origin Destination
O&M	Operation and Maintenance
PM	Particulate Matter
POD	Passenger Origin-Destination Model
PPP	Public Private Partnership
PPS	Provincial Policy Statement (Ontario)
PRACS	Preliminary Routing Assessment and Costing Study
PSD	Power Supply and Distribution
PSP	Private Sector Participation
QGR	Quebec Gatineau Railway
QOHSRPS	Québec Ontario High Speed Rail Project Study
RAC	Railway Association of Canada
RoW	Right of Way
SAAQ	Société d'assurance automobile du Québec (Car Insurance Company of Quebec)
SP	Stated Preference (survey)
SPV	Special Purpose Vehicle (financial term)

S&T	Signals and Telecommunications
TC	Transport Canada
TGV	Train à grande vitesse (High Speed Train in France)
TSB	Transport Safety Board (Canada)
UIC	Union Internationale des Chemins de Fer (International Union of Railways)
VOC	Volatile Organic Compound
VSL	Value of Statistical Life

Disclaimer

Subsequent to EcoTrain issuing this Report in draft, EcoTrain was advised that the air fares it previously received for the purposes of preparing the ridership and revenue forecast, which serves as input to this Report, required corrections resulting in wide variations in air fares adjustments from one city pair to another.

Due to the potential impact of these corrections on the analyses, EcoTrain recommended to the Governments that additional work be done to revise the ridership and revenue forecasts using the corrected air fares and to also revise the analyses depending on it. EcoTrain believes that the overall impact of using the corrected air fares could have been positive in terms of HSR ridership, revenues, cost-benefit and financial viability for the Québec – Windsor corridor. The impact could have been quite different by segment or between city pairs, from minimal to significant.

EcoTrain was asked by the Governments not to perform such additional work. The rationale the Governments provided was that, since the results are "order of magnitude" estimates and the Governments believe revised airfare data and forecasts would not materially change decisions arising from the study; they did not wish to delay the study to further revise the forecasts.

Accordingly, EcoTrain cannot be held responsible for decisions made based on these uncorrected forecasts and analyses.

Updated Feasibility Study for a High Speed Rail Service in the Quebec City – Windsor Corridor
Draft Final Report

SUMMARY

Background Information

The feasibility study for a High Speed Rail Service in the Quebec City – Windsor Corridor was conducted on behalf of Transport Canada (TC), the Ministry of Transportation of Ontario (MTO) and the Ministry of Transportation of Quebec (MTQ) by EcoTrain, a group of international consulting firms led by Dessau and comprising Deutsche Bahn International (DBI), KPMG, MMM Group, and Wilbur Smith Associates (WSA).

This final report constitutes the synthesis of a comprehensive update of the 1995 Quebec – Ontario High Speed Rail Project Study (QOHSRPS). The report is based on the various technical reports that covered all aspects of the feasibility of introducing a High Speed Rail (HSR) service in the Corridor and were submitted to the Technical Committee that oversaw the conduct of the study.

The Request for Proposal assigned the following objectives to the study:

- “To review past studies with respect to changes that would effect the conclusions and recommendations that were made at the time of the study”;
- “To identify which actions, updates, or additional studies are required and carry them out”;
- “To issue recommendations pertaining to the feasibility and relevance of issuing a Request for Interest involving the execution of subsequent studies based on a Public – Private Partnership (PPP) or an Alternative Financial Proposal (AFP) approach”.

With respect to the first objective EcoTrain examined some 17 reports, dated from 1993 to 1996 pertaining to various aspects of planning, building, and operating a HSR in the Corridor. Most of these reports were prepared as part of the QOHSRPS: they were the most extensive of all and encompassed all the issues that were partially covered in the other reports, hence the choice made at the beginning of the present study to use the QOHSRPS as the basis for updating results and data from 1995 to 2010.

Since the present study was an update of a previous study, it is important to take note of the following assumptions:

- Estimates for both initial investment costs and recurrent costs over the life of the project included all major variables that could affect costs, but without the benefit of actual measurements and investigations.
- Class D cost estimates[1] were prepared which have a level of accuracy sufficient for prefeasibility studies. They were based on historical data obtained on comparable projects already completed, with costs adjusted to take into account factors such as construction date, production capacity, dimensions and other similar general information. Their purpose was to facilitate the decision making process and determine whether the client should proceed to preparatory studies and preliminary engineering for the project under consideration.
- Accuracy ranges and contingencies varied according to the project components, with earthworks and drainage having a ±35 percent accuracy range and a 20 percent contingency, while rolling stock figures were ±10 and 5 percent accuracy range and contingency respectively.
- Comparisons were made with operating HSR systems in other countries. They showed that the favourable topography in the Quebec City – Windsor Corridor is a major factor that has the potential of keeping the construction costs relatively low compared with similar projects in North America, Europe and Asia.

Main Observations and Results

This update of the QOHSRPS report has considered the following elements: technologies, routes, stations, service, travel demand forecasting, investment costs, operations and maintenance costs, environmental and social impacts, implementation schedule and options, financial and economic analyses, impacts on the transportation system within the Corridor, review of similar HSR projects in the world, and review of transportation policies in France, Germany and Spain.

Representative technologies

Similar to the QOHSRPS, the present study evaluated two representative technologies mainly based on minimum operational speeds of 200 and 300 km/h and designated as F200+ and E300+ respectively. A representative technology is one that is typical of what a HSR system would be in the Quebec City – Windsor

[1] Please see definition of Class D Cost Estimate on top of page S-11 below

corridor in terms of travel quality and performance, investment and recurrent costs, and environmental impacts.

The two representative technologies have the following characteristics:

- Representative technologies chosen were diesel traction for F200+ and electric traction for E300+. These two technologies corresponded to the lower and upper boundaries of current HSR operation and most available technologies would fit between these boundaries. Information for intermediate technologies (i.e. for speeds between 200 and 300 km/h) could be estimated by interpolating between the boundaries.
- The F200+ option would require dual-mode locomotives with electric and diesel tractions on the Quebec City-Montréal segment because past studies have demonstrated that it would be prohibitively expensive to provide adequate ventilation in the Mount Royal tunnel to accommodate diesel-powered locomotives.
- A large number of compatible technologies available from several manufacturers exist, so there was no need to identify specific manufacturers in the present study (Manufacturers were identified in the QOHSRPS).
- For both F200+ and E300+ technologies, a 200 m trainset would comprise 6 to 8 coupled cars, or 8 to 10 articulated cars, with a capacity of 400 passengers per trainset. A train would be comprised of one or two trainsets, depending on the required capacity.
- It was recognized that either ballasted tracks or tracks laid on prefabricated or cast-in-place concrete slabs could be used for HSR operations: the choice would be made at the design stage, depending on the bearing capacity of the subsoil.
- Modern railway signalling system with signals information inside the driving cab, as opposed to wayside installation for conventional signals, would be used in the HSR.
- It was assumed that there would be no grade crossings of HSR tracks with other tracks, main and secondary roads, or private farm crossings.
- Fencing would segregate HSR from surrounding land uses throughout the Corridor.
- Winter operation of HSR has been proven in Japan, Korea, Finland and Sweden. It was assumed that the representative technologies would be adapted to local winter conditions and thus winter operation was not expected to be a major problem in the Quebec City – Windsor corridor. At the preliminary design stage, specific weather conditions such as low temperatures and high accumulation of snow would be evaluated with a view to minimize their impact HSR operation.

Representative routes

The present study identified two representative routes to accommodate respectively the F200+ and the E300+ technologies, based on representative routes developed in the QOHSRPS and modified according to intervening changes since 1995. Changes in land uses were identified by comparing recent aerial photos with QOHSRPS 1:20,000 working (unedited) maps. Changes in travel patterns were determined by comparing traffic data for the four intercity modes: auto, air, rail and bus. A representative route refers to a transportation corridor that links a given number of cities and complies with the design criteria for alignment in plan and profile and other constraints imposed by the HSR speed levels, but without any optimization. The two representative routes have the following characteristics:

- Commuter rail services in Montréal and Toronto were significantly expanded and improved in the past 15 years, thus restricting train access to Central Station in Montréal and to Union Station in Toronto.
- There is no need to provide direct HSR service to Mirabel Airport, since this airport is no longer used for commercial passenger flights, or to Toronto - Pearson Airport, since Metrolinx has recently solicited interest from companies interested in designing, building and financing the future Toronto's Air-Rail Link (ARL), a fast and frequent shuttle service between Union Station and the airport that would become operational in 2015. These new developments entailed significant changes to the QOHSRPS's recommended representative routes between Montréal and Ottawa on the one hand and west of Toronto on the other.
- HSR could share tracks with commuter rail networks in Montreal (AMT) and Toronto (GO Transit). Within other major urban areas, it was assumed that new tracks could be built within existing 30 m wide railway rights of way (RoW).
- Outside of major cities, HSR would run on exclusive tracks built parallel to existing tracks where feasible in a new adjacent 40 m RoW. Elsewhere the new HSR RoW would be 50 m wide.
- There would be no HSR tracks sharing with freight trains, except for short segments in the Toronto area.

Representative stations

Representative stations were based on the QOHSRPS report, modified to take into account intervening changes in land use patterns since 1995. The representative stations would serve the following cities:

- Quebec City (existing downtown Gare du Palais, plus one new suburban station)
- Trois-Rivières (new station)

- Montreal (existing downtown Central Station plus 2 new suburban stations)
- Ottawa (existing VIA Rail station)
- Kingston (new station)
- Toronto (existing downtown Union Station plus 2 new suburban stations)
- London (new station)
- Windsor (new station)

The representative stations were evaluated for the purpose of estimating construction costs (Class D cost estimates) and assumed to have the following characteristics:

- High level platforms would be used in all stations for the convenience of passengers and to speed up boarding and alighting operations.
- Existing urban and regional transit services would provide a high level of connectivity to HSR passengers using stations in Quebec City, Montreal, Ottawa and Toronto.
- HSR could provide international travellers coming from Quebec City, Trois-Rivières, Ottawa, Kingston, London or Windsor with connection in Montreal or Toronto to future airport rail shuttle services planned in both cities.

The actual location of representative stations would be selected during the preliminary engineering stage.

The following map illustrates the representative routes and representative stations in the Corridor for F200+ and E300+ technologies.

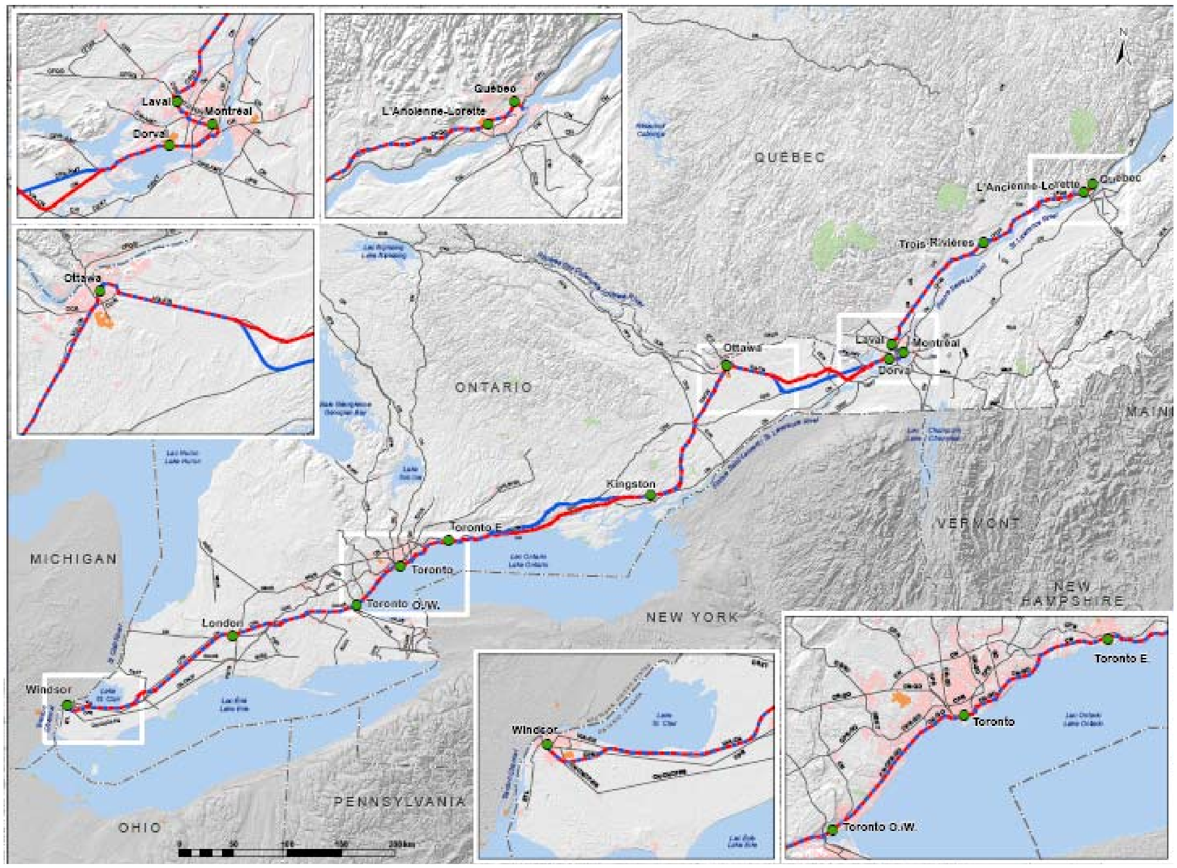


FIGURE S-1: REPRESENTATIVE ROUTES AND REPRESENTATIVE STATIONS BETWEEN QUEBEC CITY AND WINDSOR

Representative service

A representative service based on the two representative technologies and their respective routes and stations was designed to offer a competitive service compared with other intercity travel modes in the Corridor, taking into account relevant experience of comparable successful HSR systems in other countries. The main features were the following:

- For the purposes of the present study, HSR was assumed to replace existing corridor VIA Rail services. A conventional regional VIA Rail service may provide passenger service to corridors that connect to the HSR network (e.g. Halifax, Gaspé, Jonquière, Senneterre, Sarnia, and Niagara).

- HSR would operate as train shuttles within major markets, with at least one train per hour and per direction during the day and coordinated transfers in Montréal and Toronto downtown stations between shuttles to minimize passenger inconvenience. The 3 shuttles envisioned are:
  - *Québec City – Montréal via Trois-Rivières*
  - *Montréal – Toronto via Ottawa and Kingston*
  - *Toronto – Windsor via London*
- An operator could envisage different types of services tailored to the needs of its customers.
- City centre to city centre travel times between cities with a HSR station would be competitive with air services.

Introducing a HSR in the Quebec City – Windsor Corridor would increase quality of rail service by cutting down travel times between major city pairs, as shown in the following table:

Table S-1: Travel Times between Major City Pairs

City Pair	Existing VIA Rail Service[2]	F200+	E300+
Quebec City – Montréal	3 hr 09 min	1 hr 49 min	1 hr 26 min
Montréal – Ottawa	1 hr 55 min	1 hr 11 min	0 hr 57 min
Ottawa – Toronto	4 hr 36 min	2 hr 25 min	1 hr 50 min
Montréal – Toronto	5 hr 12 min	3 hr 38 min	2 hr 47 min
Toronto – London	2 hr 07 min	1 hr 05 min	0 hr 51 min
Toronto – Windsor	3 hr 59 min	2 hr 12 min	1 hr 33 min

Source: VIA Rail schedules for 2010; estimates by EcoTrain for F200+ and E300+

HSR would also increase quality of service by increasing the number of trains per direction and per day, as illustrated in the following table:

[2] Running times based on 2010 VIA Rail schedules are average for the number of trains per day on each route.

Table S-2: Number of Trainsets[3] per Direction and per Day

Segment	Existing VIA Rail Service	F200+		E300+	
		2025	2055	2025	2055
Québec - Montréal	4	15	19	19	20
Montréal - Ottawa	6	20	22	20	25
Ottawa - Toronto	5	22	29	25	32
Montréal - Toronto	7	20	22	20	25
Toronto - London	5	13	20	14	20
London - Windsor	4	8	10	8	10

Source: VIA Rail schedules for 2010; estimates by EcoTrain for F200+ and E300+

Travel demand forecasting

Travel demand forecasting was based on:

- QOHSRPS results
- existing travel data for 2006 by air[4], rail and bus provided by Transport Canada
- new travel surveys conducted by EcoTrain in 2009
- HSR fare structure designed to maximize revenue rather than maximizing ridership.

A nested logit-based mode choice model was used to forecast ridership and revenue of HSR as a new mode of transport in the Corridor. Major changes that occurred since 1992 (date of surveys for the QOHSRPS) and could influence future travel patterns were identified as follows:

- Travel by car is by far the dominant mode of travel in the Corridor, with a 92 percent market share. The number of person trips by car has increased by 19 percent between 1992 and 2009.
- There is an apparent decrease in air traffic in the Corridor from 4.1 million passengers in 1992 to 2.6 million in 2006. This is due to two factors: (i) the present study did not include connecting air passengers in the corridor since, unlike the QOHSRPS, the proposed HSR would not stop at any airport; and (ii) Transport Canada was using a different methodology to estimate air trips in 1992.
- Travel by rail increased from 2.9 to 3.2 million passengers between 1992 and 2005, and travel by bus increased from 2.6 million to 4.1 million passengers in the Corridor: The QOHSRPS forecasted no increase in rail or bus travel after 1992.

[3] Number of trains may be different as some trains would run as double trainsets.
[4] Please see disclaimer at the forefront of this report.

- Fuel price increases in real monetary terms between 1992 and 2005 may have had an impact on long-distance travel behaviour in the Corridor.

Main results of the travel demand forecasting were the following:

- According to the stated preference survey of travellers in the Corridor conducted by EcoTrain, 50 percent of current VIA Rail passengers would be willing to use HSR under certain conditions.
- The same survey showed that current users of auto, air and bus modes would in general continue to use these modes, but when asked to consider changing their preferred mode of travel, they selected HSR as their second choice (respectively 19, 40 and 32 percent) under certain conditions.
- The E300+ technology would attract 11.1 million passengers and generate $1.3 billion (2009 CAD) in revenue in 2031 for the entire corridor.
- The F200+ technology would attract 10.2 million passengers and generate $1.2 billion (2009 CAD) in revenue in 2031 for the entire corridor.
- HSR would attract 800,000 induced passengers (included in the 11.1 million above); these would be new trips by travellers who would not make such trip in the absence of HSR service.
- The E300+ service would attract about 10 percent more travellers on most segments of the Corridor and would generate more revenue than the F200+.
- The E300+ service would attract proportionally more business travellers than the F200+ service. As business travelers pay higher fares than non-business, the 9 percent ridership increase would bring in a 12 percent revenue increase.
- The majority of trips made in HSR – about 80 percent - were expected to have both origin and destination in one of the seven urban areas within the Corridor which constitute the Primary Market for HSR.
- The Montreal-Ottawa-Toronto segment would generate 56 to 57 percent of the total corridor ridership and the Quebec-Montreal-Ottawa-Toronto segment would generate 78 to 80 percent of the total corridor ridership.
- The automobile mode would continue to be the dominant mode of travel within the Corridor with 85 to 86 percent market share. HSR would become the second largest mode of travel with 8 to 9 percent market share. Bus travel would increase, since the replacement of VIA Rail by a faster but more expensive mode would push some cost conscious VIA rail customers toward bus, the less expensive mode.

- A risk analysis using Monte Carlo methods was used to estimate risks based on two variables only, population forecasts and HSR fares. It showed forecast margins of ±26 percent for ridership and ±21 percent for revenue with a confidence level of 90 percent. The risk analysis would most likely have shown higher forecast margins if more variables had been included.

Based on the demand forecasting model, annual ridership and revenues were estimated for the years 2031 and 2041 for each technology. The following table shows the expected ridership in thousands of trips per year and the revenues in thousands of 2009 Canadian dollars per year for the full Quebec City – Windsor corridor, as well as for other segments:

Table S-3: Expected Yearly Ridership and Revenues (in thousand 2009 CAD)

Trip Purpose and Segments	Technology	2031		2041	
		Trips (x1000)	Revenue (x1000)	Trips (x1000)	Revenue (x1000)
Business	F200+	5 140	699 000	5 634	774 000
	E300+	5 659	791 000	6 202	875 000
Non-business	F200+	5 088	509 000	5 496	547 000
	E300+	5 465	562 000	5 902	605 000
Total Quebec City – Windsor	F200+	10 227	1 208 000	11 130	1 353 000
	E300+	11 124	1 321 000	12 105	1 480 000
Quebec City – Toronto	F200+	7 971	985 000	8 609	1 072 000
	E300+	8 885	1 119 000	9 604	1 219 000
Montréal – Toronto	F200+	5 681	722 000	6 234	798 000
	E300+	6 346	825 000	6 969	913 000
Toronto – Windsor	F200+	2 169	189 000	2 410	211 000
	E300+	2 135	193 000	2 370	215 000

Investment costs

Investment costs included conceptual design, preliminary and detailed engineering, construction supervision and project management costs, construction costs and acquisition costs of property, rolling stock and rail systems. These costs were developed on the basis of representative technologies, routes and stations, and services envisioned for the F200+ and the E300+ HSR systems. QOHSRPS unit costs were updated to reflect current costs for all components of the project.

Construction costs were estimated on the basis of a Class D estimate which the Association of Consulting Engineers of Canada (ACEC) defines as follows:

A Class D "*estimate, also known as parametric estimating, is generally prepared during the prefeasibility studies. Its purpose is to determine the value of proceeding to the preproject stage of preparatory studies and basic plans and specifications for the project under consideration. A Class D estimate is often based on historical data obtained on comparable projects already completed, with the costs adjusted to take into account factors such as construction date, production capacity in the case of a plant, dimensions and other similar general information. It is very brief and based on a minimum of information; as a result, it has a large margin of error (20% to 100%)*."

Major assumptions which could have an impact on construction costs were the following:

- HSR would run on double tracks along entire corridor, with new track material throughout.
- Any grade crossings with HSR tracks would be eliminated and there would be no closure or diversion of public or private cross roads.
- Freight traffic would be physically separated from HSR tracks, or time separated from HSR operating hours.
- EcoTrain validated all QOHSRPS elements that were left unchanged in the present study.
- EcoTrain included a 13 percent professional and project management fees and 12 percent for contingencies, which resulted in a 70 percent probability of meeting expected project costs, whereas the QOHSRPS figures were respectively 14 percent fees, 9 percent contingencies and 45 percent probability of meeting project costs.

Total investment costs (including infrastructure and civil works, rolling stock, rail systems, stations, professional fees and contingencies) for the full Corridor and for other segments were estimated as shown in the following table:

Table S-4: Total Investment Costs (in million 2009 CAD)

Cost Item	F200+			E300+		
	QOHSRPS	EcoTrain	Ratio	QOHSRPS	EcoTrain	Ratio
Infrastructure	7 501	9 723	1.30	8 972	10 268	1.14
Rail Systems	8 477	9 205	1.09	8 924	11 032	1.24
Total Quebec City-Windsor	15 978	18 927	1.18	17 896	21 300	1.19
Quebec City – Toronto		13 983			15 987	
Montreal – Toronto		9 067			10 952	
Toronto – Windsor		4 919			5 614	

One should note that:

- The difference in investment costs between the two technologies can be explained primarily by the costs of the power supply equipment (diesel or electricity).
- The elimination of all grade crossings reduced the cost difference between the 2 options of the present study as compared to the QOHSRPS report, where many grade crossings were kept open in the 200 km/h option.
- Other factors that increased costs compared to the QOHSRPS include:
  - *the request by the Technical Committee to avoid piers in rivers;*
  - *the recommendation of using a concrete slab track where soil conditions permit instead of conventional ballasted track to minimize maintenance costs (in the absence of detailed information on soils, EcoTrain arbitrarily assumed concrete slab tracks for 50 percent of the total length of the tracks);*
  - *the cost of upgrading the signalling system of about 100 conventional locomotives assigned to existing commuter services in Montreal and Toronto that would have to share tracks with the HSR;*
  - *the need for dual-mode electric and diesel locomotives on the Quebec City – Montreal segment; and*
  - *the higher level of precision for costing of maintenance facilities.*

A review of the literature was made to compare actual HSR costs in other countries with EcoTrain's estimates for the Quebec City – Windsor E300+ HSR project. Most studies on this topic were consistent in asserting that the most cost sensitive elements of HSR infrastructure are the topography-related works such as tunnels, viaducts and bridges, followed by the land acquisition costs.

The most extensive study[5] examined 24 operating HSR systems in Europe, Japan and Korea. According to this study, the lowest project costs were the Paris-Lyon TGV (France) through generally flat terrain at $8.1 million CAD (2009) per kilometre and the Madrid-Lleira AVE (Spain) through varied terrain at $13.4 million CAD (2009) per kilometre, while the most expensive was the Bologna-Florence AV (Italy) at $113.4 million CAD (2009) per kilometre: in this case 95 percent of the tracks lie on viaducts or in tunnels. All costs excluded property acquisition, planning, and rolling stock acquisition.

Excluding property acquisition, planning, and rolling stock costs, the E300+ representative HSR project investment cost would be $12.8 million CAD (2009) per kilometre, i.e. about 60 percent more than the Paris-Lyon TGV and about the same unit cost as the Madrid-Lleira AVE.

[5] Economic Analysis of High Speed Rail in Europe. BBVA Foundation, May 2009, by Ginés de Rus (University of Las Palmas, Spain)

Both representative routes for the most part lie within the St. Lawrence river and Great Lakes plain areas and would follow existing railway RoW that have already been optimized for topography and river crossings. The relatively favourable terrain and topography in the Corridor and the availability of railway RoW in the major cities help explain in a large part why the Quebec City – Windsor HSR estimated costs were on the low side of the actual costs of 24 different HSR projects.

Operations and Maintenance costs

Operations and Maintenance (O&M) costs were developed in more details than in the 1995 study:

- Required O&M activities were based on actual and comparable HSR operations in Europe.
- For each type of work an average annual salary cost was estimated on the basis of current Canadian wages and salaries for similar types of work and current Canadian practices and productivity.
- Train schedules were based on ridership figures and estimated travel times for each type of services. The number of daily trains per direction was calculated and the required fleet size (used as an input in the investment cost model) was determined on the basis of the train schedules.

Estimates for annual operations costs included the following items:

- HSR operations: train crew, energy consumption, and operational control centre (OCC)
- Customer services: on-board service staff, station operations, sales, and advertising
- Other recurrent expenses: insurances, property and sales taxes, and right of way and track usage fees

Estimates for annual maintenance costs included the following items:

- Track, bridges and other structures: regular inspections, servicing and maintenance
- Energy supply and distribution: diesel for F200+ and electricity for E300+
- Signals and telecommunications
- Stations and maintenance facilities
- Rolling stock: cleaning and maintenance, inspection, minor and major revisions

Annual maintenance costs of grade separated structures would be borne by the owners of these structures and were not included in the O&M costs of the future HSR service.

Total O&M costs (including salaries, salary costs, and supplies) for the full Corridor and the first full year of operation (2025) were estimated as follows:

Table S-5: Total Operations and Maintenance Costs (in million 2009 CAD per year)

Cost item	F200+	E300+	Ratio E300+/F200+
Train operations	84.7	86.0	1.02
Customer services	123.9	134.2	1.08
Equipment maintenance	110.6	87.0	0.79
Infrastructure maintenance	54.5	92.4	1.70
Management and other costs	118.1	120.5	1.02
Total per year	491.8	520.2	1.06

Environmental and social impacts

Potential environmental and social impacts were evaluated to identify issues that should be considered when analyzing the feasibility of HSR based on the representative technologies, routes and alignment options presented above.

Major changes have occurred since 1995 to the environmental assessment process and evaluation, namely:

- Stakeholders and the population in general now agree more and more that environmental issues should influence the design and conduct of projects.
- A greater level of participation and consultation with local stakeholders during the project planning process and public engagement at an early stage in the environmental assessment process are now considered essential to the success of a project.
- The need to harmonize provincial and federal environmental assessment processes is now acknowledged.
- Social perceptions of environmental issues and sustainability have become more prominent for Canadians over the past fifteen years.

Changes in the federal and provincial environmental legislation since 1995 are not expected to impact the feasibility of the HSR. However specific requests may need to be satisfied on a case by case basis.

EcoTrain inventoried and mapped natural and social environmental issues in the Quebec City – Windsor corridor and identified, on a segment-by-segments basis, interactions between these issues and the HSR representative routes.

EcoTrain also analysed the following issues for which information was readily available:

- Safety: to estimate how many fatalities and injuries would be saved as a result of the implementation of HSR in the Quebec City – Windsor corridor and calculate the economic value of those savings;
- Noise and vibration: to determine the types of noise impacts that HSR would create and identify possible mitigation measures; and
- Atmospheric emissions: to estimate the reductions in atmospheric emissions that could be achieved following the implementation of HSR in the Quebec City – Windsor Corridor, and calculate their economic value.

Additional environmental issues that could not be mapped at the scale of this project, but that should be considered at a later stage of the project, were also listed. Given the scale and scope of the present study, it was not possible to identify all of the potential environmental issues along the representative routes. Also at this stage of the study and without the benefit of detailed site reconnaissance, it was not possible to identify all environmentally sensitive locations and issues.

With the exception of safety, noise and vibration, and atmospheric emissions, it was not possible to quantify environmental impacts and estimate their associated costs. In its cost analyses, EcoTrain explicitly calculated mitigation costs for noise barriers, settlement ponds, farm crossings and wildlife passages, and included other mitigation costs either in the costs of earthworks, drainage and structural works, based on similar projects recently built in the Quebec City – Windsor Corridor, or in contingencies.

Implementation schedule and options

Implementation schedule and options were analysed with a view to forecast a cash flow for the financial analysis. It was assumed that the project would be implemented following a conventional procurement process, as was the case in the QOHSRPS.

The overall schedule presented in the following figure shows that passenger service could commence 14 years following project launching, which was assumed to take place in 2011.

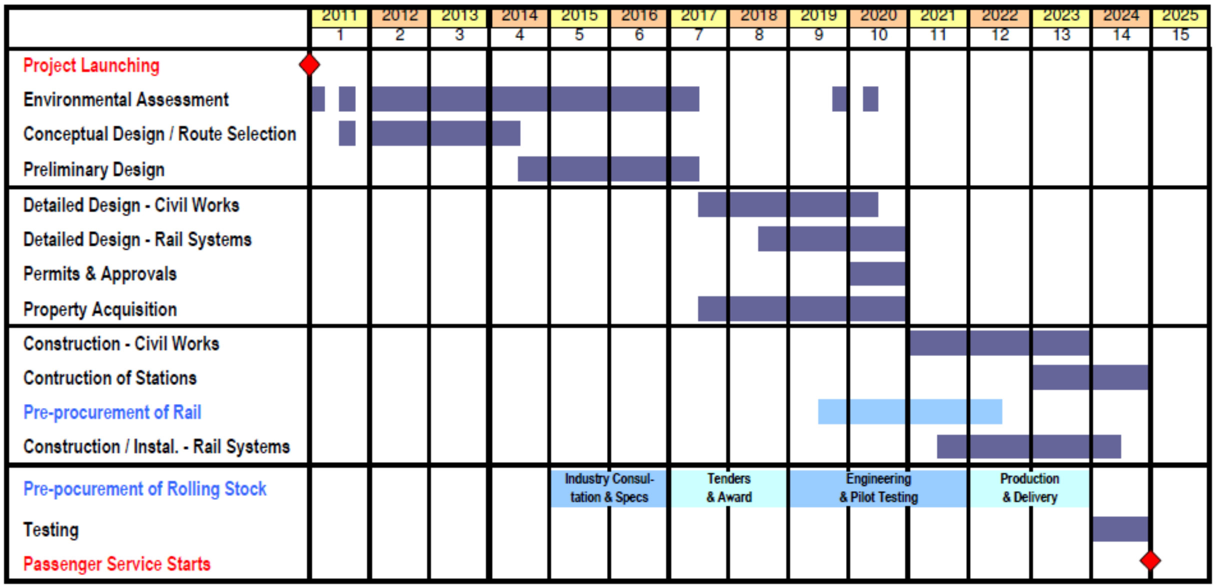


FIGURE S-2: PROJECT SCHEDULE

Following the feasibility study, the Environmental Assessment (EA) would commence with Transport Canada filling in the role of the "Responsible Authority" for the purposes of the Canadian Environmental Assessment Act. As well, it is expected that the Ontario and Quebec Environmental Assessment processes would need to be followed.

Once the Environmental Assessment process is complete, the EA will be submitted to the Minister of the Environment for approval. The EA and the preliminary engineering would proceed simultaneously, in order to allow the latter to provide geographic and other parameters to the former. Based on a streamlined EA process[6], EcoTrain estimates that the EA would be completed within 5 to 8 years.

It is recommended that a conceptual design be developed for the entire Quebec City – Windsor corridor. It is expected that it would take six months to develop Terms of Reference and sign a contract with a Consultant to undertake this study, and that the Consultant would need 30 months to complete the conceptual design and route selection study. The conceptual design and preliminary engineering would be undertaken in conjunction with the EA.

[6] Consultation with the MOE and research that was conducted on large, individual Environmental Assessments have determined that a streamlined EA process may be feasible for a project such as this one.

Detailed engineering for civil works would start immediately after the preliminary engineering had been completed. Detailed engineering for rail systems could not begin until a significant amount of the civil works design had been completed. Detailed rail design could start one year after the start of the civil works design and would be completed six months after the civil works design is finished.

Land and property acquisition would begin when detailed engineering is completed at 60 percent. A project would not be tendered without all properties in hand, due to the risk of contractor claims for delays. A 42-month duration is proposed, as compared to 36 months in the QOHSRPS. This 42-month duration included approximately six months at the end of the task for tendering civil works.

The fabrication and installation of railway systems could start six months after the civil works have started, as opposed to two years in the QOHSRPS.

Two significant schedule risks have been identified: (i) the availability of steel for rail, and (ii) the on-time availability of rolling stock (due to car manufacturer production schedules). To address these risks, advanced procurement of rail and trainsets is recommended.

Financial and economic analyses

Financial and economic analyses were performed to estimate the value of various alternatives to the project. Both analyses considered 8 scenarios, namely the 2 technologies F200+ and E300+ in each of the 4 main functional segments:

- Quebec City – Windsor, the base case scenario
- Quebec City – Toronto
- Montreal – Toronto
- Toronto – Windsor

The main objectives of the **financial analysis** were to (i) estimate the financial internal rate of return (IRR), (ii) calculate the level of required public funds, and (iii) define a mechanism for including private sector participation (PSP) in the funding of the project.

For financial analysis purpose, project structures or delivery modes need to be defined in order to provide a framework for the flow of funds. Accordingly, EcoTrain has performed financial analyses on the basis of project structures that were considered representative of the current market trends and approaches for HSR projects in other jurisdictions. This is the reason why EcoTrain recommends setting up a HSR Authority[7] that would oversee the design and construction of the system and would operate it on a commercial basis.

The financial analysis considered that the project could be entirely financed through public funds (wholly public case) or that it could be partly funded by the private sector (PSP case). In both cases, it was assumed that the Governments would create a High Speed Rail Authority that would be responsible for the execution of the project and its operations and would enter into contracts with infrastructure providers should the PSP case be chosen.

The HSR project would be executed in three (3) main stages:

- A 5 to 8 year pre-construction period would include all preliminary engineering design, environmental assessments and early work activities such as topographical, geotechnical and hydrological surveys.
- A 4-year period would be needed for detailed engineering, property acquisition, and permits and approvals. Fabrication of rolling stock could begin in this period.
- A 4-year period would include the construction of all infrastructures and the fabrication, installation and testing of all railway equipment and rolling stock.

A 30-year period was assumed for commercial operations. A terminal value was estimated at the end of the 30-year period and used as an input to the financial and economic analyses.

The results of the financial analysis were summarized by calculating the net present value (NPV) and the financial IRR of the project. A discount rate of 4.2 percent was used to calculate both NPV and IRR, based on the blended borrowing rates of the Governments of Canada, Quebec and Ontario. Further, it is assumed that the IRR required by the private sector is 13.5 percent. This assumption is based on the analysis of similar HSR projects around the globe which use availability payment concession structures and publicly-available IRR targets.

[7] The exact nature and composition of this High Speed Rail Authority of similar independent body, would be determined by the Governments.

The main results of the financial analysis for both the wholly public case and the PSP case for the Quebec City – Windsor full corridor were the following:

Table S-6: Main Results of Financial Analysis (NPV in billion 2009 CAD)

Case for the Quebec City – Windsor Corridor	Technology	Project NPV to Governments in 2009 billion CAD	Project IRR to Governments in Percentage	NPV of Investments by Governments in 2009 billion CAD
Wholly Public	F200+	-7,7	0,8	16,3
	E300+	-8,5	0,9	18,2
PSP	F200+	-14,7	-8,3	8,3
	E300+	-16,4	-7,5	9,2

Under the PSP case, the private sector was assumed to be responsible for the delivery and maintenance of the civil works, tracks, signals and telecommunication components of the project under a Design-Build-Finance-Maintain (DBFM) contract. The level of investment required from the governments could be reduced by up to 50 percent due to debt and equity financing provided by the private sector. However, due to the higher rates of return required by the private sector, the financial return to Governments would be less favourable under the PSP case than under the wholly public case. The IRR to Governments would be negative under both technologies, as shown in the above table.

Further, under the PSP case, the High Speed Rail Authority would operate the HSR service and assume the revenue risk.

Analysis of other segments and sensitivity analysis of major input variables have both shown that the NPV would be always negative from the point of view of the Governments. Even when considering sales tax on fares returned to Government as revenue, NPV remains negative. The results of the financial analysis have clearly demonstrated that the project would not be sustainable in its present form, given the available data and the assumptions used to determine the project's costs and revenues.

A wholly private sector option whereby all project risks would be transferred to the private sector was considered not financeable.

The objective of the **economic analysis** was to assess the viability of the project and its contribution to the economy as a whole by taking into account non financial costs and benefits such as changes in atmospheric emissions, public safety improvements, impact of HSR on transport operators within the Corridor, terminal value, as well as the consumer surplus.

The following table lists the NPV of non-financial benefits taken into account in the economic analysis:

Table S-7: Non-financial Benefits in the Economic Analysis (NPV in million 2009 CAD)

Segment	Technology	Atmospheric emissions	Public safety improvements	Impact on VIA Rail	Terminal value	Consumer surplus
Quebec City - Windsor	F200+	47	2 353	1 175	581	1 741
	E300+	96	2 481	1 175	650	2 665
Quebec City - Toronto	F200+	41	2 061	922	543	1 108
	E300+	85	2 198	922	614	1 906
Montreal – Toronto	F200+	35	1 688	784	504	500
	E300+	59	1 797	784	541	1 083
Toronto - Windsor	F200+	9	746	253	0	687
	E300+	14	724	253	0	829

The following table lists the NPV of costs taken into account in the economic analysis:

Table S-8: Economic Costs (NPV in million 2009 CAD)

Segment	Technology	Total investment costs	Total O&M and renewal costs (30 yr)	Impact on airlines	Impact on bus operators	Impact on airports
Quebec City - Windsor	F200+	11 291	5 266	54	-8	207
	E300+	12 622	5 822	62	-7	238
Quebec City - Toronto	F200+	8 340	4 057	46	-8	178
	E300+	9 471	4 551	54	-8	208
Montreal – Toronto	F200+	5 404	2 819	43	-9	168
	E300+	6 478	3 233	50	-8	196
Toronto - Windsor	F200+	2 934	1 287	6	-4	20
	E300+	3 316	1 451	6	-4	21

The results of the economic analysis in terms of NPV were the following:

Table S-9: Main Results of the Economic Analysis (NPV in million 2009 CAD)

Segment		F200+	E300+
Quebec City – Windsor	Revenues	9 536	10 677
	Consumer surplus	1 741	2 665
	Atmospheric emissions	47	96
	Public safety	2 363	2 481
	Impact on VIA Rail	1 175	1 175
	Terminal value	581	650
	Investment costs	-11 291	-12 622
	Operating costs	-4 091	-4 284
	Renewal costs	-1 175	-1 539
	Impact on other modes	-253	-293
	Total	-1 376	-992

Segment		F200+	E300+
Quebec City – Toronto		-190	257
Montreal – Toronto		817	869
Toronto – Windsor		-1 039	-1 433

From the point of view of the Canadian economy as a whole, the economic analysis showed that three combinations of technologies and segments have a positive NPV[8]. They were by decreasing order of importance:

- E300+ on the Montreal – Toronto segment with NPV of $869 million CAD
- F200+ on the Montreal – Toronto segment with NPV of $817 million CAD
- E300+ on the Quebec City – Toronto segment with NPV of $257 million CAD

The following table illustrates the results of the economic analysis in terms of economic benefits (positive signs) and costs (negative sign) to the economies of Quebec and Ontario:

Table S-10: Main Results of the Economic Analysis from the point of view of the Quebec and Ontario economies (NPV in million 2009 CAD)

Segment		F200+		E300+	
		Ontario	Quebec	Ontario	Quebec
Quebec City – Windsor	Net contribution by Governments	-3 321	-2 396	-3 673	-2 651
	Consumer surplus	1 104	637	1 673	991
	Atmospheric emissions	36	11	63	34
	Public safety	1 618	735	1 708	774
	Impact on VIA Rail	524	215	524	215
	Impact on Airlines	-40	-14	-45	-17
	Impact on Airports	-153	-53	-174	-64
	Impact on Bus operators	6	2	5	2
	Terminal value	275	198	308	222
	Total	49	-665	388	-494
Quebec City – Toronto		362	-132	661	108
Montreal – Toronto		779	116	983	80
Toronto – Windsor		62	-691	-49	-878

[8] Note that the benefits that would accrue to the economies of Ontario and Quebec would be sufficient to compensate for the economic losses borne by the other provinces.

From the point of view of the Ontario economy as a whole, all scenarios were shown to be economically feasible, except the Toronto – Windsor segment with E300+ technology, which had a negative NPV.

From the point of view of the Quebec economy as a whole, three scenarios were shown to be economically feasible:

- F200+ on the Montreal – Toronto segment with NPV of $116 million CAD
- E300+ on the Quebec City – Toronto segment with NPV of $108 million CAD
- E300+ on the Montreal – Toronto segment with NPV of $80 million CAD

These three scenarios were the same as the three scenarios shown economically feasible from the point of view of the Canadian economy in general, albeit in a different order.

Impacts on the transportation system

Impacts on the transportation system within the corridor are best measured by the modal shifts from existing modes of travel to HSR, based on results of the model for the year 2031 (results in percentage for the year 2041 were similar), as shown on the following table:

Table S-11: Modal Shifts from Existing Modes of Travel to HSR (year 2031)

	F200+		E300+	
Existing Mode of Travel	Trips (x 1000)	%	Trips (x 1000)	%
Auto	6 060	59	6 623	60
Air	1 032	10	1 158	10
VIA Rail	2 876	28	3 032	27
Bus[9]	-387	-4	-409	-4
New Trips	646	6	721	6
Total	10 227	100	11 124	100

Main findings were the following:

- The distribution of market ridership by mode has not varied significantly between 1992 and 2006.
- The present study estimates that 94 percent of HSR ridership would originate from other modes with the majority of riders (59 percent) originating from the auto market and that 6 percent of riders would be induced to the service in 2031.

[9] Diversion from bus is negative as some VIA Rail users would divert to bus resulting in more bus ridership with HSR operating and VIA Rail services eliminated in the Corridor than with VIA operating alone.

- Total auto ridership in the corridor was estimated at 83 million annual trips. An estimated 6.1 million auto trips would be diverted to F200+ HSR in 2031. There were no anticipated significant savings in road infrastructure requirements as a result of implementing a HSR in the Corridor.
- The QOHSRPS indicated that air carriers would lose 44 percent of their corridor ridership in 2005. The present study concluded that the air market loss in the Corridor in 2031 would be lower, at 31 percent for F200+ and 36 percent for E300+.
- The projected ridership diversion from airlines to HSR would have a direct impact on airport improvement fees assessed to the users of the various airports.
- An estimated 70 percent of VIA Rail ridership would transfer to HSR in 2031. The total number of passengers who would transfer to HSR in the present study represented a 10 percent increase over the estimated VIA Rail passengers diverted to HSR in the QOHSRPS.
- The projected overall market diversion rate observed in the bus ridership would be between minus 3 and minus 4 percent. It is anticipated that the elimination of local station stops formerly served by VIA Rail would result in riders transferring from rail to bus.
- The impacts of HSR on commuter rail, urban transit and freight rail services were analysed. The analysis has shown that the integration of the HSR with other transportation modes (both existing and planned) and their connection to the urban and regional transit/bus services at HSR stations were essential to HSR success as a new transportation mode in the Corridor.
- On segments of track in highly urbanized areas, HSR may have to share tracks with commuter trains and freight trains. This would require a high level of coordination and a modernized signal system to maximize capacity and service performance.

Review of similar HSR projects in the world

EcoTrain reviewed seven HSR projects with a significant private sector contribution, in the form of a PPP. They included: Poceirao-Caia Rave (Portugal); Perpignan-Figueras (France and Spain); GSM-R (France); TGV Bordeaux-Tours (France); High Speed 1 (United Kingdom); Taipei-Kaohsiung (Taiwan); and HSL-Zuid (Netherland).

Each project was unique in terms of size, geographic location, technical specifications, and risk profile. Still, common traits have emerged and should be considered. They include the following:

- A consultation process is a very important tool to assess the technical and financial risks of HSR projects over their lifecycle.
- Public authorities need to clearly identify and adequately assess all project risks prior to designing and structuring a procurement process.
- The ridership risk is difficult to transfer to the private sector, especially in the absence of historical information to support the demand forecasts.
- The allocation of geotechnical, land and property acquisition, and archaeological risks varies depending on circumstances.
- HSR projects require sufficient levels of equity capital to withstand the financial impacts of the risks transferred to the private sector.
- Availability based projects, i.e. PPP projects where revenues from fares or tolls are not part of a concession contract, but rather retained by the Owner, are easier to finance than projects involving a greater risk allocation to the private sector, including revenue risk.
- The size and structure of HSR projects need to be assessed early in their planning phase, in line with private sector interest and financial capacity.
- HSR projects could be packaged into several logical segments that could be tendered separately through a phased approach.
- In most cases, public funding of HSR projects built in PPP mode represents approximately half of the investment costs.
- Strong political leadership is an important factor in the development of major HSR projects, given the time required for delivering such projects and the amount of public funding required.
- Agreements related to the provision of HSR infrastructure, typically through DBFM models, and of HSR operations are usually subject to separate PPP contracts.
- It is critical that the payment mechanism be clearly defined and that there exist sufficient incentive (financial and other) to achieve all projects' objectives and requirements.

Review of transportation policies

A review of transportation policies in three countries with a large network of HSR lines, namely France, Germany and Spain, has examined how various demographic, market, infrastructure, transport, regulations, environmental, political and other considerations that could be relevant to the Quebec City-Windsor Corridor. Main conclusions and recommendations were the following:

- Reducing travel times and upgrading quality – The three countries attached much importance to these objectives by building new, dedicated HSR tracks, with Germany permitting freight traffic outside of hours of operations of passenger trains.
- Master planning – The elaboration of transport and HSR master plans has proven to be an essential step in developing HSR networks.
- Inter-modality and interconnectivity – Inter-modality with the conventional railway network and connectivity of HSR stations with other modes of transport, including commuter rail, buses and airport shuttles, were considered as success factors. The factors include:
  - *strong interface between HSR and conventional rail lines;*
  - *locating HSR stations so as to provide quick access to city centres;*
  - *developing intermediate stations to provide connectivity with other modes of transport; and*
  - *developing light rail or commuter services connected with the HSR. Rail connections from the projected HSR to Montréal – Trudeau and Toronto – Pearson airports are a case in point.*
- Railway freight transport – TGV in France was designed and built for passenger traffic only, which increased capacity for freight traffic on the conventional rail network. The Perpignan – Figueres HSR line has been designed and built for mixed passenger and freight traffic but it is not yet operational. Germany has a long experience in letting freight traffic use its HSR lines, but with strict control on the hours of operation of freight trains. The Quebec City – Windsor HSR would require building new and dedicated HSR tracks, which would free up capacity for freight transport on existing conventional lines.
- Information to stakeholders – This is of paramount importance for any large projects and public consultations and involvement are a prerequisite.
- Institutional reform – In the three countries reviewed, reforms were implemented to separate the ownership and management of rail infrastructure and rail operations, in line with EU directives to foster in-market competition. A systematic review of transportation policies in Canada, Ontario and Quebec should be undertaken to ensure that the benefits targeted by these reforms are maximized.

- Integrated taxation policy – Transport infrastructure requirements, environmental objectives and trends, and socio-economic considerations should be reviewed carefully to assess whether or not there would be a need for an integrated taxation policy aimed at achieving transport mode shift and desired levels of self-financing for upcoming HSR projects.
- Environmental concerns – The need to reduce dependence on fossil fuels as the main source of transportation energy and the availability of nuclear-based electricity were key elements that led to the selection of electrical traction technology for HSR. Long term access and dependency to energy sources should be given due considerations at the planning stage of the Quebec City – Windsor HSR.
- Interoperability – This is a major EU policy objective. Although HSR lines now planned across North America would not necessarily be interconnected, this should not prevent careful consideration being paid to the development of compatible networks within Canada and with the U.S.
- Funding – HSR infrastructure investments are generally financed by the governments and by the infrastructure provider through user charges collected from HSR operators. Services are usually provided at market based prices with a view to make HSR operations profitable. The context prevailing in the Quebec City – Windsor Corridor should be further reviewed to assess whether similar approaches could be adopted with regards to the funding of HSR infrastructure and operations.

Main Conclusions and Recommendations

Based on a thorough review and update of the 1995 QOHSRPS report and on surveys and analyses conducted expressly for the present study, EcoTrain arrived at the following conclusions and recommendations regarding the implementation of a HSR in the Quebec City – Windsor Corridor:

- Increases over the past 15 years in transportation needs within the Corridor, changes in land use patterns in the vicinity of major cities, and accumulated experiences with HSR construction and operating costs during that period in various European and Asian countries justified carrying out the present study.
- Two representative technologies were evaluated, a diesel powered 200 km/h 400-passenger trainset and an electric powered 300 km/h 400-passenger trainset. Both technologies could be suitable for the needs expressed in the Corridor, although the trend around the world is for new HSR systems to be electric powered and capable of operating speeds equal to or greater than 300 km/h.

- Significant reduction in travel times compared with existing VIA Rail schedules and added convenience would entice a number of travellers within the Corridor to switch from their present mode of travel (auto, air, VIA Rail or bus) to the future HSR: 60 percent of the HSR ridership would have previously travelled by auto, 10 percent by air and 24 percent by VIA Rail or bus. Six percent of the ridership would be induced travel, i.e. persons who would not have made any trip previously but who would take the HSR if it were available.
- Representative routes and representative stations were based on the QOHSRPS report and modified to take into account intervening changes in land use patterns. HSR stations would serve the following cities: Quebec City, Trois-Rivières, Montreal, Ottawa, Kingston, Toronto, London, and Windsor.
- HSR in the full Quebec City – Windsor Corridor would attract more than 10 million passengers (with F200+ technology) and more than 11 million passengers (with E300+ technology) in 2031 assuming "steady state" (following a ramp-up period). Expected revenues would be respectively $1.2 and $1.3 billion CAD (2009) for the same year.
- Initial investment costs were estimated on the basis of historical construction costs[10] and the cost of acquiring rolling stock[11] and railway equipment used on comparable projects and adjusted to reflect the specific parameters of the Quebec City – Windsor HSR service. Total initial investment costs for the full Quebec City – Windsor Corridor would be $18.9 billion CAD for the F200+ technology or $21.3 billion CAD for the E300+ technology.
- Operations and maintenance (O&M) costs were based on a typical on-going HSR operation, adjusted to take into account unit cost and productivity of Canadian manpower. In its first year of operation, O&M costs would be $492 million CAD for the F200+ technology or $520 million CAD for the E300+ technology.
- The review and update of the 1995 QOHSRPS report included the estimation of environmental mitigation costs for noise barriers, settlement ponds, farm crossings, and wildlife passages. Other mitigation costs were implicitly included either in the costs of earthworks, drainage, and structural works, based on similar projects recently built in the Quebec City – Windsor corridor, or in contingencies for various project elements.

[10] Construction costs were estimated at this feasibility level as Class D estimates.
[11] Rolling stock and railway equipment acquisition costs were obtained from HSR manufacturers.

- The implementation schedule of the project showed that it would take at least 14 years before the full Quebec City – Windsor Corridor HSR could enter into commercial service, whether F200+ or E300+ was chosen as the preferred technology. This included 5 to 8 years for route selection, preliminary engineering and environmental assessment, and 8 years for detailed engineering, property acquisition, construction of civil works, and procurement of rolling stock and rail equipment, plus one year for testing the system.
- If a decision were made in 2011 to go ahead with the conceptual design, the full Quebec City – Windsor Corridor HSR could enter into commercial service in 2025. This very long timeline would require strong governmental leadership and active participation of a large number of stakeholders, including interested private sector engineers, contractors, and financiers.
- From a financial point of view and if the project is financed through a PPP operation, the project would only be sustainable in its present form, given the assumptions used to determine its costs and revenues, if the Governments would pay for at least half of the investment costs. This upfront investment by Governments seems consistent with similar HSR projects recently built or under construction around the world using a PPP financing method. Once in operation, the project would be profitable, with revenues exceeding operations and maintenance costs from day one, and with profits used to reimburse half of the total investment debt.
- If the HSR project is carried out under a wholly public case, the Governments would assume all of the project risks, including the design, construction, financing, operation and maintenance, and retain all of its potential benefits. As was the case in a PPP scenario, the project would be profitable, with revenues exceeding operations and maintenance costs and profits used to reimburse a portion of the Governments contributions."
- The full Quebec City – Windsor project would not be economically sustainable in its present form, given the assumptions used to determine its costs and revenues. However the following three segments would be economically feasible from the point of view of the Canadian economy as a whole[12], with a positive net present value (NPV):
  - *E300+ on the Montreal – Toronto segment with NPV of $869 million CAD*
  - *F200+ on the Montreal – Toronto segment with NPV of $817 million CAD*
  - *E300+ on the Quebec City – Toronto segment with NPV of $257 million CAD*

[12] The benefits that would accrue to the economies of Ontario and/or Quebec would be sufficient to compensate for the economic losses borne by the other provinces.

- From the point of view of the Ontario economy as a whole, all scenarios would be economically feasible, except the Toronto – Windsor segment with E300+ technology, which has a negative NPV:
  - *F200+ on the full Quebec City – Windsor corridor with NPV of $49 million CAD*
  - *E300+ on the full Quebec City – Windsor corridor with NPV of $388 million CAD*
  - *F200+ on the Quebec City – Toronto segment with NPV of $362 million CAD*
  - *F200+ on the Montreal – Toronto segment with NPV of $779 million CAD*
  - *F200+ on the Toronto – Windsor segment with NPV of $62 million CAD*
  - *E300+ on the Quebec City – Toronto segment with NPV of $661 million CAD*
  - *E300+ on the Montreal – Toronto segment with NPV of $983 million CAD*
- From the point of view of the Quebec economy as a whole, three scenarios were economically feasible (they were the same, although in a different order, than the three scenarios shown economically feasible from the point of view of the Canadian economy in general):
  - *F200+ on the Montreal – Toronto segment with NPV of $116 million CAD*
  - *E300+ on the Quebec City – Toronto segment with NPV of $108 million CAD*
  - *E300+ on the Montreal – Toronto segment with NPV of $80 million CAD*
- To implement a HSR in the Quebec City – Windsor corridor, the three Governments of Canada, Quebec and Ontario should prepare an inter-city transportation master plan, involving air, rail and bus operators, with a view of defining a sustainable plan for the next 50 years. The master plan would include an update of the ridership and economic analyses, based on the latest fares and ridership figures for the different modes in the Corridor.
- The HSR Authority would assess market capacity in terms of costs and schedules and determine the proper size of sub-projects. The Authority would also test what risks to transfer to the private sector if a PPP approach is chosen, on the basis that the ridership risk is usually assumed by the public sector in the cases that were analysed as part of the present study.
- The size and structure of HSR projects would need to be defined early in their planning phase, in line with private sector interest and financial capacity. An overly large project, both in term of size and value, could contribute to reducing the level of interest and competitiveness from the private sector, especially in new markets where such deals have not yet been made.
- One of the first tasks of the HSR Authority would be to develop terms of reference for the Environmental Assessment, taking into account the environmental legislation in the three jurisdictions: Canada, Ontario and Quebec, and launch the EA. The Authority should also initiate the preliminary engineering phase and the early works such as geotechnical, topographical and hydrological surveys.

- Depending on circumstances, HSR projects could be divided into several logical sections that could be procured separately through a phased approach. The successful delivery of one section or segment can sometimes play an important role in motivating industry market players and funders to get involved with the other sections.

INTRODUCTION

This document is the final report of the Updated Feasibility Study for a High Speed Rail Service in the Quebec City – Windsor Corridor and presents its key findings. The study will be referred to herein as "the present study".

The present study was conducted by EcoTrain on behalf of the ministries of Transportation of Canada, Ontario, and Quebec.

EcoTrain is a group of consulting firms led by Dessau and including Deutsche Bahn International (DBI), KPMG, MMM Group, and Wilbur Smith Associates (WSA).

Objectives

The objectives of the study as stated in the Request for Proposal were:

- "To review past studies with respect to changes that would impact their conclusions and recommendations
- To identify which actions, updates, or additional studies would be required and carry them out
- To issue recommendations pertaining to the feasibility and relevance of issuing a Request for Interest involving the execution of subsequent studies based on a Public-Private Participation (PPP) or an Alternative Financial Proposal (AFP) approach."

Approach

The recommended approach for the present study was to update the findings and conclusions of the Quebec Ontario High Speed Rail Project Study (QOHSRPS). That study was conducted from 1992 to 1995 by various research and consulting firms on behalf of the ministries of Transportation of Canada, Ontario, and Quebec.

As specified by the Terms of Reference, work required for updating the QOHSRPS was divided into 13 Deliverables:

- Deliverable 1, Project Management (Dessau)
- Deliverable 2, Detailed Work Plan and Schedule (Dessau)
- Deliverable 3, Review of the Study and Updating Recommendations (All)
- Deliverable 4, Review of Available HSR Technology (DBI)
- Deliverable 5, Review of Representative Routing Options (MMM and Dessau)
- Deliverable 6, Update of the Construction and Operating Costs (Dessau, MMM and DBI)

- Deliverable 7, Demand Forecasting (WSA)
- Deliverable 8, Review of Transportation Policies in Countries with an Existing HSR System (KPMG)
- Deliverable 9, Analysis of Environmental and Social Impacts (MMM with Dessau)
- Deliverable 10, Review of Implementation Options (KPMG)
- Deliverable 11, Financial and Economic Analysis (KPMG)
- Deliverable 12, Review of Impacts of HSR on the Transportation System within the Corridor (MMM with Dessau)
- Deliverable 13, Final Report (Dessau with All).

Deliverables 3 to 12, mentioned above, are featured in separate technical reports[13]. These reports document and explain in detail the analyses and findings of each deliverable. The present report constitutes Deliverable 13, and presents a summary of the key findings of Deliverables 3 through 12.

Conduct of the Study

To facilitate the management of the present study, the sponsoring ministries set up two committees, a Steering Committee and a Technical Committee.

The Steering Committee

The Steering Committee was comprised of senior representatives of the sponsoring ministries (two representatives from each at all times), at the Assistant Deputy Minister level or equivalent. The Committee's role was to monitor the overall progress of the study, provide strategic level guidance, and approve its key findings. It met approximately once monthly throughout the study.

The Technical Committee

The Technical Committee was comprised of specialists from the sponsoring ministries (two specialists from each at all time). The Committee's role was to continuously monitor the work in progress at the technical level, provide technical guidance, review, comment, and approve technical notes as well as the interim, partial and final results and draft reports. It met approximately once a week throughout the study.

[13] Actually, there are two reports for Deliverable 6 (Part 1, Construction Costs and Part 2, Operating Costs) and a single report for Deliverables 10 and 11 (Financial and Cost-Benefit Analysis).

Outline of the Final Report

This final report highlights all key findings, while providing explanations where necessary. The contents are presented so that the reader can rapidly and easily understand and appreciate the findings, referring to the separate technical reports to obtain addition details on specific technical points.

- Chapter 1 examines the need to update the 1995 QOHSRPS, given the intervening changes that have occurred in technology, population, travel patterns, and land development.
- Chapter 2 describes the representative technologies that were analysed for 200 km/h and 300 km/h speed levels.
- Chapter 3 describes the representative routes and stations that were analysed for high speed rail (HSR) service at the two different speed levels, based on the final routes from the 1995 QOHSRPS report that have been modified due mainly to recent land development along the corridor and to changes in airport access needs.
- Chapter 4 describes the level of service that HSR could offer at the two different basic speed levels and the required railway systems to provide that service.
- Chapter 5 presents ridership and revenue forecasts based on existing travel patterns in the Quebec City - Windsor corridor, stated preference surveys, data from the previous study, data provided by the three governments and socio-economic forecast.
- Chapters 6 and 7 quantify the initial investment costs, including construction, rolling stock and railway systems equipment (chapter 6) and the operation and maintenance (O&M) costs (chapter 7) based on the operating system, routes, stations, service and railway systems for the two different basic speed levels and projected ridership. The cost model for capital cost estimate was similar to the QOHSRPS one, while the model for the O&M costs included a higher level of detail and comprehensiveness than the QOHSRPS model.
- Chapter 8 identifies potential environmental and social impacts of the HSR.
- Chapter 9 describes potential impacts of the HSR on other intercity transportation modes in the corridor.
- Chapter 10 discusses implementation of the HSR in the corridor in terms of scheduling, organization and options for public private partnerships.
- Chapter 11 presents the financial analysis and the economic analysis of the updated HSR project.
- Chapter 12 reviews transportation policies in countries with existing HSR systems in order to identify their consistencies and inconsistencies, their success factors, the lessons that can be learned from them, and their relevance to the Quebec City - Windsor Corridor.

1 JUSTIFICATION FOR AN UPDATE

An update of the QOHSRPS is required due to the evolution of high speed rail (HSR) systems and technology since 1995. It is also required due to the demographic, economic, and other changes that have occurred in the Quebec City – Windsor Corridor in the past 15 years from 1995 to 2009, namely:

- Increased land use and economic development in the vicinity of major cities
- Increased highway traffic congestion between major cities in the Corridor
- Increased public interest in environmentally sustainable transportation.

1.1 Changes in HSR Systems and Technology

HSR has undergone impressive growth on a global scale since 1995. According to UIC (Union internationale des chemins de fer), the global network of specially built lines allowing speeds of at least 200 km/h, has reached 10,000 km and approximately 1,750 high speed trainsets are in service. Total length of HSR lines is expected to reach 37,000 km within the next 15 years, as shown in the following table:

Table 1-1: Length of High Speed lines in the World - September 2008 (km)

	In Operation	Under Construction	Planned	Total
Asia	4,074	4,706	7,857	16,637
Africa			680	680
Europe	5,598	3,479	8,501	17,578
North America	734		900	1,634
South America			815	815
Total	10,406	8,185	18,753	37,344

1.1.1 World-wide Development of HSR

Three countries paved the way for high-speed rail. They developed their own HSR independently and followed different paths with their technology.

- Japan introduced its Shinkansen in 1964, now consisting of 2,145 km of lines with a maximum operating speed of 300 km/h[14]. The Shinkansen system carried 79 billion passenger-km in 2007.

[14] In this report, maximum operating speed is used to characterize HSR systems: this is the maximum speed attained where there are no speed restrictions (trains can actually travel faster to make up time). The average speed (distance between two stations divided by travel time) depends on maximum operating speed, but also on the distance between stations (due to acceleration and deceleration), time stopped in stations, and local speed restrictions along the line, if any.

- France introduced its TGV (Train à grande vitesse, High Speed Train) in 1981. There are now four main lines radiating from Paris, with various branches, for a total of 1,872 km. The most recent lines have a 320 km/h maximum operating speed. Three lines are under construction. The French TGV network carried 53 billion passenger-km in 2008.
- Germany, where the InterCity Express (ICE) was introduced in 1991, operates a network of 6,865 km (of which 1,330 are new high speed lines, and 2,125 km new and upgraded), with speeds up to 300 km/h. In 2006, ICE traffic amounted to 22 billion passenger-km.

During the last decade HSR operation has been introduced in numerous other countries. These countries used the technologies developed by the three pioneer countries directly or have used them as a model for their own developments.

In addition to Japan, France and Germany, countries now operating HSR services, in order of their implementation, are: Italy, 1981; Spain, 1992; Belgium, 1997; U.S.A. (between Washington and Boston), 2000; United Kingdom (through the Channel tunnel), 2001; South Korea, 2004; Taiwan, 2007; China, 2008; Turkey, 2009; and Russia, 2010. Planning for HSR systems is underway in Europe (Norway, Portugal, Poland, and Sweden); in Africa (Algeria and Morocco); in Asia (India, Iran, and Saudi Arabia); and in South America (Argentina and Brazil).

1.1.2 Adaptability to Specific Conditions

HSR systems around the world, whether in operation or development, share a common set of characteristics. However, each is still unique as it is customized to its track parameters (grades, curves, speed restrictions), traffic patterns, commercial and social objectives, services provided, etc. One important aspect common to all these HSR systems is that they are grade separated from rail, road, and other traffic.

The adaptability of the latest HSR technologies to specific conditions is of great interest to this present study and following two examples are particularly relevant.

U.S.A: Locomotives and Cars Made FRA Compatible. Trains operating on the US national railway network have to comply with crashworthiness and other regulations of the Federal Railway Administration (FRA). When Amtrak ordered high-speed Acela trains, these FRA requirements were included as part of the specifications that car builders had to meet. Additionally these trains derived from the French TGV technology were designed and built with the necessary structural reinforcements and other adaptations. These adaptations included a tilting mechanism, due to the 400 remaining curves that could not be straightened to allow higher speeds. This issue of crash management and adapting equipment to meet Canadian standards would face any HSR application in the Quebec City – Windsor corridor that would use shared tracks.

Russia: Track Gauge and Trainset Width Changed. The trainset chosen for the Moscow to St. Petersburg HSR was based on the Velaro-E technology, which runs between Madrid and Barcelona. The following adaptations were made:

- The bogies were widened from the standard track gauge (1435 mm) to the Russian broad gauge (1520 mm).
- The cars were widened by 330 mm, to 3265 mm allowing improved insulation for cold climate operation.
- The power pick up and power conditioning equipment was changed from 25 kV AC to 3000 V DC, the current electrification on the existing line.

1.2 Demographic, Economic and other Changes

The QOHSRPS forecasted population for the years 2005 and 2025 based on 1992 figures. The present study has concluded that these forecasts were optimistic with respect to the actual changes, as shown on the following table:

Table 1-2: Comparison of Population Forecasts – This Study versus the 1992 Study

	1992 Study Population Forecast (thousands)				
Year	1992	2005	*2006**	2025	
Quebec	6 926	7 800	7 845	8 700	
Ontario	10 262	12 200	12 375	15 700	
Total	17 188	20 000	20 220	24 400	
	This Study Population Forecast (thousands)				
Year			2006	*2025**	2031
Quebec			7 546	8 501	8 802
Ontario			12 161	15 024	15 929
Total			19 707	23 525	24 731
Difference			-2.5%	-3.6%	

*Interpolated

Source : Quebec/Ontario High Speed Rail Project, Socio Economic Variables;
Economic Analysis Directorate; December 1992

Changes also occurred in forecast growth of total trips, as illustrated in the following table, which shows that the 1995 Study overestimated the annual growth rate of trips by auto and by air, while underestimating trips by rail and by bus:

Table 1-3: Comparison of Total Trips Growth 2006-2025 – This Study vs. the 1992 Study

	Trips (millions) 1992	1992-2005 Total Growth	Trips (millions) 2005	2005-2025 Annual Growth	Trips (millions) 2006	Trips (millions) 2025	2006-2025 Total Growth	Trips (millions) 2031
1992 Study								
Auto	99.0	33%	131.2	2.10%	134.0	198.8	48%	
Air	4.1	46%	6.0	2.58%	6.1	10.0	62%	
Rail	2.9	0%	2.6	0%	2.9	2.9	0%	
Bus	2.6	0%	2.6	0%	2.6	2.6	0%	
Total Trips	108.6	31%	142.7	2.05%	145.6	214.3	47%	
This Study								
Auto		18%						
Air		18%						
Rail		24%						
Bus		23%						
Total Trips					92.7	106.8	15%	111.7

Sources : 1992 Study : Québec – Ontario High Speed Rail Project; Final Report; August 1995. Tables 4.4 and 4.6.
Notes : The 1992 Study included additional markets such as Hamilton to Toronto so total trips are not comparable but growth are comparable since the 1992 Study growth applied to all markets.
To permit easier comparison, trips were interpolated for 2006 in the 1992 Study and for 2025 for this study.

Other changes concern land use, travel patterns, and environmental evaluation.

- Changes in land use occurred mainly around larger cities, where new development required modifications to HSR route alignments.
- Changes in travel patterns were induced by the large increases in commuter rail services in Montreal and in Toronto. Proposed rail shuttle service between downtown and the major airport in Montreal and Toronto, combined with the abandonment by the railway companies of various segments of tracks, have led to major modifications to the representative routes between Montreal and Ottawa and west of Toronto, as will be seen in Section 3, Representative Routes.
- Changes that occurred in the environmental evaluation procedures since 1995 are documented below in Section 8, Social and Environmental Impacts.

2 REPRESENTATIVE TECHNOLOGIES

As used herein, the term Technology designates all the civil, mechanical, electrical, electronic, and informational components of a HSR service, as well as all equipment and processes needed to operate a HSR service safely and cost effectively on a regular basis. Technology also refers to consideration of the interactions between each of these components as well as with their environment.

To evaluate the feasibility of HSR in the Quebec City – Windsor Corridor, routes and alignments were defined in order to calculate travel times, forecast ridership, estimate costs, and identify potential environmental impacts. To avoid the need to evaluate these important parameters abstractly or for all possible technologies, a representative technology was adopted for the analysis, as was done in the QOHSRPS. By doing so, more realistic estimates were obtained, resulting in more reliable feasibility conclusions.

Representative, here, means that the technology retained was typical of what an actual HSR system would be in the Corridor, in terms of travel quality and performance, capital and recurring costs, and environmental impacts.

This section presents the key representative technologies and components that were retained for analysis. A detailed discussion of the representative technologies can be found in the technical report for Deliverable 4, Representative Technology Options.

2.1 Strategic Guideline

Early in the study a strategic decision was made, with the approval of the Technical Committee, to retain the following two representative technologies for analysis based on the representative technologies selected in the QOHSRPS and the recent HSR implementations and developments:

- A modern high-speed diesel-fuelled technology, with a minimum operating speed of 200 km/h or more referred to as F200+.
- A modern high-speed electric technology, with a minimum operating speed of 300 km/h or more referred to as E300+.

2.2 Recent Improvements in Technology Components

HSR services require a high level of compatibility between their infrastructure, rolling stock, and other equipment. Performance levels, safety, quality of service and cost depend upon that compatibility.

2.2.1 Rolling Stock

There is now a wide variety of rolling stock for HSR. Their maximum operating speed, ranging between 200 km/h and 350 km/h, is directly related to the design speed of the line on which they run and the distances between the cities they serve. The discussion that follows applies to rolling stock with a maximum operating speed that may vary between 200 km/h and 300 km/h.

2.2.1.1 *Typical Configuration*

High-speed trains are typically bi-directional sets with a control cab at each end of the train for rapid direction changes at the end of the line or terminal. The cars are permanently coupled and the train configuration cannot be changed during operation. They have auxiliary couplers at both ends of the train for coupling with conventional rolling stock in cases of emergency, e.g. for towing a stranded train. The length of high-speed trains currently in operation varies between 55 and 405 m, differing mainly as a result of required seating capacity, the length of station platforms, etc. The established standard length is between 200 m and 400 m. Typically 200 m trainsets with 6 to 8 coupled cars or 8 to 10 articulated cars are chosen for moderate passenger traffic volumes and are used throughout Europe, China, and Japan.

2.2.1.2 *Passenger Cars*

Most cars for HSR are designed for level boarding and alighting at stations, thus facilitating handicapped access, reducing the time required for passenger entry and exit, and enhancing passenger comfort. The floor of the compartment is between 1,000 to 1,200 mm above top of rail. A typical 200 m long high-speed trainset with single-deck cars has a capacity of about 400 seated passengers. For coping with seasonal or daily peak demand, two of these trainsets (platform length permitting) could be coupled in operation to double the train’s length and seating capacity.

2.2.1.3 *Installed Power*

Operation of HSR requires considerable traction power, depending on trainset weight, maximum operating speed, non-traction electrical loads (heating, air conditioning, etc.) and the profile of the line where the trainset is operating. Depending on the grades and other line-specific factors, the power required for a 200 m trainset varies from 3,000 to 5,000 kW at 200 km/h, and from 6,000 to 10,000 kW at 300 km/h. The differences in power required for a given maximum operating speed depends on the mass and aerodynamic performance of the trainset, as well as on the grades of the line.

2.2.1.4 Tilting Technology

Using tilting rather than conventional trains would entail higher capital costs as well as additional costs for maintenance of rolling stock and infrastructure. On new alignments the tilting technology would bring only minor reductions in travel time. In addition, because of its reported sensitivity to winter conditions, tilting did not appear as a suitable candidate for a representative technology in the present study. Further developments could warrant examining this technology at the conceptual design stage of the project.

2.2.2 Track

The track constitutes the physical guideway for the trainsets. Its characteristics enable the trainsets to run under the desired conditions of speed, comfort and safety.

In principle, HSR could use any track. The track must have the proper gauge, and the signalling system and energy supply should be compatible with the needs of the trainset. Limitations to the maximum allowed speed usually result from:

- Alignment parameters. Independent of track technology, the maximum operating speed is limited by the combination of curve radii, banking and allowable banking deficiency for the trainsets. For speeds of 300 km/h and above curves with a minimum radius of 6,000 m were recommended, while, for speeds of 200 to 250 km/h, a minimum radius of 2,500 m was recommended.
- Quality of track geometry. In order to limit undesirable forces between rail and wheel, track geometry should be consistent with the speed and only very small deviations to the initial position are allowed. When sharing an existing track, HSR must comply with any speed limitations on that line.

When existing tracks do not provide sufficient capacity and quality, nor a suitable geometry (e.g. curves are too sharp), and/or cannot be upgraded, new tracks should be installed for HSR. These new tracks could also be used by other types of trains.

There are two main options for track configuration: conventional with ballast and ballast-less track systems. Both systems are proven for operation at speeds higher than 300 km/h. There are no relevant specification changes within the 200 up to 350 km/h speed range. Figure 2-1 shows typical configurations for both track systems.

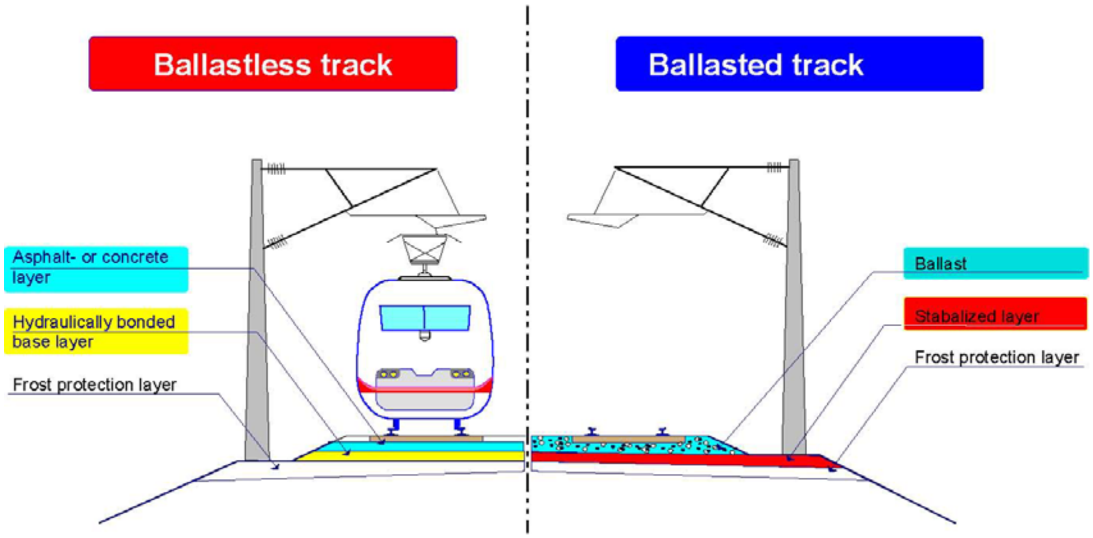


FIGURE 2-1: BALLASTED AND BALLAST-LESS TRACK

Ballasted track is the conventional method for laying out railway tracks. Their main advantages are: highly mechanized construction procedures; low sensitivity to construction defects; highly mechanized maintenance procedures; lower construction cost; good adaptability to settling; and low noise emission. Their main disadvantages are: change of initial geometric conditions caused by operational loads; the resulting high cost and time for monitoring and maintenance; and heavier dead loads on bridges and other structures.

Different types of ballast-less tracks are available today. The main characteristic of all types is the replacement of the ballast by concrete in the form of prefabricated or cast in place concrete slabs. Common goal of ballast-less track systems is to preserve the initial geometric conditions of the track. This leads to low maintenance efforts; but, due to the required accuracy, results in high construction cost. Ballast-less tracks generally require good sub-soil bearing capacity.

Due to lack of detailed information on subsoil conditions, a 50%-50% combination of ballasted and ballast-less track was chosen as the representative technology for estimating construction and maintenance costs.

2.2.3 Energy

2.2.3.1 Energy Source

There are two different energy sources for HSR - diesel fuel or electricity. The choice between these two systems depends on the requirements of the intended operation.

Diesel power is quite simple to introduce, with little infrastructure required. However, the traction power that can be installed in a typical 200 m long diesel-powered trainset is limited, with a current maximum of 4,000 kW. Thus, for HSR service, diesel traction can be used only in the lower speed range.

Electric power supply makes it possible to have considerably more powerful trainsets. The maximum traction power currently installed in a typical 200 m long trainset is near 10,000 kW. Electric power is used in the entire speed range from 200 km/h, up to the current maximum operating speed of 350 km/h. However, infrastructure costs are higher than in the case of diesel traction.

The respective advantages and disadvantages of diesel and electric traction are outlined in Table 2-1.

Table 2-1: Comparison of Diesel and Electric Energy Sources for HSR

Characteristic	Diesel Power	Electric Power
Financial		
Investment Costs	Lower due to absence of power supply and distribution systems	Higher due to power supply and distribution systems
Operating Costs	Higher traction energy costs	Lower traction energy costs
Maintenance Costs	Higher for vehicle due to complexity of power apparatus	Higher for infrastructure due to poor distribution system
Operational		
Maximum speed	200-225 km/h	300-325 km/h
Maximum Installed Power	4,500 kW	10,000 kW
Flexibility and autonomy	Can be rerouted to non-electrified lines in case of power loss	Cannot be rerouted to non-electrified lines in case of power loss
Clearance	No restrictions	Restrictions due to catenary wires and poles
Circulation in tunnels	Requires ventilation and may be disallowed	Does not require ventilation
Energy consumption	Braking energy may not be recovered	Braking energy may be recovered
Weather susceptibility	Emergency on-board power supply from main diesel engine	Emergency on-board power supply for winter operation is necessary (kerosene-fuelled APU)
Environmental		
Greenhouse Gases (GHG)	Direct emission of GHG's	Indirect emission GHG's where electricity produced from thermal plants
Criteria Air Contaminants (CAC)	Direct emission of CAC's	Indirect emission of CAC's where electricity produced form thermal plants
Danger	Large amount of flammable liquids on board	Minimal amount of flammable liquids on board
Noise	Higher, especially at low speeds	Lower at low speeds
Source of Energy	Constant dependence on fossil fuels	Dependence on fossil fuels only if from thermal power plant

Thus, typical applications of diesel power are found in cases where the ridership is quite low and there are relatively low traction power requirements. Electric traction is typically applied for busy lines with high passenger volumes and high traction power requirements (i.e. higher speed, steep grades). As the traction power requirements of HSR trainsets are often very high, electric traction is usually the preferred power source.

In the present study, the relative merits of the two main energy sources, diesel fuel or electricity, were evaluated with respect to their construction, operation, and maintenance costs and their environmental impacts, as well as in the financial and economic analysis.

2.2.3.2 Power Supply and Distribution for Diesel Trainsets

The prime component in most diesel powered locomotives is a diesel engine which drives an electrical generator whose output provides power to the electric traction motors. No external power supply system is needed (fuel is carried on board) and the infrastructure for the operation of diesel-fuelled trainsets is limited to filling stations at terminals and at some stations. There are no special requirements for the fuel: diesel fuel for HSR is the same as that used for other railway trains.

For a given load, the performance of a diesel locomotive is inferior to that of an electric locomotive, since the former has to carry its own fuel for traction. This restriction becomes even more important as maximum speed increases.

2.2.3.3 Power Supply and Distribution for Electric Trainsets

Electricity is brought from the utility's high-voltage transmission lines to the system's power supply stations built along the line. From there, electricity is distributed along the line to the moving trainset by an overhead catenary system (OCS). In the trainset, high voltage current is collected from the catenary by a pantograph, which continuously touches the contact wire, and is transformed to the medium voltage that feeds the traction motors.

Power from the utility can be produced from fossil fuels or from clean and/or renewable sources, including geothermal, hydroelectric, nuclear, solar power, and/or wind turbines.

The feeding voltage preferred worldwide today for mainline OCS is 25 kV AC. In North America, this system is already used in the Mount Royal tunnel and the Deux-Montagnes commuter line in Montreal. Also, the Amtrak Northeast Corridor from Boston to Washington line is electrified at 25 kV.

FIGURE 2-2: CATENARY ON THE COLOGNE – FRANKFORT HIGH SPEED LINE

2.2.4 HSR Signals and Telecommunications

The following discussion applies to both the 200 and 300 km/h speed levels. The basic functions of a signalling and train control system in HSR operation are:

- Collision protection
- Speed control
- Interlocking and protecting train routes on the line and in stations

2.2.4.1 System Requirements

Existing railway signal systems for conventional freight and passenger trains (up to 160 km/h) are based on detecting whether a track section is occupied and relaying that message to wayside signal lights displaying the status of track sections ahead.

For higher speeds (200 km/h and more), a separate signalling system should be implemented, for the following reasons:

- The train driver cannot reliably observe wayside conventional signals in case of rain, fog or snow. For this reason, messages are displayed inside the cab to avoid loss of visibility
- The long braking distance of a train travelling at high speed cannot be covered by a conventional signalling system.

HSR signalling and train control systems are designed to provide automatic enforcement of both signal messages and speed limits.

The current railway signalling system used in the Québec City-Windsor Corridor could not cover the needs of HSR operation above 200 km/h, nor could it be upgraded for such an operation. Most rail lines of interest in the Corridor are equipped with visual signalling systems, which are not adequate for HSR. These systems are augmented with more complex equipment in areas of high traffic, such as near major stations. Conventional trains travelling on these dense lines, such as commuter trains, are already equipped with improved signalling equipment. When sharing these tracks, HSR trainsets should possess the necessary equipment to respond to the signalling systems already in place. Conversely, commuter rail cabs should also be equipped with on-board equipment to respond to the HSR signalling system.

2.2.4.2 Representative Signalling System

Several signalling systems suitable for HSR are in service worldwide. They have evolved from conventional systems and are available from numerous suppliers and manufacturers.

To estimate costs of the HSR signalling system in the present study, the ERTMS (European Railway Traffic Management System) Level 2 was chosen as a representative technology. ERTMS includes the most current technology developments. It is proven in operation, is available from at least six independent international manufacturers, and provides Automatic Train Protection (ATP) for all types of HSR.

ERTMS can be overlaid on existing signalling systems and meet all the requirements of HSR. The system works for high speeds from 200 km/h up to 500 km/h without any major differences in system design and costs. A high proportion of the system's functions are controlled by its software, which is programmed for each application according to design speed and local conditions.

2.2.5 Track Sharing and System Protection

In the Quebec City - Windsor Corridor, HSR could easily use conventional tracks (while accepting their speed and other restrictions), particularly in urban areas, under the condition that track capacity is sufficient and the lines are electrified in the case of the E300+ system.

2.2.5.1 Sharing Tracks with Freight Trains

When shared electrified tracks are used by freight as well as HSR trainsets, the height of the OCS line above the top of rail has to take into account the height of the freight cars, which is typically higher than that of a passenger car.

Running fast passenger trains and slow freight trains on the same track may cause scheduling problems due to differences in operating speeds. Sharing track with freight traffic has significant constraints. This is the reason why freight trains on German high-speed lines run mostly at night when passenger traffic is shut down.

2.2.5.2 *Sharing Track with Commuter and Other Passenger Rail Traffic*

Sharing track with commuter and other passenger rail traffic occurs mainly as HSR and other trains approach and leave stations, due to the limited space for adding exclusive HSR track in highly developed urban areas. The time penalty to HSR is generally not significant, as HSR travels at a reduced speed near stations when braking and accelerating.

Sharing Right of Way (RoW) with conventional trains (or roads and highways) is possible under the following conditions:

- There is enough lateral clearance between the HSR and conventional railway lines for protection measures to accommodate the dynamic envelopes of both types of trains. In addition, mitigation and/or protection measures are needed to prevent freight items from falling down on the high-speed track.
- Alignment parameters (radii and gradients) are consistent with the desired speed for HSR.
- Grade crossings of HSR and other tracks (or highway lanes) are eliminated and replaced with grade separation structures.
- Depending on the number of industrial sidings and grade crossings, additional bridges or underpasses would be necessary as grade crossings with existing rail and roads are not acceptable.

2.2.5.3 *Grade Crossings with Roads*

Grade crossings are a hazard for both rail and road traffic. Severity of accidents rises with an increase in train speed. Grade crossings with roads have been eliminated from nearly all of the lines in Europe wherever train speeds exceed 160 km/h. In Asia, most new lines are designed for the exclusive use of HSR and grade crossings were eliminated from the start.

When a train travels at 200 km/h, the gates protecting the crossing would have to be closed five minutes before the train arrived at the crossing to ensure that the train could safely stop before it reached the crossing in case of emergency. On busy streets, long lines of waiting cars may accumulate on both sides of the closed gates, obstructing traffic and increasing congestion and vehicular emissions. Furthermore, as the train would not be seen nor heard, impatient drivers could decide to drive around the closed gates, especially on rural roads. For this reason, all over the world, railway operators are replacing grade crossings by overpasses or underpasses on HSR lines.

Between urban areas and in smaller cities and villages there are still a substantial number of grade crossings remaining in the Corridor. Furthermore, in agricultural areas, the railway RoW often bisects farm properties and farmers have the right to cross the track with their farm equipment. These grade crossings are incompatible with the intended HSR operation. For the purpose of cost estimation, it was assumed that all public highways would be grade separated and that all private roads and farm crossings would be replaced by grade separations.

2.2.5.4 Fencing the HSR Tracks

Most high-speed lines are segregated from adjacent areas, for safety and security. Except in tunnels or on long bridges continuous fences should be erected to prevent trespassing.

Regardless of whether the line should be fenced or not, grade crossings should be strictly forbidden. The selection of the best method may require further analysis and would be carried out at the conceptual design stage. For the purpose of cost estimation in the present study, it was assumed that the whole route would be fenced.

2.2.5.5 Security

Most HSR systems (and passenger railway services in general) provide open, uncontrolled access to their passengers, although HSR passengers riding through the Channel Tunnel connecting France and the UK have to undergo airport-like security at their departure station.

Setting up such security controls for a high-speed system would increase travel times and therefore reduce the advantages against other transportation modes. Also, it is nearly impossible to seal surface transportation systems like railways, including local and long distance passenger and freight services.

Following worldwide practice, no airport-like security controls would be necessary for the Québec City – Windsor Corridor. Due to the importance of this issue, a final decision, which is highly dependent on the development of potential hazards and prevention technologies should be made at the conceptual design stage.

2.2.6 Geometric Requirements

HSR has specific geometric requirements. Some of them, such as maximum grade, influence the amount of power installed in the trains. Others, such as minimum radii for horizontal curves, are for passenger comfort.

These geometric requirements influence the choice of an alignment. Representative routes selected for the present study comply with appropriate geometric requirements for each level of maximum operating speeds.

These requirements were used to estimate the associated costs and identify the potential environmental impacts.

2.3 Corridor Constraints and Requirements

The length and geographic location of the Quebec City - Windsor corridor impose certain constraints and requirements on HSR technology. These constraints and requirements involve travel distances in the Corridor, winter operation of HSR, and existing railway infrastructure and equipment.

2.3.1 Distances

The 1200 km distance between Quebec City and Windsor is too long for HSR to provide competitive travel times with other intercity modes, and thus ensuring a successful operation. However, the majority of intercity travel in the Corridor would be over shorter distances. Based on the data from the QOHSRPS, major travel markets were, in descending order of 1992 all-mode one-way trips (with the corresponding distance):

- Toronto-Kitchener (100 km);
- Quebec City-Montreal (260 km);
- Toronto-London (195 km);
- Montreal-Ottawa (195 km);
- Montreal-Toronto (550 km);
- Ottawa-Toronto (400 km).

The ridership forecasts estimated in the present study have come up with the same ranking as the 1995 study.

The HSR could provide a competitive service on the required distances, except for the Toronto-Kitchener leg, due to its short length. This has been proven in all countries where HSR is operated on comparable routes.

2.3.2 Winter Operation

Operation of HSR technology under winter conditions has been an issue ever since the first studies of HSR in the Quebec City – Windsor Corridor were conducted. At the time of the QOHSRPS, substantial HSR operational experience was limited to Japan and France, on lines built under relatively mild climates. The situation is different now. Sweden and Finland, where winter conditions show similarities to winter conditions in Eastern Canada in terms of snow accumulation and temperature, have been operating 200+ km/h[15] electric trains for many years. South Korea, with an average temperature of minus 6°C in winter and lows to minus

[15] Speed limitations are due to obsolete signalling systems, not infrastructure or rolling stock.

15^{0}C, operates HSR at 300 km/h and the HSR line from Moscow to St. Petersburg is being upgraded to accommodate a maximum speed of 250 km/h and eventually 300 km/h.

Considerable research, development, and experience have accumulated regarding HSR operation under winter conditions. The design and engineering of the Quebec City-Windsor HSR would benefit from the results of such expertise and winter operation is not expected to be a major problem in the Corridor. At the conceptual design stage, specific weather conditions such as low temperatures and high accumulation of snow would be examined with a view to minimize their impacts on the operation of the HSR.

2.3.2.1 Problems Caused to Infrastructure and their Solutions

Several problems may be observed on the track and infrastructure by extreme climatic conditions, including frost in subsoil, breakdown of turnouts, and ice or ballast thrown on platforms and snow accumulation. Winter operation might pose some challenges in the peculiar St. Lawrence valley weather.

Measures to support sufficient snow clearing include:

- providing sufficient stocking space for snow removed from the track at stations and along the line;
- heating platforms;
- operating additional train runs in time periods without regular service to avoid snow build up on the tracks; and
- installing snow fences at locations with a high risk of snow drifts.

In order to avoid the possibility of frost damage to the sub-grade, an adequate frost protection of the track structure, including an effective drainage system, would be provided.

Measures to minimize breakdowns of switches due to the snow accumulation include:

- electrical heating of all switches;
- brushing;
- snow fences and sheds; and
- rubber or brush spoilers mounted outside the rails.

To avoid parts of the switch mechanism from freezing, the casings of the switch motors should be properly sealed against intrusion of water and snow. Effective drainage of the point machines and the switch rod area is essential to avoid ice build- up. The quickest manner in which to clear a switch blocked by ice and snow is to remove the obstruction manually.

Ice on the track could be thrown up on the platforms by passing trains and may harm passengers waiting for their train. The problem may be dealt with through the following actions:

- preventing trains from accumulating snow by sealing the trainset underfloor;
- decreasing the train speed prior to entering the platform area;
- in stations, building platform tracks on each side of high speed tracks.

2.3.2.2 Ballast Pickup

Ballast pickup also called "flying ballast" refers to the uncontrolled movement of single ballast stones. This dangerous condition is caused by ice particles falling from the train or ballast stones lifted by the aerodynamic impacts of a train travelling at high speed. Ballast pickup could be reduced by the following measures:

- lowering the ballast level between the ties by 3 to 6 cm,
- optimizing aerodynamic characteristics of trainsets,
- use of ballast covering,
- use of ballast-less track.

2.3.2.3 Problems Caused to Power Systems and their Solutions

The major problems that could affect the performance of HSR's electrified power system during wintertime in the Corridor are related to the failure of high voltage electric transmission lines, the failure of one or several power sub-stations feeding the HSR line, and/or the overhead contact wire being covered with ice or sleet on some portion of the line.

To prevent such problems or limit their impact, the design should be based on a systematic requirement that the HSR service could be operated even in case of a double failure in the feeding network, as well as in the power distribution and substation power installation.

In winter operation, it is common practice to heat the contact wire (at night when there is less traffic) at certain locations to prevent the build-up of heavy frost or ice. Under special conditions, the traction power substations may heat the catenary system.

To reduce and prevent ice accumulation, it would be possible to operate trains during the night as traction current and the pantograph's mechanical movements prevent the formation of ice. Electrification would contribute to resolving winter problems in other parts of the system such as switches and control systems, while pre-heating parked trains would be another viable prevention measure that could improve customer satisfaction by the same token.

There is considerable expertise in Canada regarding the transportation and distribution of electricity under severe climatic conditions and the problems they can cause. This expertise would be put to use when designing the HSR electric power supply and distribution system.

2.3.2.4 *Problems Caused to Signalling Systems and their Solutions*

If a radio-based cab signalling system such as the representative ERTMS was chosen for the HSR application, new trackside signalling would not be required [16]. Only robust installations should be used, for instance, rail bonds, connectors, transponders and possibly axle counters. These installations are known to work very reliably under winter conditions and are sealed and duly protected against snow, ice and very low temperatures.

2.3.2.5 *Major Measures for the Corridor*

Expenses for the following weather protecting measures have been considered in evaluating capital cost as well as O&M costs:

- Maintenance bases (19 altogether) along the line, all near stations or crossovers
- Sufficient snow blowers and other maintenance and repair equipment at the maintenance bases
- Personnel available on a permanent or stand-by basis
- Switch heaters for all switches (including in yards and near maintenance shops and bases)
- Additional train runs to remove ice from catenary
- Snow and wind warning system

Those solutions would be included as requirements in the procurement specifications of the trainsets and other railway systems. As a last resort, the speed of trains could be reduced under very adverse weather as all train service would be adversely affected by side winds and winter conditions. Although unpopular, speed restrictions are a common measure in railway operation. The need for more information on topographical and meteorological information and for additional measures would be investigated at the conceptual design stage

[16] Existing trackside signals would need to remain in place where HSR tracks would be shared with freight trains or commuter trains.

2.3.3 Existing Railway Infrastructure and Equipment

2.3.3.1 Network

The railway network in the Corridor is fairly well developed. The major city pairs are linked by at least one, most often two and sometimes three relatively direct rail routes.

2.3.3.2 Right of Way Ownership

Most railway RoW in Quebec and Ontario are owned by private railway operators, namely, Canadian National (CN), Canadian Pacific (CP), Quebec and Gatineau Railway (QGR), with few segments owned by publicly owned railway operators VIA Rail and GO Transit. When VIA Rail and commuter rail operators in Montreal and Toronto use any of these private lines, they must pay running rights and access fees to the railway owners. Unless there is a change in the RoW ownership, a similar situation would apply to HSR in the Quebec City – Windsor Corridor if it were to use shared tracks or travel in a RoW owned by a third party.

2.3.3.3 Right of Way Width

The existing railway rights of way are generally 30 m wide (actually, 100 feet) and there is often only one track for most of their length. It would appear possible to locate new exclusive track inside the existing RoW at many locations. This would be advantageous particularly in urban areas where land acquisition would be cost-prohibitive due to existing development. This should be verified carefully at the conceptual design stage.

2.3.3.4 Geometry

Most of the existing Corridor rail lines were designed at a time when high speeds were not a major concern for railways and providing low grades (in the order of one percent) was a more important consideration in terms of operating costs. Since these lines have been used mainly for freight traffic over the last fifty years or so, it was not considered important to improve their geometry as part of the maintenance and upgrades carried out over the years. As a result, there are numerous curves along those routes, which would not allow high speeds. This was investigated as part of routing and alignment. Vertical curves are less of a problem, since there are no mountains and very few major hills to climb as most of the line lies in the St. Lawrence River valley or in the Great Lakes plain.

2.3.3.5 Urban Areas

Existing rail lines were built to serve cities through their central business districts (CBD). In addition, small and medium-sized cities and villages grew up around the areas where the train stopped. As a result, existing lines often intersect the centre of numerous small towns and villages. This issue was also investigated as part of routing and alignment.

2.3.3.6 Mount Royal Tunnel in Montreal

Mount Royal tunnel was opened to commuter rail traffic in 1918. At the time, the electric traction current was 2400V DC. Major rehabilitation works in the mid 1990's modified the traction current to 25kV AC. When assessing the extent of the modernization program, a study was commissioned to evaluate the costs of installing a ventilation system in the tunnel to accommodate diesel powered locomotives: the cost proved prohibitive, hence the decision to keep the electric traction current on the Deux-Montagnes commuter line.

The ventilation of the tunnel was again addressed in 2007 when the AMT launched the studies for the Train de l'Est new commuter rail line to Repentigny and Mascouche. One of the conclusions of the studies was that it would be much cheaper to buy dual-mode locomotives – diesel powered and electric powered – than to install a ventilation system.

Any representative system that would use the Mount Royal tunnel would need to be equipped with dual-mode locomotives in the case the total system was not electrified.

2.3.3.7 Signalling on Shared Track

Most rail lines of interest in the Corridor are equipped with visual signals that are not adequate for HSR operation. These systems are fitted with more complex equipment in areas of high traffic, such as near major stations. Conventional trains travelling on these dense lines, such as commuter trains, are already equipped with improved signalling equipment. When sharing tracks with HSR trainsets, commuter trains should be equipped with on-board equipment to respond to the HSR signalling system. The cost of retrofitting commuter trains to run on HSR shared tracks have been explicitly factored in the capital costs of the project.

2.4 Representative Technologies Retained for Analysis

Table 2-2 presents the essential features of the two representative technologies used for analysis. During conceptual design and preliminary and detailed engineering, further studies would be needed to optimize these features and detailed specifications should be developed and issued with calls for tenders to the various firms that could provide the required equipment and expertise.

These two representative technologies correspond to the lower and upper boundaries of current HSR operation and most other technologies can fit between these boundaries. Information for intermediate technologies, i.e. for speeds between 200 and 300 km/h, can be estimated by interpolating between the boundaries.

Table 2-2: Features of Representative Technologies Retained

	F200+	E300+
Trainset		
Configuration	Bi-Directional Trainset	Bi-Directional Trainset
Maximum Operating Speed (km/h)	200	300
Passenger Capacity	400	400
Approximate length (m)	200	200
Number of cars, if single	6 or 7	6 or 7
Number of cars, if articulated	8 or 9	8 or 9
Floor Height	Platform Level	Platform Level
Installed Power (kW)	4000	8000
Motor Configuration	Power cars at the end	Power cars at the end
Auxiliary Power Unit	Not needed	Installed
Track		
Continuous welded rail	Throughout	Throughout
Ties	Concrete	Concrete
Ballast track	50 % by length	50 % by length
Slab track	50 % by length	50 % by length
Energy		
Source	Regular Diesel Fuel	Electricity
Supply	Diesel vendors	Public power grid
Distribution	Refuelling at some stations	Overhead catenary
Signalling		
Cab Signalling	Required due to speed	Required due to speed
Automatic Train Control	Required for safety	Required for safety
Representative Signalling System	ERTMS Level 2	ERTMS Level 2
System Protection		
Sharing Track	Possible – all trains equipped with ERTMS Level 2	Possible – all trains equipped with ERTMS Level 2
Sharing Right Of Way	Possible with protection	Possible with protection
Road Grade Crossings	Should be grade-separated	Should be grade-separated
Rail Grade Crossings	Should be grade-separated	Should be grade-separated
Geometric Requirements		
Maximum Grade	3.5 %	3.5 %
Recommended Curve Radius (m)	4,500	8,500
Minimum Curve Radius (m)	2,500	6,000

2.5 Comparison with the QOHSRPS

In terms of technology, the QOHSRPS had similarly retained two representative technologies, one for a 200 km/h system and one for a 300 km/h system, as summarized by the following extract from its final report:

"The representative technologies were chosen to provide operating plans and system costs based on actual data. The representative technology for the 300 km/h system was the TGV Atlantique as produced by GEC-Alsthom. For the 200 km/h system, the X-2000 technology produced by ABB was chosen. "

Today there are a large number of compatible HSR technologies, available from several manufacturers worldwide. Hence it did not seem necessary at this time to specify precise types and/or name specific trainsets and systems. This is why the representative technologies retained in the present study are generic and described by their functional specifications only. They may be considered as modern versions of those retained by the QOHSRPS, to facilitate comparisons.

3 REPRESENTATIVE ROUTES AND REPRESENTATIVE STATIONS

This section is a summary of the technical report for Deliverable 5, Representative Routing Options. It presents the key representative routes[17] retained for analysis and their key components and explains how they were selected.

3.1 Strategic Guideline

As was the case for technologies, representative routes and representative stations were chosen to define the alignments, calculate travel times, estimate ridership, and evaluate the costs of a representative route for each representative technology.

According to the QOHSRPS, a representative route was defined as a route or alignment that was selected for analysis because it contained physical design attributes consistent with the technical criteria, provided opportunities for locating stations in reasonable proximity to the market and represented a potentially cost effective and environmentally acceptable solution. As quoted in the QOHSRPS report: "Such routes do not represent the overall best alignment, nor necessarily the possible preferred alignment, but provide a reasonably representative range of costs given the topographic, technological, environmental and political constraints."

Early in the present study, a strategic decision was made, with the approval of the Technical Committee, that the search for updated representative routes would answer the following question: "Since 1995 have there been any policy, land or other developments along those routes of such importance that the representative routes retained by the QOHSRPS would now have to be updated, adjusted, or even changed, and if so, where?"

In cases where the QOHSRPS representative routes needed to be modified or replaced, the following criteria were used for defining a new updated representative route among the possible alternatives:

- Technical feasibility: the possibility to develop an alignment with the appropriate geometric characteristics
- Quality of service: preference was given to updated representative routes allowing shorter travel times along the transportation corridor considered
- Construction cost: preference was given to updated representative routes resulting in lower capital costs
- Environmental impact: preference was given to updated representative routes creating fewer and less objectionable impacts on the natural and social environments.

[17] The term Route, as used in this report, refers to a transportation corridor that links a number of given cities. For instance, the route Z goes from A to B using an existing abandoned railway right of way.

3.2 Changes Potentially Requiring Route Updates

This section reviews changes in legislation, land use, and transportation services that could require modifying the QOHSRPS composite representative routes.

The objective of this analysis was to identify modifications to the QOHSRPS representative routes that were required due to external changes. It was not to inventory, identify, and evaluate all the changes in policy, land development, rail traffic, airport access, and other factors, that took place from 1995 to 2009. Nor was it to attempt to forecast what development might take place in the forthcoming years beyond 2009.

3.2.1 Changes in Environmental Legislation

Federal, Quebec, and Ontario environmental legislation applicable to the HSR project that was enacted or amended since 1995 was reviewed in detail (see Section 8, Environmental and Social Impacts). At the level of detail of the present study, it was found that the new legislative requirements do not necessitate changes to the QOHSRPS representative routes.

3.2.2 Changes in Rail Transport Legislation

Federal, Quebec, and Ontario railway legislation applicable to the HSR project and that was enacted or amended since 1995 was reviewed in detail (see Section 8). At the level of detail of the present study, it was found that the new legislative requirements would not require a change in the QOHSRPS representative routes.

3.2.3 Changes in Land Use

A detailed analysis of the QOHSRPS composite representative routes was performed from Quebec City to Windsor. This was done using the Google Earth© software that provided access to very recent aerial photos, as well as the most up to date topographical maps. Working on a segment-by-segment basis, the QOHSRPS representative routes were literally "walked" from Quebec City to Windsor.

By comparing the present land use along the routes to the land use appearing on the 1:20,000 working (unedited) maps used for the QOHSRPS alignments, it was possible to identify the significant changes in land use and development that have taken place since 1995.

Some of these changes required local adjustments to the QOHSRPS representative routes. Future changes in land development should be taken into account at the conceptual design stage.

3.2.4 Changes in Rail Traffic

3.2.4.1 *VIA Rail Intercity Passenger Traffic*

Strictly for the purposes of defining updated representative routes, and with the concurrence of the Steering Committee, it was assumed that the existing VIA Rail services in the Corridor would be replaced by the HSR services. Consequently, changes in these services since 1995 have no impact on defining updated representative routing options. This would not prevent VIA Rail to share tracks with HSR for regional services, since there would be spare capacity in the whole corridor. This should be further investigated at the conceptual design stage.

3.2.4.2 *Freight Rail Traffic*

Increases in freight rail traffic (8.7 percent from 1998 to 2007 overall in Canada, as per the Rail Association of Canada, 2008) do not result in a need to make major adjustments to the QOHSRPS representative routes. Changes in rail traffic impacting specific segments of the routes were reviewed.

3.2.4.3 *Commuter Rail Traffic in Montréal and in Toronto*

The expansion of commuter rail services in the Greater Montreal area since completion of the 1995 study was significant. Currently the Montreal Metropolitan transport agency (Agence métropolitaine de transport AMT) operates two commuter services with their terminal at Central Station: Mont-Saint-Hilaire and Deux-Montagnes; the latter accesses Central Station through the Mount Royal Tunnel. There are plans to divert the existing Saint-Jérôme commuter line through the Mount Royal tunnel, build a new line towards Mascouche (the future Train de l'Est) which would also use the Tunnel, and add rail access to Montréal-Trudeau Airport from Central Station. This station is also used by VIA Rail and Amtrak as their Montréal main terminal, as it was in 1995.

The expansion of the GO Transit commuter rail services in the Greater Toronto area since completion of the 1995 study was also significant. Currently GO Transit provides services to the towns of Hamilton, Milton, Georgetown, Barrie, Richmond Hill, Stouffville, and Oshawa. All these services have their terminal at Union Station. Not only are many of the GO Transit service corridors reaching capacity, but Union Station itself, also used as the Toronto terminal for VIA Rail and Amtrak, currently operates at or near capacity.

3.2.5 Changes in Airports and Airport Access

Changes in airports and airport access since the QOHSRPS have been taken into consideration. Specifically:

- In Montreal, a rail access link to Montreal-Trudeau Airport is being actively planned and evaluated.
- Mirabel airport is no longer used for commercial passenger flights.

- In Toronto, a rail access link to Toronto-Pearson Airport is being tendered for design, construction and finance under the name Air Rail Link (ARL).

These changes have important implications for defining updated representative routes, as there is no longer a need for providing direct HSR service to Mirabel and Pearson airports.

3.3 Stations as Bases for Routes

3.3.1 Cities with HSR Stations

Based on the QOHSRPS list of cities served by HSR and confirmed by route analysis and demand forecasting in the present study, the following cities would be served by the updated representative routes:

- Quebec City, with a main station at Gare du Palais and a new suburban station
- Trois-Rivières (new station)
- Montreal, with a main station at Central Station and new suburban stations north and west of downtown
- Ottawa, with a main station at the existing VIA Rail station
- Kingston (new station)
- Toronto, with a main station at Union Station and new suburban stations east and west of downtown
- London (new station)
- Windsor (new station)

The above list implies that the following stations listed in the QOHSRPS would no longer be required:

- Mirabel, on the QOHSRPS 300 km/h route, since the airport is no longer used for commercial flights
- East Pickering, on the QOHSRPS 200 km/h route, since this is no longer considered a site for a major airport
- Kitchener-Waterloo, served by the QOHSRPS 200 km/h route, as experience with HSR has shown that it cannot provide competitive service given the short distance from Toronto (100 km). Moreover, starting in 2011 GO Transit would offer commuter rail service to the Kitchener-Waterloo area.

3.3.2 Guidelines for Station Location and Design

3.3.2.1 Space Requirements

For locating and designing stations, including renovating existing stations as required, the following should be taken into consideration:

- For railways: the number and length of platforms required and the number of train storage tracks adjacent to the station if any.
- For cities: the integration of the HSR stations with other transportation modes (both existing and planned) such as connections to urban and regional transit/bus services and their connection through access ramps and other means to the surrounding road network, as well as their relationship with other relevant transportation and land use plans for the area in which it is to be located.
- For passengers: the number, size, and spatial organization of access to platforms, links to other modes including interconnecting bus bays or platforms, ticket counters, service areas including washrooms, waiting rooms, pedestrian walkways and access, parking spaces etc., and their integration into an appropriate building design that could be built alone or as part of a larger multi-function building.

3.3.2.2 Transit and Auto Accessibility

In proposing a potential station along a representative route, it was assumed that the envisioned approximate location was free of major constraints, provides a reasonable degree of accessibility (by local or regional transit and by automobile) and was expected to have a construction cost that would be representative for such a facility. Construction cost estimates developed in technical report for Deliverable 6.1, Capital Costs were consistent with such assumptions.

3.3.2.3 Main Stations

There should be a main station in each of the major cities, Montreal, Ottawa and Toronto. This station would be the preferred HSR station for passengers arriving in that city, as their destination would often be a place of business or visit in or near the central business district (CBD), where the main station would preferably be located.

The assumption that HSR service would replace most of the current VIA Rail services in the Corridor has major implications for the future use of tracks at Central Station in Montreal and Union Station in Toronto. At the present time, VIA Rail and Amtrak use 8 tracks in Montreal and 6 in Toronto. In both cases HSR service would require two tracks and two platforms. The other tracks could be used by VIA Rail non-Corridor or by commuter services, with extra capacity available for future increase in non-corridor traffic.

3.3.2.4 Suburban Stations

Depending on the location of the central station in major cities, there should be one or two suburban stations in major cities. This would be the preferred HSR station for trips originating in that city, as a suburban station would likely be more easily accessible to a high proportion of departing passengers leaving their home, rarely located in or near the CBD. These stations should provide many of the same amenities and have the same characteristics as the main stations. In addition the suburban stations would most likely have more passengers arriving by automobile and therefore require convenient drop-off facilities and parking. The interest of suburban stations is already recognized by VIA Rail, which currently operates them in Quebec City (Sainte-Foy), Montreal (Saint-Lambert and Dorval), Ottawa (Barrhaven) and Toronto (Oshawa and Aldershot), with the Toronto-Montreal service even starting at a suburban station (Aldershot) west of central Toronto.

3.3.2.5 Connection to Urban and Regional Transit

In the QOHSRPS, several potential HSR stations coincided with existing railway stations: Gare du Palais in Quebec City, Central Station in Montreal, VIA Rail Station in Ottawa, and Union Station in Toronto. Due to their location and existing function, these candidate HSR stations enjoy a high degree of connectivity with existing urban and regional transit services. Potential new stations were also conceptually located so as to enjoy a good degree of connectivity with urban and regional transit. In the present study, it was verified whether these stations were still potentially suitable for HSR and would still provide a high degree of local and regional transit connectivity.

3.3.2.6 Connection to Freeway and Highway Networks

In the QOHSRPS, most of the proposed new candidate HSR stations were suburban stations. They were located so as to be easily accessible by automobile, using the existing highway networks. In the present study, it was verified whether these potential stations were still potentially suitable for HSR and would still provide a high degree of connectivity with the major road networks.

3.3.2.7 Detailed Location and Design Decisions

Detailed aspects of station location and design were beyond the scope of the present study. These would be taken into consideration when designing the HSR system, including the transportation and other plans and projects that could be underway at that time.

3.3.2.8 Connections to Airports

In the Corridor, Montreal-Trudeau and Toronto-Pearson airports offer a broader range of international flights than other airports. Consequently, Quebec residents living east of Montreal and Ontario residents living east of Ottawa would probably board their international flights at Montreal-Trudeau Airport and might wish to use HSR from Trois-Rivières, Quebec City, or Ottawa to travel to Montreal and use the airport shuttle. Similarly, Ontario residents living west of Kingston and west of Toronto would probably board their international flights at Toronto-Pearson Airport and might wish to use HSR from Kingston or from London to travel to Toronto and use the airport shuttle. This issue was addressed in establishing representative routes.

3.4 Description of Updated Representative Routes

The updated representative routes that were developed in the present study were not recommended routes, but rather a necessary instrument for use in a feasibility analysis.

The actual design would start with a route selection and conceptual design phase, followed by a preliminary engineering phase. Any definitive route and alignment choices would then be made based on a more detailed analysis of the precise physical conditions (topography, geology, and hydrology) taking into account land use, transportation networks and services, environmental constraints, legislation and regulations, and other relevant conditions, constraints, and requirements prevailing at the time the system would be designed.

The updated representative routes and representative stations are illustrated in Figure 3-1 and their main characteristics are summarized in Table 3-1; they are described segment by segment in Chapters 5 to 10 of the technical report for Deliverable 5, Representative Routing Options, and illustrated in the detailed maps that accompany that report.

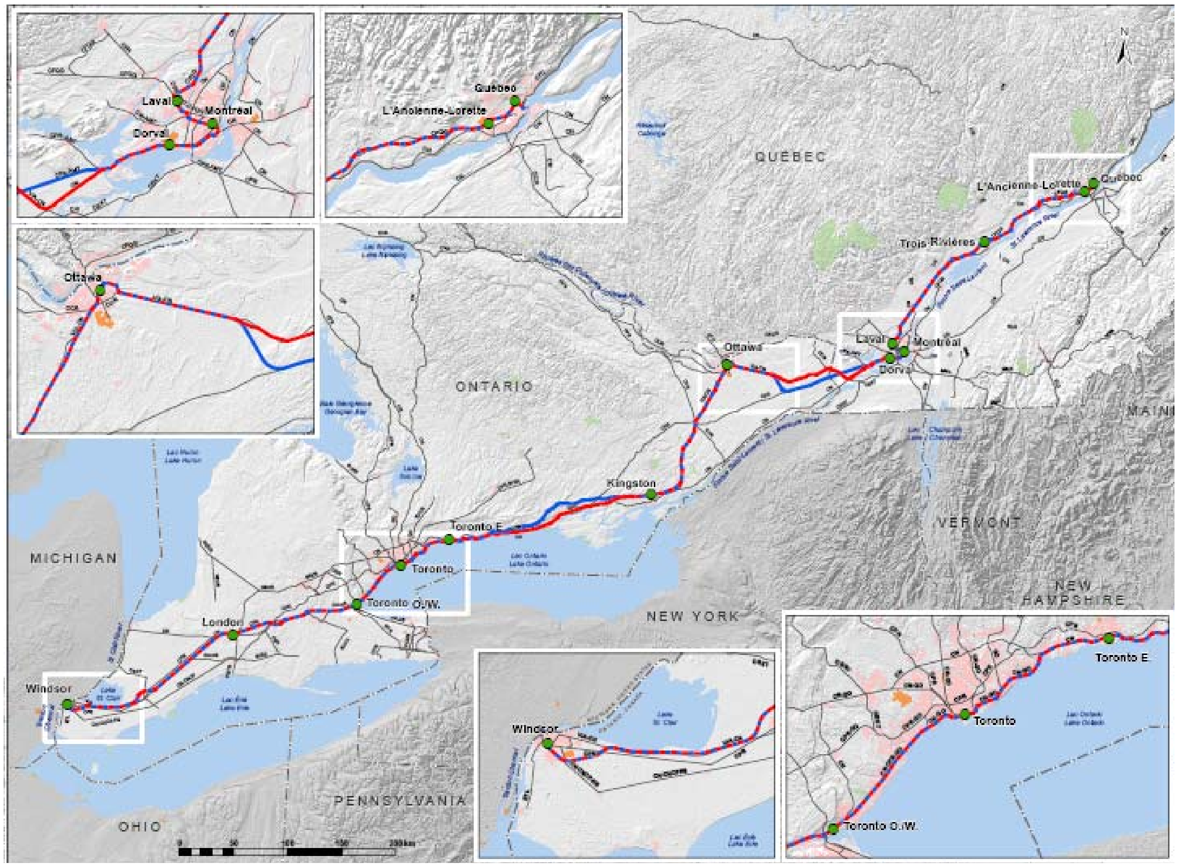


FIGURE 3-1: REPRESENTATIVE ROUTES AND REPRESENTATIVE STATIONS BETWEEN QUEBEC CITY AND WINDSOR

Table 3-1: Highlights of Representative Routes Retained

	F200+	E300+
Québec City, existing Gare du Palais		
	Within existing CN and CP RoW	
Québec City, L'Ancienne Lorette new station		
	Mainly alongside the QGR RoW, with local adjustments for curves	
	Approximately 15 km new greenfield RoW to bypass the centre of Trois-Rivières	
Trois-Rivières, new station		
	Continuation of the Trois-Rivières bypass	
	Mainly alongside the QGR RoW, with local adjustments for curves	
Montréal, Laval new station		
	Within CN and CP RoW to access Central Station via Mount Royal tunnel	
Montréal, existing Central Station		
	Within existing CN RoW	

<table>
<tr><th></th><th>F200+</th><th>E300+</th></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td colspan="3">Montréal, Dorval new station</td></tr>
<tr><td rowspan="4"></td><td colspan="2">Within CN RoW to Dorion</td></tr>
<tr><td>Alongside the CN RoW to Coteau</td><td>Alongside CP RoW to Avonmore</td></tr>
<tr><td rowspan="2">Within the acquired VIA Rail RoW to Ottawa, with many local adjustments for curves</td><td>New RoW between Avonmore and Casselman</td></tr>
<tr><td>Within the acquired VIA Rail RoW to Ottawa</td></tr>
<tr><td colspan="3">Ottawa, existing VIA Rail Station</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Alongside the VIA Rail and CN RoW to Smiths Falls, with local adjustments for curves</td></tr>
<tr><td colspan="2">New greenfield RoW to Kingston</td></tr>
<tr><td colspan="3">Kingston, new station</td></tr>
<tr><td rowspan="2"></td><td>New greenfield RoW to Napanee</td><td>New greenfield RoW to Cobourg</td></tr>
<tr><td colspan="2">Alongside and within the CN RoW, with local adjustments for curves to Toronto East</td></tr>
<tr><td colspan="3">Toronto, new East Suburban Station (in the vicinity of Oshawa)</td></tr>
<tr><td></td><td colspan="2">Within existing CN RoW</td></tr>
<tr><td colspan="3">Toronto, existing Union Station</td></tr>
<tr><td></td><td colspan="2">Within existing CN RoW</td></tr>
<tr><td colspan="3">Toronto, new West Suburban Station (in the vicinity of Hamilton)</td></tr>
<tr><td rowspan="4"></td><td colspan="2">Alongside or within CN RoW to Woodstock, local adjustments for curves and a new RoW bypass of Paris</td></tr>
<tr><td colspan="2">20 km new greenfield RoW to bypass Woodstock</td></tr>
<tr><td colspan="2">Alongside or within the CP RoW between the Woodstock and London bypasses</td></tr>
<tr><td colspan="2">20 km new RoW to bypass central London</td></tr>
<tr><td colspan="3">London, new station</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Continuation of the London bypass to Longwood</td></tr>
<tr><td colspan="2">Alongside or within the CN RoW, with local adjustments for curves and a new RoW bypass of Chatham</td></tr>
<tr><td colspan="3">Windsor, new station</td></tr>
</table>

3.5 Comparison with the QOHSRPS

Overall, the updated representative routes retained in the present study were not very different from the QOHSRPS composite representative routes. The major differences are as follows.

- From Quebec City to Trois-Rivières and from Trois-Rivières to Montreal Central Station there were only minor differences due to recent developments or to the revised minimal horizontal curve radius (2,500 m instead of 2,000 m for F200+).

- From Montreal to Ottawa, there were two major differences: (i) The QOHSRPS route for 200 km/h used the CP M&O subdivision. This route can no longer be used, since the right-of-way has been sold and is now reserved for recreational activities. (ii) The QOHSRPS route for 300 km/h through Mirabel has lost relevancy because that airport is no longer used for passenger flights; a variant of it also used the CP M&O subdivision, therefore the updated representative routes also differ from each other.
- From Ottawa to Toronto, the QOHSRPS routes for 200 km/h and 300 km/h were different. The updated F200+ route differs only slightly from the QOHSRPS route for 200 km/h. Similarly, the E300+ updated route differs only slightly from the QOHSRPS route for 300 km/h.
- From Toronto to London, there were major differences. From Union Station, both QOHSRPS routes used the CN Weston subdivision towards Pearson Airport, which they served, and followed a mainly green field route, essentially parallel to Highway 401, all the way to London. Given the planned Air Rail Link between Union Station and Pearson Airport, there is no need now for HSR to provide direct service to Pearson. Consequently, the updated routes follow mainly CN and CP RoW, with bypasses as needed.
- From London to Windsor, both QOHSRPS routes followed CP subdivisions, whereas both updated routes follow CN subdivisions. Also, the updated London station would be located southwest of the city rather than downtown.

4 REPRESENTATIVE SERVICE AND SYSTEM

A representative service was designed based on each of the two representative technologies and their respective routing, with the following service objectives:

- HSR would replace all VIA Rail services in the Corridor. VIA Rail could share tracks with HSR for regional services.
- HSR should provide, to its major markets, a service that would be truly competitive with other intercity travel modes within the Corridor
- The service offered should take into account the relevant experience of comparable successful modern HSR services in other countries.

4.1 Representative Service

4.1.1 Operating Programs

HSR service would be provided at all the stations identified above in Section 3.3.1, Cities to be served. The operating programs used for analysis were based on the following basic assumptions:

- HSR shuttle service operating on segments between major market cities, namely:
  - *between Quebec and Montreal;*
  - *between Montreal and Toronto, via Ottawa and Kingston; and*
  - *between Toronto and Windsor.*
- In general, there would be no through trains between these three operating segments. Passengers travelling over several segments would change trains at Montreal and/or Toronto, as needed. Train schedules would be timed so that transfers could be made in less than 15 minutes.
- In case of substantial variance of traffic loading within segments, additional trains could be scheduled to service operating segments with higher traffic loads.

In practice, a system operator would develop a more sophisticated timetable, including through trains serving more than one segment and/or skip-stop trains. Since the main purpose of this study was to develop representative train schedules for costing purposes, using the simplified service definition above was considered reasonable and appropriate.

4.1.2 Frequency and Capacity

To ensure the competitiveness of HSR, an average minimum frequency of 12 departures per day from every station was assumed at the start of the analysis. When updated ridership forecasts became available, this frequency was adjusted, as required to provide the necessary capacity. Table 7-5, Daily Trains per Direction (2025 – 2055) illustrates the revised frequencies. In actual operation, frequencies would vary between seasons and between days of the week to adjust to demand.

4.1.3 Travel Times

For the purpose of establishing a representative service for analysis, in-vehicle travel time was provisionally assumed to be equal to those of the QOHSRPS. After a detailed representative alignment for the representative routes was designed (as part of construction cost estimate updating), travel times were calculated by simulating the representative technologies travelling on these alignments.

4.1.4 Train Schedules

Train schedules were developed for estimating O&M costs and are discussed below in Section 7.1.2, The O&M Cost Model and its Structure.

4.1.5 On-Board and Other Passenger Services

Representative on-board services offered to HSR passengers would normally include:

- Meals served at the seat (as provided by airlines and VIA Rail) or in a dining car, depending on travel time, for first class passengers
- Snacks offered from a travelling cart for standard class passengers
- Internet connections at each seat
- Areas in each coach for storing self-carried luggage (no unaccompanied baggage on train).

Representative other services offered to HSR passengers would normally include:

- Reservation and ticket purchase by Internet, by telephone, and at departure stations
- Information services at all stations.

Resources required for these services were taken into account when estimating operating costs. The actual range of services offered would be optimized during the conceptual design stage and fine-tuned during operations, based on expressed or perceived rider needs and expectations.

4.2 Representative System

The representative operation and services to be offered were used to develop a representative system configuration which served as a basis for updating estimates for construction and other capital costs. These two systems are described below in Tables 4-1 and 4-2. These tables relate to the full Quebec City to Windsor HSR corridor. Details may be found in the technical report for Deliverable 6.1, Capital Costs.

Table 4-1: Elements of Representative Systems: Infrastructure

Elements	F200+	E300+
Route Length, km	1 222	1 228
Alongside Existing Right-of-Way, km	482	330
Within Existing Right-of-Way, km	379	321
Within New Right-of-Way, km	361	577
Earthworks and Drainage		
Embankments, thousand m³	13 500	21 300
Sub-ballast layer, km	1 100	1 080
Minor culverts, unit	4 800	4 450
Major culverts, unit	417	430
Storm water settlement pounds, unit	104	105
Retaining walls, km	8	15
Noise attenuation barriers, km	46	86
Bridges, Viaducts, and Tunnels		
River crossings < 30 m in length, m	257	174
River crossings 30-100 m in length, m	1 530	1 405
River crossings over 100 m in length, m	1 030	1 400
Modifications to existing bridges, m	3 654	1 871
Viaducts over 250 m in length, m	8 700	8 600
Double track tunnelling, m	0	1 200
Modification to existing tunnel (Mount-Royal)	1	1
Grade Separations (unit)		
Rural secondary highway crossing	409	451
Rural major highway crossing	11	17
Urban secondary highway crossing	32	30
Urban highway crossing over 4 lanes	9	8
Private farm crossing	486	526
Major wildlife passage	2	2
Other Accommodation Works		
Removal of rail lines, km	336	244
Access tracks, km	65	63
Rail/rail grade separation, unit	28	41
Stations		
Existing, to be modernized	Québec, Montréal, Ottawa, Toronto	Québec, Montréal, Ottawa, Toronto
New, to be built	L'Ancienne-Lorette, Trois-Rivières, Laval, Dorval, Kingston, Toronto East, Toronto West, London, Windsor	L'Ancienne-Lorette, Trois-Rivières, Laval, Dorval, Kingston, Toronto East, Toronto West, London, Windsor

Table 4-2: Elements of Representative Systems: Railway Equipment

Elements	F200+	E300+
Track		
New ballasted double track, km	610	613
New ballastless double track, km	605	608
High Speed Turnouts, unit	192	192
Low Speed Turnouts, unit	36	36
Energy		
Source	Diesel Fuel	Electricity
Refuelling Stations at yards, unit	5	
Power Supply Substations, unit		30
Catenary System, km of single track		2421
Signalling		
New Interlocking Stations, unit	9	9
Crossovers, unit	30	30
Line-km to be equipped with ERTMS	1211	1216
Operation Control Centre	1	1
Trainsets for 2025 (unit)		
Diesel-fuel	36	
Dual-mode	12	
Electric		46
Maintenance Facilities		
Shops	Montréal and Toronto VIA Rail facilities adapted	Montréal and Toronto VIA Rail facilities adapted
Yards	Québec, Montréal, Ottawa, Toronto, Windsor	Québec, Montréal, Ottawa, Toronto, Windsor
Information and Ticketing System		
	Equipment required for telephone, Internet, and counter information, reservations, and sales	Equipment required for telephone, Internet, and counter information, reservations, and sales

5 RIDERSHIP AND REVENUE

This section presents ridership and revenue forecasts, and the process used for developing them; it is thus a summary of Deliverable 7, Demand Forecasting technical report.

5.1 Process

The process of estimating the future ridership for HSR transport service consisted of the following steps shown in Figure 5-1:

1. Determine the total number of trips made in the corridor using existing modes of transportation. This represents the total travel market that might potentially choose to divert to HSR.
2. Estimate the share of the total market that would be captured by HSR given its fare structure, travel time and other service attributes, and those of competing modes.
3. Estimate the number of induced trips, i.e. trips made using HSR that would not be made otherwise if HSR was not available.

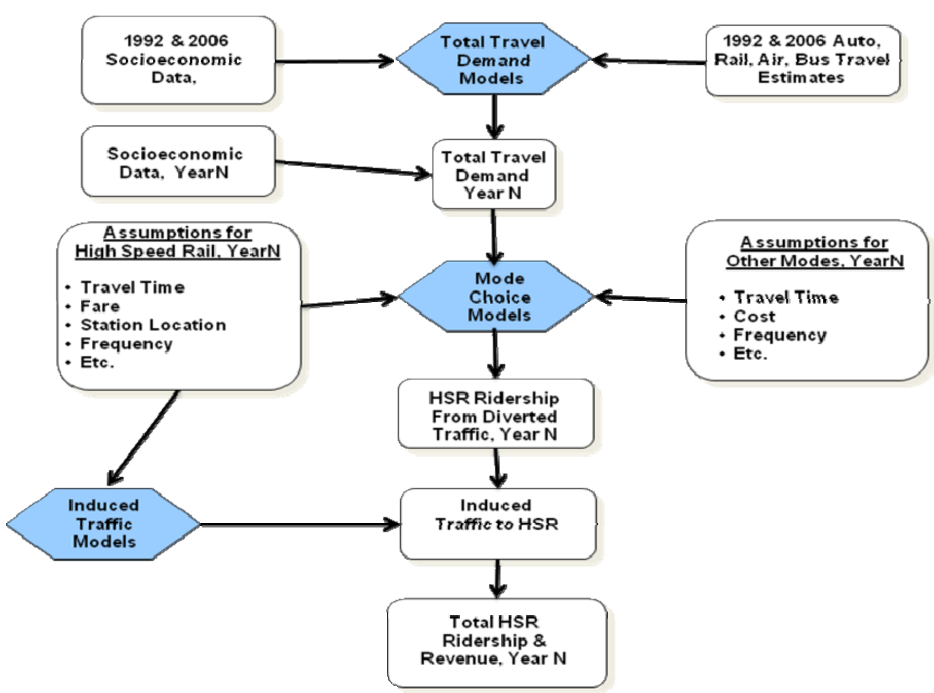


FIGURE 5-1: RIDERSHIP AND REVENUE FORECAST OVERVIEW

5.2 Geographic Markets

In this study, ridership forecasts were developed at a disaggregated geographic level (2,342 zones) but were summarized in this report by aggregate markets. The main geographic markets consisted of the seven major metropolitan areas in the corridor, namely: Québec City, Montréal, Ottawa, Kingston, Toronto, London, and Windsor.

It should be noted that the definition of these seven metropolitan areas has changed since the 1995 QOHSRPS (Census 1991 versus Census 2006 definition). Direct comparison between results shown in this report and the results shown in the QOHSRPS report may not be valid. While the 2001 Census definition was used to present results of this study, comparisons between the two studies shown in this report were done using the 1995 QOHSRPS definition since the 1995 data could not be “translated” to the more recent Census definition.

Results were also aggregated as follows:

- Primary (or Major) markets refer to 19 pairs of metropolitan areas (out of 49 possible pairs), which constitute the primary potential markets for HSR.
- Secondary (or Minor) markets, 35 of them, refer to trips with an origin (or destination) in one of the 7 metropolitan areas and destination (or origin) somewhere else. They were considered as being a potential market for HSR, despite a longer access or egress trip to HSR.
- Other markets refer to all other travel in the corridor. They were considered as less of a potential market for HSR

5.3 Existing (2006) Travel

To have a basis for forecasting ridership for HSR, it was first necessary to establish the volumes of passenger traffic in the Quebec-Windsor Corridor today or more exactly for a base year which was chosen as 2006 for data availability reasons.

5.3.1 Existing Travel by Public Transport Modes

5.3.1.1 Air Travel

Transport Canada provided 2006 total air travel data between groups of airports as defined in their Passenger Origin-Destination Model (PODM). There are 5 PODM in the Quebec City - Windsor corridor: Québec City, Montréal, Ottawa, Toronto, and London.

The 2006 PODM data was used to update the results of the 1995 QOHSRPS Origin Destination (OD) air survey on an airport to airport basis.

5.3.1.2 Rail Travel

Transport Canada provided station to station VIA Rail trips for 2006.

The same approach applied to air trips was used for rail trips. The 2006 station-to-station data was used to update the results of the 1995 QOHSRPS OD rail survey on a station to station basis.

5.3.1.3 Bus Travel

Transport Canada provided station-to-station OD bus trips for 2006, for the city pairs served by Greyhound and a summary of all bus trips for the Quebec City-Montreal route based on data provided by Orleans Express.

Again, the same approach was used for bus trips. The 2006 bus data was used to update the results of the 1995 QOHSRPS OD bus survey on a station to station basis or on a corridor basis depending on the data available.

Table 5-1 shows some of the characteristics of public mode travel in the corridor based on the methodology described above. It also shows how these characteristics have changed since the 1995 QOHSRPS.

Table 5-1: Summary of Public Mode Travel in the Quebec City - Windsor Corridor

	2006 Person Trips				
	Air*	VIA Rail	Bus	Total	Share
Person Trips by Purpose					
Business	2,198,000	908,000	618,000	3,724,000	38%
Non-Business	403,000	2,307,000	3,459,000	6,169,000	62%
Person Trips by Geographic Market					
Primary Market	2,191,000	2,035,000	2,213,000	6,439,000	35%
Secondary & Other Markets	410,000	1,180,000	1,865,000	3,455,000	35%
Total Public Mode Person Trips	2,601,000	3,215,000	4,078,000	9,894,000	100%

	1992 Person Trips				
	Air*	VIA Rail	Bus	Total	Share
Person Trips By Purpose					
Business	1,827,000	761,000	440,000	3,028,000	42%
Non-Business	341,000	1,796,000	2,122,000	4,259,000	58%
Person Trips by Geographic Market					
Primary Market	1,803,000	1,699,000	1,513,000	5,015,000	69%
Secondary & Other Markets	366,000	858,000	1,050,000	2,274,000	31%
Total Public Mode Person Trips	2,169,000	2,556,000	2,563,000	7,288,000	100%

	1992 to 2006 Person Trips Growth			
	Air*	VIA Rail	Bus	Total
Person Trips By Purpose				
Business	20%	19%	40%	23%
Non-Business	18%	28%	63%	45%
Person Trips by Geographic Market				
Primary Market	22%	20%	46%	28%
Secondary & Other Markets	12%	38%	78%	52%
Total Public Mode Person Trips	20%	26%	59%	36%

Sources : Transport Canada, 1995, QOHSRPS and EcoTrain calculations
* This table does not include connecting air traffic because it was not considered a potential market in this study.

Some general observations are:

- Overall travel by public transport mode has increased by 36 percent from 1992 to 2006.
- Bus travel has grown the most, 59 percent overall.
- Non-business trips have grown more than business trips overall and for VIA rail and bus modes but not for air where business trips grew more.
- The secondary and other markets which were less competitive for HSR have grown more than the primary market.

5.3.2 Existing (2006) Travel by Auto

Since the greater part of travel in the corridor was done by automobile (91 percent in 1992), EcoTrain considered it was essential to measure the current characteristics of auto travel with new surveys. For this reason, new License Plate (LP) surveys were conducted to update the QOHSRPS intercity car trip estimates. The new surveys were more limited than in the 1995 QOHSRPS (less stations, only one season) but it was compensated to some extent by using more strategic locations and some of the results of the 1992 LP surveys.

5.3.2.1 *License Plate Surveys*

Following discussion and approval from the Technical Committee, EcoTrain conducted LP surveys at six different locations in Quebec and in Ontario. At each location, license plate numbers were recorded in both directions on one week day and one weekend day, for a period of 12 hours each. A random sample of license plates was then selected for each survey station. The sample was sent to the Société d'assurance automobile du Québec (SAAQ) for Quebec license plates and to the Ministry of Transportation of Ontario (MTO) for Ontario license plates. SAAQ and MTO mailed a letter and a questionnaire with a return envelope to the vehicle owners.

EcoTrain had no involvement whatsoever in the matching of licence plate numbers with their owners. In addition, the questionnaire was designed so that no personal information – name, address, or license plate number – was needed or could be extracted from the returned questionnaires.

Overall, more than 11,000 valid surveys were returned, bringing the return rate to about 18 percent. The return rate for Quebec was nearly three times higher than for Ontario, 29 percent versus 11 percent (8,000 surveys for Quebec and 3,000 for Ontario).

The 11,000 valid surveys were expanded in several steps, similar to the QOHSRPS survey, to obtain auto traffic estimates for 2006 (using 2006 Average Annual Daily Traffic (AADT) provided by MTQ and MTO).

The resulting estimates of 2006 auto trips are summarized in Table 5-2, showing an overall increase of 19 percent over 1992 for the primary market. The reliability of the 1992 and 2006 estimates as well as the estimated increase was discussed in Deliverable 7 report.

Table 5-2: Summary of Auto Person Trips in the Quebec-Windsor Corridor

	1992	2006	1992-2006 Growth
Person Trips by Geographic Market			
Primary Market	21,897,000	26,136,000	19%
Secondary & Other Markets	77,096,000	56,729,815	*
Total Auto Person Trips	98,993,000	82,865,815	*

* Comparison is not valid as the 1995 QOHSRPS included large markets which were not included in this study (example: Toronto to Kitchener)

5.3.2.2 Auto Trips Characteristics

Given the substantial information obtained from the LP survey, it was possible to present specific characteristics of the LP survey respondents (not necessarily a representative cross–section of all travellers, as the respondent would usually be the driver).

Table 5-3: Characteristics of License Plate Survey Respondents

Week Day vs. Week End		Gender	
Week Day	62%	Male	62%
Week End	38%	Female	38%
Average Party size	2.6	Employed	72%
Type of Place Trip Began		**Type of Place Trip Ended**	
Private home	69%	Private home	61%
Place of Business	13%	Place of Business	13%
All Others	18%	All Others	26%
Household Income		**Age Group**	
Less than $50K	29%	Under 34 years old	18%
$50K to $75K	25%	35 to 49 years old	32%
$75K to $100K	22%	50 to 64 years old	36%
Greater than $100K	24%	65 years old or more	15%

5.3.3 Total 2006 Travel by Market Group

The 2006 base year corridor intercity trips by mode are summarized in Figures 5-2 and 5-3. As shown, the majority of trips were made by car. While 93 percent of trips were made by car in the secondary and other markets, a lower 82 percent of trips were made by car in the primary markets, as other options (air, rail and bus) were more available and convenient in the primary market than in the other markets. The secondary and other markets were nearly twice as big as the primary market.

Travel Mode	2006 Annual Trips (1,000) Primary Markets	
	Trips	Share
Auto	26,147	82%
Air	1,962	6%
VIA Rail	1,832	6%
Bus	2,018	6%
Total	31,959	100%

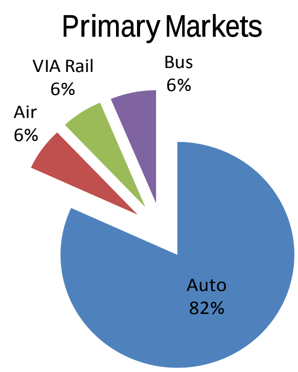


FIGURE 5-2: PRIMARY MARKETS. BASE YEAR (2006) TRIPS BY MODE

Travel Mode	2006 Annual Trips (1,000) Secondary & Other Markets	
	Trips	Share
Auto	56,719	93%
Air	620	1%
VIA Rail	1,383	2%
Bus	2,059	3%
Total	60,781	100%

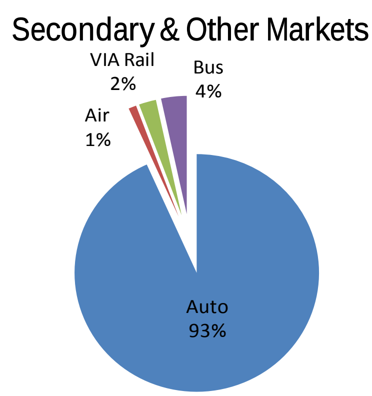


FIGURE 5-3: SECONDARY AND OTHER MARKETS, BASE YEAR (2006) TRIPS BY MODE

5.4 Travellers Mode Choice: Stated Preferences Surveys

EcoTrain designed and administered a Stated Preference (SP) survey that gathered information on travel preferences from individuals who were making or had made a trip in the Quebec City-Windsor Corridor.

5.4.1 Stated Preference Survey Administration

Respondents could take the survey in either English or French. Only those respondents who had made or were making a trip at least 80 kilometres long in the corridor completed the SP survey. The reported trip was used as the backbone of the survey. The SP survey instrument employed a computer-assisted self-interview technique. The survey instrument was customized for every respondent by presenting questions and modifying wording based on respondents' previous answers. These dynamic survey features provided an accurate and efficient means of data collection and allowed the survey to present realistic future conditions that corresponded with the respondents' reported travel experiences.

Administration of the survey instrument occurred over a seven-week period from June 17 to July 30, 2009. Potential respondents were intercepted at rail and bus stations in Toronto, Ottawa, Montréal, and Québec; as well as at activity sites such as convention centres and public libraries in the same cities. Potential respondents were also intercepted at the domestic departure gates at Montréal Trudeau International Airport. Finally, auto travellers who responded to the LP survey were invited to take the SP survey for the reported trip over the Internet.

A total of 2,479 respondents completed the SP questionnaire. Following a rigorous data cleaning, 1,702 of these SP questionnaires were used to estimate the mode choice models.

The survey included questions about current mode choice ("revealed preference"), as well as questions about the effects of possible change in mode choice in light of the potential new HSR service ("stated preferences").

5.4.2 Stated Preference Surveys Results

The primary mode of travel, according to the respondent's annual household income, is shown in Figure 5-4. Respondents travelling by air had higher incomes while respondents travelling by bus had lower incomes.

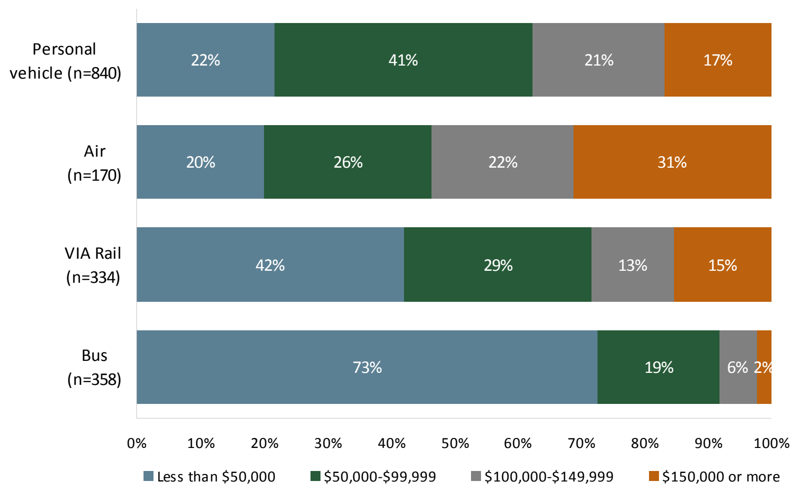


FIGURE 5-4: CURRENT PRIMARY TRAVEL MODE BY ANNUAL HOUSEHOLD INCOME

Each respondent who travelled by air, bus, or VIA Rail was asked how they travelled from their origin to the station or airport (access mode), and how they travelled from the station or airport to their final destination (egress mode). This information was important as it could influence the overall time and cost of a trip.

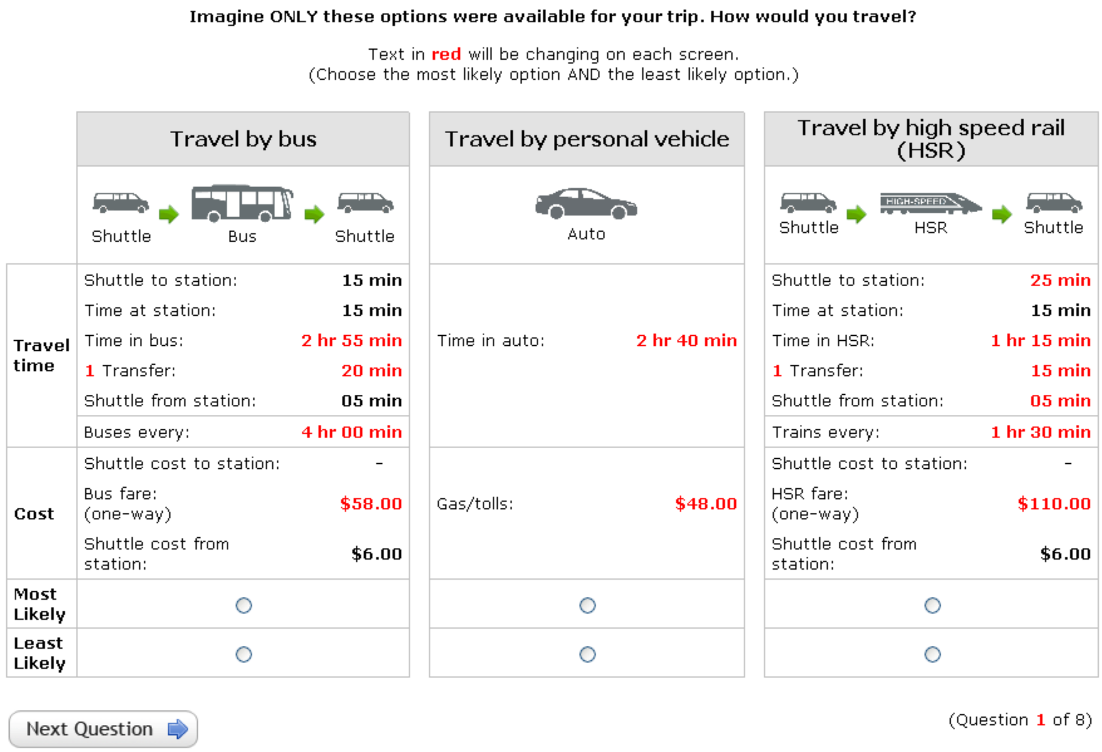
Business travellers were more likely to use a taxi/limo (27 percent) or drive and park their own vehicle (23 percent) as their access mode. Non-business travellers relied on the subway (25 percent) or being dropped off (21 percent) as their access mode to the airport, bus station, or train station.

Overall, respondents were most likely to be picked up (29 percent) or to take a taxi/limo (26 percent) at their destination. Almost half of business respondents (44 percent) used a taxi/limo to reach their destination from the airport, bus station, or train station, while non-business respondents were more likely to be picked up (35 percent) at their destination.

During the SP experiments, respondents were presented with three alternatives for making their trip in the future:

- Current travel mode
- Travel by the proposed HSR
- Travel by a third mode (auto, bus, VIA rail, or air – different than their current travel mode).

For each of the three alternatives, a set of attributes was shown describing the details of the trip for that travel mode. These trip details included attributes such as travel time, parking costs, and fare. Figure 5-5 contains an example of a stated preference experiment.



Imagine ONLY these options were available for your trip. How would you travel?

Text in **red** will be changing on each screen.
(Choose the most likely option AND the least likely option.)

	Travel by bus		Travel by personal vehicle		Travel by high speed rail (HSR)	
	Shuttle → Bus → Shuttle		Auto		Shuttle → HSR → Shuttle	
Travel time	Shuttle to station:	**15 min**	Time in auto:	**2 hr 40 min**	Shuttle to station:	**25 min**
	Time at station:	**15 min**			Time at station:	**15 min**
	Time in bus:	**2 hr 55 min**			Time in HSR:	**1 hr 15 min**
	1 Transfer:	**20 min**			1 Transfer:	**15 min**
	Shuttle from station:	**05 min**			Shuttle from station:	**05 min**
	Buses every:	**4 hr 00 min**			Trains every:	**1 hr 30 min**
Cost	Shuttle cost to station:	-	Gas/tolls:	**$48.00**	Shuttle cost to station:	-
	Bus fare: (one-way)	**$58.00**			HSR fare: (one-way)	**$110.00**
	Shuttle cost from station:	**$6.00**			Shuttle cost from station:	**$6.00**
Most Likely	○		○		○	
Least Likely	○		○		○	

Next Question

(Question 1 of 8)

FIGURE 5-5: EXAMPLE OF STATED PREFERENCE EXPERIMENT

Each respondent was presented with eight such experiments. Just over half (52 percent) of respondents selected the HSR option at least once. Of the 48 percent of respondents who never selected the HSR option, the primary reason was cost with 69 percent citing the fact that the HSR fare was too high. However, 84 percent of all respondents favour a HSR rail in the Quebec City – Windsor corridor (whether they chose a HSR alternative or not). A further 13 percent of respondents had a neutral opinion and 3 percent of respondents opposed a HSR in the Quebec – Windsor corridor. These results are shown in Figure 5-6 below.

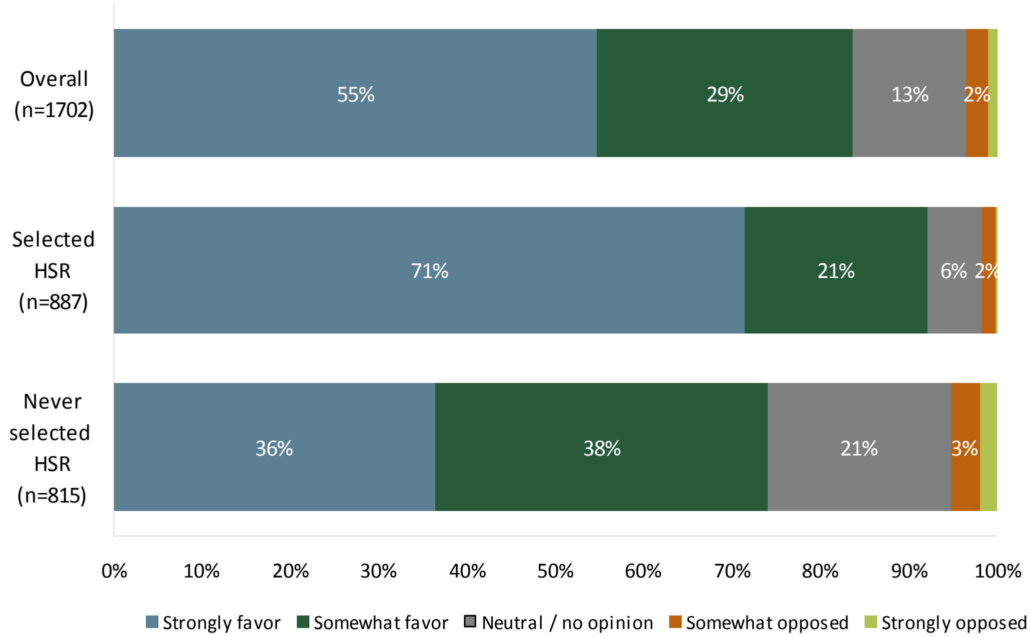


FIGURE 5-6: OPINION OF QUEBEC CITY – WINDSOR HIGH SPEED RAIL

After answering all eight stated preference questions, those respondents who had selected at least one HSR option for their trip were asked how many additional trips in the Quebec City – Windsor corridor they would make by HSR that they did not currently make. Of this group of respondents, one-quarter (25 percent) would not make any additional trips. Of those who would make additional trips by HSR, 8 percent would make three or more new trips each month, 22 percent would make one or two new trips each month, 23 percent would make a new trip every other month, and 22 percent would make at least one new trip per year.

5.5 Ridership Forecasting Models

5.5.1 Mode Choice Models Estimation

The statistical estimation of model coefficients and testing of alternative model structures were completed using industry standard discrete choice modelling methods and the Biogeme discrete choice modelling software[18]. The model estimation process included testing numerous utility function specifications. Over 325 separate model specifications were estimated and evaluated.

The tests aimed at developing a specification that provided the best overall model fit and a realistic representation of the choices faced by travellers within the Quebec City – Windsor corridor.

[18] Bierlaire, M. (2003). BIOGEME: A free package for the estimation of discrete choice models , Proceedings of the 3rd Swiss Transportation Research Conference, Ascona, Switzerland.

The SP data was used to support estimation of the coefficients of a nested logit (NL) choice model for two segments:

- Business trips (paid by employer and not paid by employer)
- Non-business trips (all other trip purposes)

The SP survey was conducted to measure the attractiveness of the HSR beyond the traditional time, cost and frequency attributes. The analysis of the SP surveys resulted in statistically valid models that separated HSR from VIA Rail as a different mode of travel.

5.5.2 Total Travel Demand Models

The models proposed to estimate future total travel demand for the Quebec City – Windsor corridor were classified as “growth” models. This means that future travel for each market was estimated by applying growth factors to known travel demand for the base year. In order to develop such a model, EcoTrain first estimated direct demand models (total travel for a given year without reference to previous travel). Growth was then estimated by comparing the change in direct demand, from the base year to the future year, and applying it to the base year total travel. The main advantage of growth models is that they are more reliable since they are anchored to “actual” trips for the base year.

Several combinations of the available development variables, population and employment, were tested. The final models selected used population at origin plus population at destination and are described in details in the technical report for Deliverable 7, Demand Forecasting.

5.5.3 Induced Travel Demand Models

Based on the answers to the question (and screen shown) in the SP survey as to whether the respondent would make more trips if HSR was available, a model for forecasting induced demand was developed based on behavioural and statistical considerations. This process and the resulting models, one for business trips and one for non-business trips, are described in the technical report for Deliverable 7.

5.6 Ridership and Revenue Forecasts

5.6.1 Population Forecast

As the total travel demand models described in the previous section indicate, the main component for estimating future travel in the Quebec City – Windsor corridor was the estimation of future socio-economic variables, and more specifically population in the corridor.

EcoTrain received socio-economic data from a variety of sources including: Informetrica, Conference Board, MTQ, and the Centre for Spatial Economics (C4SE). After careful review of these forecasts, the Technical Committee and EcoTrain agreed to use a combination of C4SE forecast and MTQ forecast as shown in the following table.

Table 5-4: Population Forecast

Province	2006 Population	2031 Population	2006-2031 Growth	2041 Population	2006-2041 Growth
Quebec	7,546,000	8,802,000	17%	9,022,000	20%
Ontario	12,161,000	15,929,000	31%	17,540,000	44%
Total	19,707,000	24,731,000	25%	26,562,000	35%

Sources : Census Data, MTQ and C4SE

5.6.2 2031 and 2041 Estimated Total Intercity Travel

Using the total travel demand models described in Section 5.5.2 and the population forecast described above, total intercity future trips in the corridor without HSR were estimated for 2031 and 2041.

Table 5-5 shows the expected volumes and growth rates by market and trip purpose.

Table 5-5: Growth in Travel without HSR: 2006-2031-2041

Markets	Annual Trips			Total Growth	
	2006	2031	2041	2006-2031	2006-2041
Primary Markets					
Business	10,035,824	14,908,844	16,306,263	49%	62%
Non-Business	21,924,028	29,667,099	31,906,238	35%	46%
Total	31,959,852	44,575,942	48,212,501	39%	51%
Secondary & Other Markets					
Business	12,088,692	13,682,440	14,761,002	13%	22%
Non-Business	48,691,674	53,443,605	56,636,476	10%	16%
Total	60,780,367	67,126,045	71,397,478	10%	17%

As shown, the primary markets for HSR were expected to grow by 39 percent between 2006 and 2031 and by 51 percent between 2006 and 2041. These expected growth rates for the primary markets were significantly higher than the corresponding 10 and 17 percent expected growth for the secondary and other markets.

When considering growth by purpose, business trips were expected to grow at a faster rate in all markets. For example business trips in the primary markets were expected to grow by 49 percent between 2006 and 2031 while non-business trips were expected to grow by 35 percent. In other words, the highest expected growth rates in travel were for those markets most likely to use the proposed HSR i.e. business trips and trips in the primary markets.

5.6.3 Assumptions on Services Offered by Mode

Table 5-6 summarizes the assumptions made as to the services offered by the competing intercity travel modes in the corridor.

Table 5-6: Services Offered by Mode

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="4">Service Assumptions by Mode</th></tr>
<tr><th>Air</th><th>Bus</th><th>Auto</th><th>HSR</th></tr>
<tr><td colspan="6">Accessibility</td></tr>
<tr><td colspan="2">Terminal Location</td><td>Same Airport locations as today</td><td>Same Airport locations as today</td><td>NA</td><td>Assumed Location (existing or new)</td></tr>
<tr><td colspan="2">Service Frequency</td><td>Same as today</td><td>Same as today</td><td>NA</td><td>One departure per hour on average</td></tr>
<tr><td colspan="6">Travel Time and its Components</td></tr>
<tr><td colspan="2">Access Time</td><td>Calculated for each zone based on shortest highway path to most convenient airport</td><td>Calculated for each zone based on shortest highway path to most convenient bus station</td><td>NA</td><td>Calculated for each zone based on shortest highway path to most convenient HSR station</td></tr>
<tr><td colspan="2">Parking Time</td><td>20 min. major airports, 15 min. others</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td rowspan="2">Process Time</td><td>Business</td><td>1h to 1h15 depending on airport</td><td rowspan="2">30 minutes</td><td rowspan="2">NA</td><td rowspan="2">25 min. for Central and Union Stations, 15 min. for other stations</td></tr>
<tr><td>Non-Business</td><td>1h15 to 1h30 depending on airport</td></tr>
<tr><td colspan="2">In vehicle Time</td><td>Same as current schedule</td><td>Same as current schedule</td><td>Calculated on a zone to zone basis using shortest highway path</td><td>Train running times based on technology (F200 or E300)</td></tr>
<tr><td rowspan="2">Exit Time</td><td>Business</td><td>15 to 20 minutes depending on airport</td><td rowspan="2">NA</td><td rowspan="2">NA</td><td rowspan="2">10 min. for Central and Union Stations, 5 min. for other stations</td></tr>
<tr><td>Non-Business</td><td>20 to 40 minutes depending on airport</td></tr>
<tr><td colspan="2">Egress Time</td><td>Calculated for each zone based on shortest highway path from most convenient airport</td><td>Calculated for each zone based on shortest highway path from most convenient bus station</td><td>NA</td><td>Calculated for each zone based on shortest highway path from most convenient HSR station</td></tr>
<tr><td colspan="6">Fares and other costs</td></tr>
<tr><td rowspan="2">Fares</td><td>Business</td><td rowspan="2">Same as in 2006</td><td rowspan="2">Same as in 2006</td><td rowspan="3">Trip cost based on zone to zone distance and unit cost derived from surveys</td><td>Revenue maximization fares: 2.5 times VIA Rail fares</td></tr>
<tr><td>Non-Business</td><td>Revenue maximization fares: 1.8 times VIA Rail fares</td></tr>
<tr><td colspan="2">Access/Egress costs</td><td>Based on distance and unit cost derived from surveys</td><td>Based on distance and unit cost derived from surveys</td><td>Based on distance and unit cost derived from surveys</td></tr>
</table>

5.6.4 HSR Ridership and Revenue Forecast – Full Quebec City – Windsor Corridor

This section presents the estimates of HSR ridership and passenger revenue for the years 2031 and 2041 for the proposed two technologies, F200+ and E300+, using the assumptions and models described in the previous sections. The number of trips that could be expected to be diverted or induced to the various HSR alternatives were estimated by purpose on a zone to zone basis and then summarized by primary, secondary, and other markets as defined in Section 5.2.

As shown in Tables 5-7 and 5-8, the ridership forecast for the entire Quebec City - Windsor corridor would be 10.2 million riders in 2031 for the F200+ HSR system and 11.1 million riders in 2041. The E300+ HSR system is expected to carry 11.1 million riders in 2031 and 12.1 million in 2041.

The corresponding passenger revenue, shown in table 5-8 would amount to CAD 1.2 billion in 2031 and CAD 1.3 billion in 2041 for the F200+ alternative. For the E300+ alternative, revenue from passengers would amount to CAD 1.4 billion in 2031 and CAD 1.5 billion in 2041.

Table 5-7: HSR Ridership by Market, Purpose & Year

	Annual Ridership - Year 2031				Annual Ridership - Year 2041			
	F200 HSR		E300 HSR		F200 HSR		E300 HSR	
Markets	Trips	Percent	Trips	Percent	Trips	Percent	Trips	Percent
Primary Markets								
Business	4 436 000	43%	4 840 000	43%	4 873 000	44%	5 316 000	44%
Non-Business	3 692 000	36%	3 939 000	35%	3 963 000	36%	4 228 000	35%
Sub-Total	8 128 000	79%	8 779 000	79%	8 836 000	79%	9 544 000	79%
Secondary Markets								
Business	478 000	5%	554 000	5%	547 000	5%	633 000	5%
Non-Business	867 000	8%	957 000	9%	956 000	9%	1 055 000	9%
Sub-Total	1 344 000	13%	1 511 000	14%	1 503 000	14%	1 688 000	14%
Other Markets								
Business	226 000	2%	239 000	2%	240 000	2%	253 000	2%
Non-Business	529 000	5%	600 000	5%	546 000	5%	619 000	5%
Sub-Total	755 000	7%	839 000	8%	785 000	7%	872 000	7%
Grand Total	10 227 000	100%	11 130 000	100%	11 124 000	100%	12 105 000	100%

Note: The results presented in this table are subject to the limitation noted under the Disclaimer presented at the forefront of this report

Table 5-8: HSR Passenger Revenue (2009$) by Market, Purpose & Year

	Annual Revenue ($1,000) - Year 2031				Annual Revenue ($1,000) - Year 2041			
	F200 HSR		E300 HSR		F200 HSR		E300 HSR	
Markets	Revenue	Percent	Revenue	Percent	Revenue	Percent	Revenue	Percent
Primary Markets								
Business	593 236	49%	665 937	49%	654 388	50%	734 752	50%
Non-Business	367 867	30%	401 968	30%	395 833	30%	432 656	29%
Sub-Total	961 103	80%	1 067 905	79%	1 050 221	79%	1 167 408	79%
Secondary Markets								
Business	83 288	7%	99 859	7%	94 805	7%	113 471	8%
Non-Business	98 738	8%	111 410	8%	108 471	8%	122 349	8%
Sub-Total	182 026	15%	211 269	16%	203 276	15%	235 820	16%
Other Markets								
Business	23 230	2%	25 185	2%	24 588	2%	26 658	2%
Non-Business	42 060	3%	48 503	4%	43 413	3%	50 068	3%
Sub-Total	65 290	5%	73 688	5%	68 001	5%	76 726	5%
Grand Total	1 208 419	100%	1 352 862	100%	1 321 498	100%	1 479 954	100%

Note: The results presented in this table are subject to the limitation noted under the Disclaimer presented at the forefront of this report

As presented in Tables 5-7 and 5-8, the majority or 79 to 80 percent of HSR ridership were expected to come from trips in the primary markets i.e. trips with both origin and destination in one of the seven urban areas in the corridor with a HSR station.

The following Tables 5-9 through 5-12 show the source of the expected HSR ridership, whether diverted from existing modes or induced for the two HSR technologies, F200+ and E300+, and the two forecast years, 2031 and 2041. As shown, the majority of HSR trips would be diverted from auto. The percentages of HSR riders diverted from auto would change very little with the technology or the year, but would be significantly different by purpose. For business travel, 56 to 57 percent of HSR trips were expected to be diverted from auto, but this percentage would increase to 62 or 63 percent for non-business travel since a larger portion of travel is currently done by auto for non-business travel than for business travel.

Similarly, the percentage of HSR trips diverted from air would be about 11 to 13 percent for business travel and about 9 percent for non-business, since a larger portion of business travel is currently done by air. Finally the percentage of HSR trips diverted from VIA Rail and bus was expected to be in the 18 to 21 percent range for business travel and 26 to 28 percent for non-business since a larger portion of non-business travel is currently done by VIA Rail or bus.

For non-business travel the percentages of HSR trips diverted from bus appear negative because there would be more trips made by bus with a HSR in place than without it. This is due to the assumption that HSR would replace VIA Rail Corridor services.

Because HSR tickets were assumed to cost significantly more than current VIA Rail tickets for the same trip, some riders currently using VIA Rail would not be willing to pay the higher HSR ticket cost and would use the cheapest public mode available i.e. bus.

Table 5-9: HSR Ridership by Market by source – F200 – year 2031

Purpose & Market	Diverted From				Induced	Total
	Auto	Air	Rail	Bus		
Business HSR Ridership						
Primary Markets	2,497,000	476,000	821,000	116,000	526,000	4,436,000
Percent of Total	*56%*	*11%*	*19%*	*3%*	*12%*	*100%*
Secondary Markets	233,000	101,000	87,000	5,000	51,000	478,000
Percent of Total	*49%*	*21%*	*18%*	*1%*	*11%*	*100%*
Other Markets	199,000	3,000	17,000	1,000	7,000	226,000
Percent of Total	*88%*	*1%*	*8%*	*0%*	*3%*	*100%*
Total	2,929,000	579,000	925,000	123,000	584,000	5,140,000
Non-Business HSR Ridership						
Primary Markets	2,194,000	327,000	1,510,000	-391,000	52,000	3,692,000
Percent of Total	*59%*	*9%*	*41%*	*-11%*	*1%*	*100%*
Secondary Markets	537,000	109,000	302,000	-89,000	8,000	867,000
Percent of Total	*62%*	*13%*	*35%*	*-10%*	*1%*	*100%*
Other Markets	400,000	16,000	140,000	-29,000	2,000	529,000
Percent of Total	*76%*	*3%*	*26%*	*-5%*	*0%*	*100%*
Total	3,131,000	452,000	1,951,000	-509,000	62,000	5,088,000
Grand Total	6,060,000	1,032,000	2,876,000	-387,000	646,000	10,227,000
Percent per source	*59%*	*10%*	*28%*	*-4%*	*6%*	*100%*

Notes : Diversion from bus is negative as some VIA Rail users divert to bus resulting in more bus ridership with HSR operating and VIA Rail eliminated than with VIA Rail operating alone. The results presented in this table are subject to the limitation noted under the Disclaimer presented at the forefront of this report.

Table 5-10: HSR Ridership by Market by Source – E300 – year 2031

Purpose & Market	Diverted From				Induced	Total
	Auto	Air	Rail	Bus		
Business HSR Ridership						
Primary Markets	2,751,000	543,000	870,000	123,000	586,000	4,873,000
Percent of Total	*56%*	*11%*	*18%*	*3%*	*12%*	*100%*
Secondary Markets	273,000	115,000	94,000	6,000	59,000	547,000
Percent of Total	*50%*	*21%*	*17%*	*1%*	*11%*	*100%*
Other Markets	211,000	3,000	17,000	1,000	7,000	240,000
Percent of Total	*88%*	*1%*	*7%*	*0%*	*3%*	*100%*
Total	3,235,000	661,000	980,000	129,000	653,000	5,659,000
Non-Business HSR Ridership						
Primary Markets	2,373,000	359,000	1,588,000	-413,000	57,000	3,963,000
Percent of Total	*60%*	*9%*	*40%*	*-10%*	*1%*	*100%*
Secondary Markets	598,000	121,000	323,000	-96,000	9,000	956,000
Percent of Total	*63%*	*13%*	*34%*	*-10%*	*1%*	*100%*
Other Markets	416,000	17,000	140,000	-30,000	2,000	546,000

Purpose & Market	Diverted From				Induced	Total
	Auto	Air	Rail	Bus		
Percent of Total	*76%*	*3%*	*26%*	*-5%*	*0%*	*100%*
Total	3,387,000	497,000	2,051,000	-539,000	68,000	5,465,000
Grand Total	6,623,000	1,158,000	3,032,000	-409,000	721,000	11,124,000
Percent per source	*60%*	*10%*	*27%*	*-4%*	*6%*	*100%*

Notes : Diversion from bus is negative as some VIA Rail users divert to bus resulting in more bus ridership with HSR operating and VIA Rail eliminated than with VIA Rail operating alone. The results presented in this table are subject to the limitation noted under the Disclaimer presented at the forefront of this report.

Table 5-11: HSR Ridership by Market by Source – F200 – Year 2041

Purpose & Market	Diverted From				Induced	Total
	Auto	Air	Rail	Bus		
Business HSR Ridership						
Primary Markets	2,664,000	582,000	821,000	127,000	647,000	4,840,000
Percent of Total	*55%*	*12%*	*17%*	*3%*	*13%*	*100%*
Secondary Markets	263,000	128,000	87,000	6,000	70,000	554,000
Percent of Total	*47%*	*23%*	*16%*	*1%*	*13%*	*100%*
Other Markets	209,000	3,000	17,000	1,000	8,000	239,000
Percent of Total	*87%*	*1%*	*7%*	*0%*	*3%*	*100%*
Total	3,137,000	713,000	925,000	134,000	725,000	5,634,000
Non-Business HSR Ridership						
Primary Markets	2,380,000	342,000	1,510,000	-364,000	71,000	3,939,000
Percent of Total	*60%*	*9%*	*38%*	*-9%*	*2%*	*100%*
Secondary Markets	613,000	116,000	302,000	-84,000	11,000	957,000
Percent of Total	*64%*	*12%*	*32%*	*-9%*	*1%*	*100%*
Other Markets	469,000	18,000	140,000	-29,000	2,000	600,000
Percent of Total	*78%*	*3%*	*23%*	*-5%*	*0%*	*100%*
Total	3,462,000	475,000	1,951,000	-477,000	84,000	5,496,000
Grand Total	6,599,000	1,189,000	2,876,000	-343,000	809,000	11,130,000
Percent per source	*59%*	*11%*	*26%*	*-3%*	*7%*	*100%*

Notes : Diversion from bus is negative as some VIA Rail users divert to bus resulting in more bus ridership with HSR operating and VIA Rail eliminated than with VIA Rail operating alone. The results presented in this table are subject to the limitation noted under the Disclaimer presented at the forefront of this report.

Table 5-12: HSR Ridership by Market by Source – E300 – Year 2041

Purpose & Market	Diverted From				Induced	Total
	Auto	Air	Rail	Bus		
Business HSR Ridership						
Primary Markets	2,930,000	662,000	870,000	133,000	721,000	5,316,000
Percent of Total	*55%*	*12%*	*16%*	*3%*	*14%*	*100%*
Secondary Markets	307,000	146,000	94,000	7,000	80,000	633,000
Percent of Total	*48%*	*23%*	*15%*	*1%*	*13%*	*100%*
Other Markets	222,000	4,000	17,000	1,000	9,000	253,000
Percent of Total	*88%*	*2%*	*7%*	*0%*	*4%*	*100%*
Total	3,460,000	811,000	980,000	141,000	810,000	6,202,000

Purpose & Market	Diverted From				Induced	Total
	Auto	Air	Rail	Bus		
Non-Business HSR Ridership						
Primary Markets	2,574,000	376,000	1,588,000	-386,000	77,000	4,228,000
Percent of Total	*61%*	*9%*	*38%*	*-9%*	*2%*	*100%*
Secondary Markets	682,000	128,000	323,000	-90,000	12,000	1,055,000
Percent of Total	*65%*	*12%*	*31%*	*-9%*	*1%*	*100%*
Other Markets	487,000	19,000	140,000	-29,000	2,000	619,000
Percent of Total	*79%*	*3%*	*23%*	*-5%*	*0%*	*100%*
Total	3,743,000	522,000	2,051,000	-505,000	92,000	5,902,000
Grand Total	7,202,000	1,333,000	3,032,000	-364,000	902,000	12,105,000
Percent per source	*59%*	*11%*	*25%*	*-3%*	*7%*	*100%*

Notes : Diversion from bus is negative as some VIA Rail users divert to bus resulting in more bus ridership with HSR operating and VIA Rail eliminated than with VIA Rail operating alone. The results presented in this table are subject to the limitation noted under the Disclaimer presented at the forefront of this report.

Table 5-13 presents the expected modal shares of intercity travel in the Quebec City – Windsor corridor with HSR operating in the full corridor. As shown, the auto mode would remain the predominant mode of travel with a modal share of 72 percent for business and 91 percent for non-business or 86 percent total (the modal share for auto was estimated at over 89 percent without HSR). HSR would capture around 16 to 17 percent of the travel market for business and 6 to 7 percent of the travel market for non-business.

Table 5-13: Modal Shares in Percent by Purpose – Year 2031

F200	Auto	Air	Bus	HSR
Business Travel	72	11	1	16
Non-Business Travel	91	0	3	6
All Markets	86	3	3	8
E300				
Business Travel	72	10	1	17
Non-Business Travel	90	0	3	7
All Markets	85	3	3	9

As shown in Table 5-14, modal shares vary significantly by market. Auto shares would increase from 72 percent in the primary markets (where HSR would be most competitive) to 85 percent in the secondary market and to 98 percent in the other markets (where HSR would be least competitive). By contrast, HSR modal shares would decrease from 17 percent in the primary markets to 7 percent in the secondary market to one percent in the other markets.

Table 5-14: Modal Shares by Market – Year 2031

F200	Auto	Air	Bus	HSR
Primary Markets	72	5	6	17
Secondary Markets	85	5	3	7
Other Markets	98	0	1	1
E300				
Primary Markets	72	5	5	18
Secondary Markets	84	5	3	8
Other Markets	98	0	0	2

5.6.5 HSR Ridership and Revenue Forecast – Shorter Segments

Results presented so far assumed that the proposed HSR would operate in the entire corridor from Quebec City to Windsor. Estimates of ridership and passenger revenues were also developed for three shorter functional segments:

- Quebec City - Toronto
- Montreal - Toronto
- Toronto - Windsor

For all these alternatives, the operation of the HSR in the shorter corridors would be the same as in the full corridor. Table 5-15 presents a summary of ridership and passenger revenues for the years 2031 and 2041 for the four alternatives.

Table 5-15: Annual HSR Ridership and Revenue (2009 $) Forecasts – Shorter Corridors

Year	Technology	Corridor	Annual HSR Results		Change from Full Corridor	
			Trips	Revenue (million $)	Trips	Revenue
2031	F200	Quebec City - Windsor	10,227,000	1,208		
		Quebec City - Toronto	7,971,000	985	-22%	-18%
		Montreal-Toronto	5,681,000	722	-44%	-40%
		Toronto-Windsor	2,169,000	189	-79%	-84%
	E300	Quebec City - Winsor	11,130,000	1,353		
		Quebec City - Toronto	8,885,000	1,119	-20%	-17%
		Montreal-Toronto	6,346,000	825	-43%	-39%
		Toronto-Windsor	2,135,000	193	-81%	-86%
2041	F200	Quebec City - Windsor	11,124,000	1,321		
		Quebec City - Toronto	8,609,000	1,072	-23%	-19%
		Montreal-Toronto	6,234,000	798	-44%	-40%
		Toronto-Windsor	2,410,000	211	-78%	-84%
	E300	Quebec City - Windsor	12,105,000	1,480		
		Quebec City - Toronto	9,604,000	1,219	-21%	-18%
		Montreal-Toronto	6,969,000	913	-42%	-38%
		Toronto-Windsor	2,370,000	215	-80%	-85%

Note : The results presented in this table are subject to the limitation noted under the Disclaimer presented at the forefront of this report.

As expected, the shorter corridors would result in smaller ridership and revenue. Compared to the full corridor, estimated ridership was about 22 percent lower for the Quebec City - Toronto segment, 43 percent lower for the Montreal-Toronto segment and 80 percent lower for the Toronto-Windsor segment. For revenue, the decrease would be around 18 percent for the Quebec City - Toronto segment, 40 percent for the Montreal-Toronto segment and 85 percent for the Toronto-Windsor segment. The decrease in revenue for the Toronto-Windsor segment was higher than for ridership as the revenue per rider was becoming significantly smaller for this short segment.

5.7 Comparison with the 1995 QOHSRPS

The 1995 QOHSRPS prepared a forecast of HSR ridership for 2005 and 2025 using a similar approach. Conditions have changed since the study was completed that could have a significant impact on these forecasts. Among those conditions with the largest potential to affect HSR ridership estimates are:

- Changes in the amount of travel in the corridor
- Impact of fuel price increases on travel costs and trip maker behaviour
- Competitive position of HSR as a new mode of travel vis-à-vis existing modes of travel
- Increased travel time associated with enhanced security measures at airports and perceived security risks associated with air travel.

The ridership forecast in the present study was not simply an update of the previous study but was based instead on an entirely new set of models and data. However a comparison of the two studies can highlight some of the changes that occurred in the intervening years. The major differences include the following:

- The QOHSRPS used an annual growth rate by mode of travel. Only auto and air travel were assumed to grow between 1992 and 2005, while rail and bus travel were assumed to stay at the 1992 level. These growth rates were assumed to apply to all city pairs in the Corridor. The present study used a total travel demand model, with different growth factors by city pairs based on the expected change in population in each city. As a result the 1995 study estimated that between 2006 and 2025 total travel would grow at more than 3 times the total growth predicted in the present study.
- The present study ridership forecasts for 2031 are about the same as the 1995 study forecasts for the year 2005 despite the 26 years difference: 10.2 million trips by HSR in 2031 recorded in the present study compared to 10.1 million by HSR in 2005 recorded in the QOHSRPS.

- Induced trips in the QOHSRPS report were 18 percent of HSR trips, as opposed to 6 percent in the present study.
- Air connect represented 5 percent of HSR ridership in the 1995 study but it was not considered a market in the present study since the proposed HSR would not stop at any airport.
- HSR ridership from local air travel was larger in the 1995 study than in the present study, both in terms of percentage and absolute value, because air travel in the previous study was estimated using a different methodology which resulted in higher estimates of air travel.
- In the 1995 study, ridership was estimated by two consultants using different mode choice models. One of these models diverted trips from each existing mode separately and the other model estimated diversion to HSR as a whole but not diversion between other modes. EcoTrain believes that the diversion models developed in the present study are more realistic because they looked at all modes together, thus anticipating diversion of VIA Rail riders to bus for instance.
- While the ridership forecasts are similar despite the 26 years difference, revenues in the present study are about 30 percent higher for the F200+ system and 14 percent higher for the E300+ system. This is due to the estimated higher share of business trips diverting or induced to HSR in the present study and the higher fares estimated as the revenue maximization fares.

5.8 Sensitivity and Risk Analyses

The ridership forecasts have been conducted using standard industry practices and have been thoroughly reviewed by the Technical Committee at every step of the present study. EcoTrain is of the opinion that the ridership figures are reasonable based on the following:

- Deliverable 7 included a comparison with the 1995 QOHSRPS results which indicated that the present forecast was lower than the one in the previous study: Table 6-14 of Deliverable 7 showed that the present forecast for 2031 was about the same as the previous study forecast for 2005.
- The analysis of the potential impact of using inaccurate air fares indicated that the overall ridership and/or revenues are most likely under-estimated.
- According to the O&M analysis, the frequency of the HSR trains may need to be higher than the one used in the ridership forecast, which would indicate that the present ridership was probably under-estimated.

5.8.1 Level of Details

An assumption about the number of trains per day was required as input to the ridership forecast. The ridership results were then used to estimate the number of trains needed to satisfy the demand. Ideally, there should be some iterations between the two estimates – ridership and train operations – until the number of trains converge to a reasonable solution.

This refinement should be performed at a later stage during the conceptual design and would probably result in increased ridership figures. However it is expected that the order of magnitude of such an adjustment to the ridership forecast would be marginal as shown in Deliverable 7 sensitivity analysis and would not materially change the conclusions and recommendations of the present study.

5.8.2 Sensitivity Analysis

Ridership and passenger revenue forecasts are sensitive to the various assumptions used in the forecast models. Based on recommendations from both the Technical Committee and EcoTrain the following sensitivity analyses were conducted:

- A 15-minute process time increase at HSR stations would result in an 11 percent decrease in business ridership and 6 percent decrease in non-business ridership, with a decrease in revenue of 8 percent.
- Lower air fares in the Corridor would reduce business ridership by 11 percent, non-business ridership by 15 percent and revenue by 18 percent.
- A higher growth scenario combined with an increase in land use density would result in 21 to 23 percent increase in HSR ridership and revenue.
- A decrease of 20 percent in HSR fares would result in an increase of 17 percent in business ridership and 16 percent for non-business ridership, and a decrease of 4 percent in revenues.
- An increase of 20 percent in HSR fare results in a 14 percent decrease in ridership for both business and non-business and practically no changes in revenues.
- A decrease in frequency from 12 to 8 trains per day would result in a decrease in ridership of 13 percent for business travel and 7 percent for non-business, resulting in a decrease in revenue of 11 percent.
- An increase in frequency from 12 trains to 16 trains per day would result in an increase in ridership of 10 percent for business travel and 4 percent for non-business travel, resulting in a 7 percent increase in revenue.
- Increase or decrease of transfer time between shuttle services by 3 minutes have minimal impact on ridership or revenue since such a change is very small compared to the overall travel time.

5.8.3 Risk Analysis

EcoTrain performed a risk analysis that incorporated Monte Carlo procedures to test the potential effect of population and HSR fares as "risk variables" on the ridership and revenue forecasts for the E300+ system in the full Quebec City – Windsor corridor for the year 2031.

The likelihood of achieving the input base case values was described by the probabilistic distribution of each risk variable. Normal distributions were assumed for both variables. Three hundred runs were conducted. Results are shown in the following table:

Table 5-16: Risk Analysis Based on Population and HSR Fares (2009 $)

HSR E300 – Year 2031	Base Case	Standard Deviation	Risk Analysis Results (Population and HSR Fares)		
			5%	Mean	95%
Ridership	11,130,000	2,122,000	9,793,000	13,274,000	16,754,000
Revenue ($1,000)	1,353,000	162,000	1,008,000	1,274,000	1,540,000

The coefficient of variation (standard deviation/mean) of ridership and revenue were 0.16 and 0.13 respectively indicating more uncertainty for ridership than for revenue. The variation of the forecast in the 90 percent confidence interval (with 5 percent and 95 percent percentiles) was in the range ±26 percent for ridership and ±21 percent for revenue. The risk analysis would most likely have shown higher forecast margins if more variables had been included.

6 CONSTRUCTION AND OTHER CAPITAL COSTS

A detailed estimation procedure was developed and used for updating construction and other capital costs; this was done separately for the F200+ and E300+ technologies, for the whole Quebec City – Windsor corridor.

The basis for estimating capital costs was the representative system design that was described in Chapter 4, Representative Service and System, on the basis of the representative technologies, their respective representative routes, and the levels of service envisioned.

The scope, approach, and methodology used for updating estimates of capital costs are summarized below, as well as the main results and a comparison with the QOHSRPS estimates. Details can be found in the technical report for Deliverable 6.1, Construction Costs and its appendices.

6.1 Cost Elements

The following Infrastructure-related cost elements (identified as Sub-systems) were included in the estimation and broken down in the same fashion as in the QOHSRPS:

- Right of Way (RoW) acquisition, separated into acquisition of urban land (residential, commercial, and industrial areas) and rural land (agricultural and natural areas), and purchase of existing RoW
- Earthworks and drainage, including:
  - *clearing and roadbed preparation,*
  - *embankment construction,*
  - *haulage of fill material,*
  - *sub-ballast,*
  - *drainage (including minor and major watercourse culverts, environmental storm water controls),*
  - *retaining walls,*
  - *noise mitigation structures, and*
  - *security fencing*
- Bridges, viaducts, and tunnels, by type of river and other obstacle crossings
- Grade separations, by type, by location (urban, rural) and number of road lanes, including private farm crossings and major wildlife passages
- Site-specific accommodation works such as construction of new access tracks and rail/rail grade separation structures to give access to the other side of the RoW where needed

- Stations[19].
- The following cost elements related to railway systems were included in the estimates, using as much as possible the same structure as in the QOHSRPS:
- Track: cost of track in place, 50 percent ballast track and 50 percent slab track, including high-speed and low-speed turnouts
- Power supply and distribution: fuelling facilities for F200+ and electric power supply substations and overhead catenary system for E300+
- Signalling and telecommunications, including installed interlocking systems, automatic train control (ATC) equipment, operating control centre (OCC), and telecommunications equipment
- Rolling stock
- Maintenance facilities, including maintenance shops and their equipment (in Montreal and in Toronto), yards for overnight storage (Quebec, Montreal, Ottawa, Toronto, Windsor); specialized vehicles, and maintenance bases for track, power, and signalling systems
- Information and ticketing systems, including sales hardware at counters, ticketing machines at stations, Internet information, reservation, and data centre and supporting organization
- Start-up
- Each cost sub-system also included the associated professional fees for conceptual design and preliminary and detailed engineering, environmental assessment, construction supervision and project management, and a contingency amount, based on the level of accuracy of the quantity measured, covering the risk of a cost overrun at a specified confidence level.

6.2 Approach and Methodology

EcoTrain's approach was not different from the one generally used in similar studies by most transportation infrastructure planning organizations. At this stage, time and financial resources were limited and physical information – topography, geology, hydrology and environmental conditions – were minimal since systematic surveys and analyses could not yet be performed.

[19] These estimates include only what is needed to provide HSR service to travellers. Local communities might use the rehabilitation or construction of a station as an opportunity for local development or adding non-transportation-related facilities to the station. These associated costs are not included in the capital costs estimates.

6.2.1 Capital Cost Model

Since the present feasibility study was essentially an update of a previous one, the general approach for updating the construction and other capital costs was based in many respects on the one used in the QOHSRPS. This approach was adopted in order to use what was still valid from the QOHSRPS and to facilitate comparisons with previous individual results. The costing items and sub-items were grouped under 13 sub-systems, eight (8) of them as previously used in the QOHSRPS - Preliminary Routing Assessment and Costing Study (PRACS), the five (5) others derived from the QOHSRPS - System Operations and Costs Study. The base year for the determination of the revised unit costs was 2009.

Various assumptions adopted in the QOHSRPS were reviewed and some were revised or adapted to reflect the new context. The main assumptions adopted for the present study are the following:

- The entire HSR line between Quebec City and Windsor would be double-tracked and built with new track material, whether or not there were existing passenger service tracks on the route followed (QOHSPRS proposed using existing passenger service tracks if these were in good condition and speed was less than 200 km/h).
- Existing RoW would be shared with other passenger services in dense urbanized areas where land acquisition would be impossible or prohibitively expensive. If freight traffic is present, it should be separated physically or in time from HSR operations (as in QOHSRPS).
- In rural areas where the HSR route followed an existing rail RoW (shared corridor) it was assumed that an additional 40 m width of land would be acquired for the exclusive use of HSR, along the existing RoW (as in the QOHSRPS).
- New HSR RoW in rural areas (for curve corrections and for new alignments) would be 50 m wide (as in the QOHSRPS).
- All existing grade crossings, including private farm crossings, would be eliminated along the HSR route, including those within cities, and none would be added.
- As requested by the Technical Committee, no existing public cross roads would be closed and diverted.

The quantities (lengths, areas, volumes, numbers, etc.) of all items and sub-items were worked out in detail. For each portion of route that was modified from the QOHSRPS representative routes as described above in Chapter 3, Representative Routes, a revised representative alignment was designed in sufficient detail to adequately measure the new quantities of infrastructure work.

Similar quantities along the unchanged portions of the 1995 alignments were taken from the QOHSRPS-PRACS, with the most significant ones submitted to a succinct validation.

The margin of error in measuring the quantities may vary from 10 percent for Track and Rolling Stock to 50 percent for Accommodation Works, depending on the sub-system, for a weighted average of 17 percent, which is typical of a Class D estimate[20] and generally accepted for a feasibility study such as the present study.

Over 150 unit costs were estimated on the basis of prices paid for recent and comparable construction projects for corresponding items (land acquisition, earthworks, road and rail structures, track, rolling stock, electrification, signals, etc.).

A Capital Cost Model incorporating the cost sub-systems, items and sub-items, their quantities, unit costs and computed total costs, was designed in order to establish the capital costs of various geographical and functional segments for each representative technology, F200+ and E300+.

6.2.2 Cost of Environmental Mitigation Measures

The types and costs of mitigation measures for protection against potential environmental impacts were considered in developing the construction cost estimates. This was done at a level of detail consistent with the scope of the study.

The types of environmental impacts potentially caused by HSR, as well as the circumstances under which they could be caused, were identified in Deliverable 9, Environmental and Social Impacts, where corresponding possible mitigation measures were also identified.

The precise locations where environmental impacts of a given type would be caused, their precise dimensions and level of intensity were not described, as a determination of these characteristics would require detailed on-site investigations, site specific surveys, and detailed topographical, geotechnical, and hydrological maps, which were not commensurate with the nature, time and cost constraints of the present study.

[20] According to the definition in the "Engineering Services Management Guide and Glossary" published by the Association of Consulting Engineers of Canada, a Class D *"estimate, also known as parametric estimating, is generally prepared during the prefeasibility studies. Its purpose is to determine the value of proceeding to the preproject stage of preparatory studies and basic plans and specifications for the project under consideration. A Class D estimate is often based on historical data obtained on comparable projects already completed, with the costs adjusted to take into account factors such as construction date, production capacity in the case of a plant, dimensions and other similar general information. It is very brief and based on a minimum of information; as a result, it has a large margin of error (20% to 100%)."*

When developing quantities for construction cost estimates, a comparative approach was taken, because construction challenges, including difficult topography or hydrology, and poor soil quality or stability, as well as the mitigation measures required for protection against environmental impacts, could not be precisely located in the absence of detailed and recent mapping and on-site surveys and investigations.

Typical physical mitigation measures like noise attenuation structures, storm water controls (settlement/retention ponds), farm crossings and wildlife passages were explicitly included in the estimates. The costs of other types of environmental mitigation measures, such as wetland protection, fish habitat protection and erosion and sediment control measures were implicitly included in the unit costs for earthworks, drainage, bridges, viaducts, grade separations, and other civil works. These unit costs were developed based on average unit costs experienced on recent construction of comparable infrastructures in the Corridor. For that reason, these unit costs include the costs of mitigation measures as required under current legislation and regulation in Canada, Quebec and Ontario.

6.3 Updated Cost Estimates

Table 6-1 presents the resulting updated cost estimates for both the F200+ and the E300+ technologies, at the sub-system level, with subtotals for infrastructure costs and railway systems costs. All costs are in 2009 Canadian dollars (CAD). The last column of Table 6-1 highlights the ratios of E300+ sub-systems costs over those of F200+; some ratios under 100 percent or exceeding 110 percent deserve comments as follows.

- The relative lower costs of land acquisition for the E300+ system are explained mainly by the new alignments between Dorion and Casselman on the Montreal - Ottawa segment and in the vicinity of London, where the types of land acquired are of lower unit costs (natural or agricultural vs. residential or commercial) than in the QOHSRPS.
- Rolling stock costs depend on fleet size and on technology. Costs for standard diesel and electric trainsets are within the same range. Costs for dual-mode trainsets are estimated to be about 45 percent higher than standard trainsets. Furthermore, fleet size varies with passenger demand and with average speed, since increasing the average speed leads to higher productivity of the rolling stock.

Table 6-1 excludes any comparison between the Power Supply and Distribution (PSD) costs of each technology. Nonetheless, the electric PSD equipment and installations also explain the higher costs of Maintenance Facilities and Start-up for E300+. It also explains, on the bottom line, the net difference between the two representative technologies.

Table 6-1: Updated Capital Costs for Representative Systems (all costs in million CAD 2009)

	F200+		E300+		Ratio E300+/F200+
Infrastructure	Cost*	percent	Cost*	percent	percent
Right-of-Way Acquisition	1 043	5.5%	931	4.4%	89.2%
Earthworks and Drainage	2 652	14.0%	2 931	13.8%	110.5%
Bridges, Viaducts, and Tunnels	1 562	8.3%	1 683	7.9%	107.7%
Grade Separations	3 979	21.0%	4 209	19.8%	105.8%
Other Accommodation Works	209	1.1%	237	1.1%	113.1%
Stations	277	1.5%	277	1.3%	100.0%
Summary for Infrastructure	*9 723*	*51.4%*	*10 268*	*48.2%*	*105.6%*
Railway Systems					
Track	3 298	17.4%	3 306	15.5%	100.3%
Power Supply and Distribution	9	0.0%	2 010	9.4%	N/S**
Signalling & Telecom.	1 102	5.8%	1 105	5.2%	100.3%
Rolling Stock	3 506	18.5%	3 052	14.3%	87.1%
Maintenance Facilities	844	4.5%	1 022	4.8%	121.1%
Information & Ticketing	46	0.2%	46	0.2%	100.4%
Start-up	400	2.1%	489	2.3%	122.5%
Summary for Railway Systems	*9 205*	*48.6%*	*11 032*	*51.8%*	*119.9%*
Total	18 927	100%	21 300	100%	112.5%

* All costs are in million 2009 Canadian dollars

** Comparison for Power Supply and Distribution would not be significant on account of different power sources

6.4 Risk Analysis

The accuracy range of an estimate is directly linked to the level of definition of the information available to conduct it, particularly the state of progress of engineering design.

The end result of the estimation process is a single evaluation, or base cost of the project cost, which could vary with regards to the level of accuracy. An amount of contingency is added to this base cost, in order to obtain a project cost in which all stakeholders may have confidence.

The amount of contingency added to the project allows for a confidence level in the project cost that would insure the probability of meeting that cost, usually 50 percent. If the confidence level needed is higher and requires a higher probability of meeting the project cost, for example 70 percent, then the amount of contingency added to the base cost must increase.

However, the estimated accuracy range would not change with the contingency amount of the chosen probability of meeting the project cost, since it depends on the level of definition of the project design.

Table 6-2 summarizes the project costs with the contingencies added to the various subsystems and the expected accuracy.

Table 6-2: Summary of Project Costs, Contingency and Accuracy

Technology	Base cost * without contingency	Planned contingency**	Total	Expected accuracy
F200+	16 990 M$	1 937 M$ (12%)	18 927 M$	20%
E300+	19 009 M$	2 291 M$ (12%)	21 300 M$	20%

* Including Professional Fees
** On Construction Costs + Professional Fees

The accuracy range is also a function of the confidence interval. The statistical confidence interval is the interval in which there is a defined probability that a specific value would be found within. It is expressed as a percentage. For example, results given at an 80 percent confidence interval signify that there is an 80 percent probability that the chosen project cost would fall within a specific accuracy range.

The use of a Monte-Carlo simulation generated a probability distribution of the project cost. Starting with the base cost, without contingency, and the accuracy range of each subsystem, the accuracy of the estimation and the probability of meeting the target cost within a specified statistical interval of confidence could be determined.

Following the Monte-Carlo simulation and considering no correlation between subsystems (as in the initial study), the information obtained is presented in Table 6-3.

Table 6-3: Results of Monte Carlo Simulations (all costs in million 2009 CAD)

Technology	Level of Confi-dence	Proba-bility of Overrun	Base Cost	Contingency		Total Cost	Calculated Accuracy (Statistical confidence interval of 80%)
				Cost	%		
F200+	A	50%	16 990	1 276	7.5%	18 266	-6% to +6%
	B	30%	16 990	1 747	10%	18737	-8% to +4%
	C	20%	16 990	2 088	12%	19 078	-10% to + 2%
	D	10%	16 990	2 493	15%	19 483	-12% to + 0%
E300+	A	50%	19 009	1 513	8%	20 522	-6% to +7%
	B	30%	19 009	2 033	11%	21 042	-9% to +4%
	C	20%	19 009	2 384	12.5%	21 393	-10% to + 2%
	D	10%	19 009	2 806	15%	21 815	-12% to + 0%

6.5 Comparison with the QOHSRPS

Table 6-4 compares the capital costs, in constant 2009 CAD dollars, of the project as estimated in the present study versus those quoted in the QOHSRPS for each technology.

Table 6-4: Comparison of Updated Construction and Capital Costs with the QOHSRPS
(all costs in million 2009 CAD)

	F200+			E300+		
Infrastructure	This study*	QOHSRPS**	Ratio	This study*	QOHSRPS**	Ratio
Right-of-Way Acquisition	1 043	834	125,1%	931	872	106,7%
Earthworks and Drainage	2 652	2 953	89,8%	2 931	3 376	86,8%
Bridges, Viaducts, and Tunnels	1 562	1 210	129,1%	1 683	1 274	132,1%
Grade Separations	3 979	1 974	201,6%	4 209	2 878	146,2%
Other Accommodation Works	209	265	79,0%	237	286	82,8%
Stations	277	265	104,5%	277	286	96,8%
Summary for Infrastructure	*9 723*	*7 501*	129,6%	*10 268*	*8 972*	114,4%
Railway Systems						
Track	3 298	1 851	178,2%	3 306	1 896	174,4%
Power Supply and Distribution	9	1 643	0,5%	2 010	1 610	124,9%
Signalling & Telecom.	1 102	1 344	82,0%	1 105	1 537	71,9%
Rolling Stock	3 506	2 550	137,5%	3 052	2 731	111,8%
Maintenance Facilities	844	551	153,2%	1 022	590	173,3%
Information & Ticketing	46	81	57,1%	46	84	55,2%
Start-up	400	457	87,4%	489	476	102,8%
Summary for Railway Systems	*9 205*	*8 477*	108,6%	*11 032*	*8 924*	123,6%
Total	18 927	15 978	118,5%	21 300	17 896	119,0%

* All amounts in million 2009 Canadian dollars

** Cost estimates from the QOHSRPS reports were updated to 2009 using non-residential construction cost indices.

The two columns entitled “Ratio” express in percentage the costs of E300+ in relation to those of F200+; they deserve some comments:

- Using a unique inflation factor – the only feasible tool at this stage -- to express the QOHSRPS costs in 2009 dollars is somewhat simplistic since the various materials and construction or installation techniques have evolved differently over the past 16 years. This is particularly true for the price of steel, an important component of tracks, bridges, viaducts and grade separation structures, which increased much more rapidly than the prices of other commodities. On the other hand, the mean costs of earthworks and drainage works increased more slowly than the average over the same period.
- The elimination of all grade crossings and road closures or diversions has an important impact on the cost of Grade Separations, especially for F200+[21].
- The instruction from the Technical Committee to avoid piers[22] in rivers has a direct impact on the cost of bridges.
- The proposed substitution of conventional ballast by concrete slab on 50 percent of the length of the route adds to the unit cost of the track sub-system.
- The use of fuel instead of electricity as power supply for F200+ adds to the cost of the rolling stock, requiring dual-mode locomotives for the Quebec City - Montreal segment going through the existing Mount-Royal tunnel, where diesel locomotives are prohibited for safety reasons.
- Maintenance Facilities were mentioned and costed but were not detailed and discussed in the QOHSRPS reports, so their comprehensiveness could not be assessed. The 1995 study may have underestimated their costs.
- Signalling, telecommunications, and information and ticketing systems have benefited from new technologies though the years and their costs have decreased over time.

Another difference between the QOHSRPS and the present study is the following. Whereas in the present study, the costs include a provision of approximately 13 percent for professional fees and project management, and 12 percent for contingencies, which results in a 70 percent probability of meeting the project cost, the corresponding figures in the QOHSRPS were 14, 9, and 45 percent respectively, which suggests a lower probability of meeting the project cost in the latter case.

[21] The QOHSRPS accepted level crossings with low traffic secondary roads for the 200 km/h technology, which, internationally, is no longer an accepted practice, due to safety considerations.

[22] Federal statutes do not prohibit piers in rivers but they impose conditions: it is frequent that bridge piers are built in rivers while conforming to environmental prescriptions. Such is the case of the A-25 bridge presently under construction across Rivière des Prairies in Montréal.

6.6 Comparison with Existing HSR Systems

Comparing the estimated project construction costs with the historical costs of building HSR systems could be interesting and generally informative but, unless scrutinized in exacting detail, it could be difficult and even risky to draw absolute conclusions from such comparisons. Most of the available literature on this topic is consistent in asserting that the most cost sensitive elements of HSR infrastructure are the topography-related works such as tunnels, viaducts and bridges, followed by the land acquisition costs.

In the Quebec City – Windsor corridor, the implementation conditions for HSR illustrated by the representative routes for the two technologies are generally devoid of terrain difficulties that could present significant cost issues and increase the construction cost risk. The routes for the most part lie within the St. Lawrence/Great Lakes plain area and follow existing rail RoW which have already been optimized for topography and river crossings. Furthermore, the routes already penetrate within existing rail RoW or circumvent major urban areas and this also reduces the potential for significant and unexpected costs.

As a result, it is reasonable to expect that the estimated construction costs for the Quebec City-Windsor HSR project would reflect the relatively favourable route conditions.

To compare construction costs, two recent studies were reviewed; one by the U.S. Government Accountability Office[23] (GAO) dated March 9, 2009, and another by researchers[24] at the University of Las Palmas (Spain) dated May 2009. The latter study considered 45 HSR projects from around the world. The construction cost per kilometre of the 24 operating HSR systems varied between 4.7 million and 39.5 million EUR (2005) with a mean value of 18 million EUR (2005), corresponding to 31 million CAD (2009). These costs exclude rolling stock, planning, and land costs.

The GAO study reviewed six European and Japanese HSR projects. The approximate cost per route mile in 2008 USD varied between $37 million and $143 million USD, corresponding to $24.6 million CAD(2009)/km and $95.1 million CAD(2009)/km respectively. The same study analysed four planned HSR projects in the US, for which the estimated construction costs varied between $22 and $132 million USD per route mile, depending upon the selected technology, topography, and prevailing land costs. The corresponding figures would be $14.6 and $87.8 million CAD(2009)/km.

[23] United States Government Accountability Office, High Speed Passenger Rail, Report No. GAO-09-317, March 9, 2009
[24] Economic Analysis of High Speed Rail in Europe, for the BBVA Foundation by Ginés de Rus, University of Las Palmas, Spain, May 2009

According to the Spanish study, the lowest European HSR project cost per kilometre is the Paris-Lyon (France) line, constructed in 1981 through generally flat terrain at a cost of $8.1 million CAD(2009)/km, the second lowest is the Madrid-Lleida (Spain) line through varied terrain at $13.4 million CAD(2009)/km and the highest is the Bologna-Florence (Italy) line at $113.4 million CAD(2009)/km where 95 percent of the tracks lied on viaducts or in tunnels.

EcoTrain estimated that the Quebec City-Windsor HSR E300+ project could cost approximately $12.8 million CAD(2009)/km, excluding rolling stock, land acquisition and planning costs, which is 58 percent higher than the Paris-Lyon line costs and 4 percent lower than the Madrid-Lleida line costs.

In the GAO Report, the California (Victorville) to Nevada (Las Vegas) HSR project is estimated to cost $14.6 million CAD(2009)/km including land acquisition and planning costs, but excluding rolling stock. This project lies along a relatively flat corridor. By starting at Victorville, the route avoids costly bridges and tunnels through the mountain range between Los Angeles and Victorville and avoids the high costs of building through high density areas of Los Angeles. This compares relatively well with the estimate of $14.9 million CAD(2009)/km, excluding rolling stock but including land acquisition and planning costs, prepared by EcoTrain for the Quebec City-Windsor HSR E300+ system.

By and large, the construction cost estimates for the Quebec City-Windsor HSR E300+ fall within the range of construction costs of similar HSR systems and tend to be at the low end of the ranges of systems studied, reflecting the relatively favourable terrain and topography throughout the Corridor.

7 OPERATION AND MAINTENANCE COSTS

A new and detailed estimation procedure was developed and used for updating operation and maintenance (O&M) costs. This was done separately for the F200+ and E300+ representative technologies, for the whole Quebec City – Windsor corridor.

The basis for estimating O&M costs was the service levels envisioned (Section 4.1, Representative Service), considering the conceptual system design that was developed (Section 4.2, Representative System), based on the representative technologies (Section 2.4, Representative Technologies Retained for Analysis), and the representative routes (Section 3.4, Description of Representative Routes). Details can be found in the technical report for Deliverable 6.2, Operations and Maintenance Costs, and its appendices.

7.1 Overall Approach

The overall approach adopted for updating the estimates of O&M costs was as follows:

- Start with a given system configuration
- Select first and last years of operation for estimation purposes, i.e. 2025 to 2055
- Define an operational plan for each function, based on the representative services described in Section 4.1
- Develop a cost model
- Evaluate its parameters.

7.1.1 Base Years

Costs were estimated in 2009 Canadian dollars (CAD), for the first and last year of the 30-year operation period considered for analysis, namely 2025 and 2055.

Assuming the HSR project is launched in 2011, and given the time required for system design and engineering, environmental assessment, construction and commissioning (as described below in Chapter 10, Implementation Schedule and Options), HSR operation could start in 2025. Assuming a 30 year operation period for the purpose of financial analysis, the final year of operation would be 2055.

Ridership forecasts were developed for 2031 and 2041, for reasons explained in Chapter 5, Ridership and Revenue. Ridership and cost estimates were reconciled by interpolation and extrapolation, as explained in the technical reports.

7.1.2 The O&M Cost Model and its Structure

For updating O&M cost estimates, EcoTrain used a cost model developed by DBI. This model has numerous similarities with other cost models used in feasibility studies for passenger rail projects, and was customized for the conditions of the Quebec City – Windsor Corridor, specifically for the selected representative technologies, routes, services, and railway systems presented previously.

7.1.2.1 Structure and Cost Elements

The following cost elements related to operations were included in the structure of the model:

- Train operation, including the cost of salaries and supplies for train crews and the operational control centre, and the cost of energy (whether diesel or electricity)
- Customer services, including the cost of salaries and supplies for on-board service staff, station and reservation, ticketing and booking at stations, Internet, telephone and counter sales, and advertising and merchandising
- Insurance and claims, property taxes, and right of way and usage fees paid to railways.

The following cost elements related to maintenance were included in the structure of the model:

- Rolling stock including the cost of salaries and supplies for personnel performing routine maintenance, major maintenance, and cleaning
- Infrastructure, including the cost of salaries, supplies, and the cost of operating maintenance equipment, for maintaining stations and shops, track, power supply and distribution, catenary, signals and telecommunications.

7.1.2.2 Work Requirements for Major Cost Items

For each major cost item, specific work requirements were developed on the basis of one or several of the following:

- The configuration of the HSR system
- The characteristics of the service provided
- The known amount of work that must be performed for the different O&M activities, in actual and comparable HSR operations[25]
- The known costs for the specific O&M activities, in actual and comparable HSR operations[26].

[25] Main sources of information are DB AG and German-French Cooperation for HSR systems (Deufraco)

The staff required for a given O&M function was based on the nature of the function (for instance, train-hours of service provided and number of on-board personnel in a trainset) and categories of staff required (for instance, train driver, train conductor, etc.).

7.1.2.3 Unit Costs: Average Annual Salary Costs

For each specific type of work to be executed, an annual average salary cost was developed, based on:

- Current Canadian wages and salary costs for similar types of work
- Current Canadian practices and productivities.

These costs include all taxes and social costs for the railway operator.

7.1.2.4 Supplies, Consumables, and Operational Management

Provisions were added for the cost of supplies and materials (in the order of 5 percent), and that of operational management (in the order of 15 percent), as a specific percentage for each cost item.

7.1.2.5 Ridership

City-to-city ridership forecasts were developed as part of Chapter 7, Demand Forecasting for 2031 and 2041. For operation planning, city-to-city ridership volumes were needed for the first and last year of the analysis period (2025 and 2055).To meet this objective a linear extrapolation was performed for each city pair. Results are shown on Tables 7-1 and 7-2 for F200+ and E300+ technologies respectively.

Table 7-1: Expected Ridership F200+

Functional segment	Trips per day and line section (both directions) F200+					
	Year	Québec - Montréal	Montréal - Ottawa	Ottawa - Toronto	Toronto - London	London - Windsor
Quebec City - Windsor	2025	6524	7986	9811	6112	1912
	2055	7329	9712	13386	8306	2570
Quebec City - Toronto	2025	6510	7859	9339	-	-
	2055	7316	9577	12767	-	-
Montréal - Toronto	2025	-	7474	9227	-	-
	2055	-	9077	12613	-	-
Toronto - Windsor	2025	-	-	-	5499	1781
	2055	-	-	-	7471	2397

[26] Main sources of information are DB AG, DB Systemtechnik, Munich and DB Systel, Frankfurt

Table 7-2: Expected Ridership E300+

Functional segment	Trips per day and line section (both directions) E300+					
	Year	Québec - Montréal	Montréal - Ottawa	Ottawa - Toronto	Toronto - London	London - Windsor
Quebec City - Windsor	2025	7216	9043	11336	6127	2198
	2055	8121	11032	15462	8313	2946
Quebec City - Toronto	2025	7200	8882	10778	-	-
	2055	8104	10855	14723	-	-
Montréal - Toronto	2025	-	8387	10610	-	-
	2055	-	10204	14490	-	-
Toronto - Windsor	2025	-	-	-	5414	2050
	2055	-	-	-	7345	2757

A trip assignment to the different line segments gives the corresponding passenger load, as illustrated on Table 7-3:

Table 7-3: Typical Trip Assignment

Trips between			Daily, 2-way
Quebec City	And	Trois-Rivières	6 687
Trois-Rivières	And	Montréal	7 216
Montreal	And	Ottawa	9 043
Ottawa	And	Kingston	10 301
Kingston	And	Toronto	11 336
Toronto	And	London	6 127
London	And	Windsor	2 198
The above values are for 2025, with E300+			

Comparing the different passenger loads along the line, five main line sections with similar loads can be distinguished as a basis for operation planning: Quebec City – Montreal; Montreal – Ottawa; Ottawa – Toronto; Toronto – London; and London – Windsor. The traffic loads are quite balanced within these sections, whereas there are other noticeable differences between the sections.

7.1.2.6 Travel Times

City-to-city and station-to-station travel times were estimated using the DECrun train simulator, based on the representative routes and alignments defined previously. The calculation of running times was performed for trains stopping at all intermediate stations and was based on:

- The installed power of the trains: 4,000 kW for F200+ system; and 8,000 kW for E300+ system
- The running resistance of the trains

- The resistance of curves and gradients
- Speed limitations resulting from track geometry and other restrictions.

The minimum running times produced by the train simulator were increased by recovery margins to guarantee timekeeping according to UIC recommendations, as follows:

- One minute per 100 km plus 5 percent of the minimum running time for F200+
- One minute per 100 km plus 7 percent of the minimum running time for E300+.

In addition, the following assumptions were used for calculating the total travel times:

- The dwell time in intermediate stations was one minute (2 minutes at Ottawa station)
- Changing trains at Toronto or Montreal would take 15 minutes on average.

Travel times were thus calculated between all stations and are shown for major city pairs in Table 7-4. This table shows that downtown to downtown travel times between cities with a HSR station would be competitive with air services.

Table 7-4: Travel Times for Major City Pairs

City Pair	Existing VIA Rail Service[27]	F200+	E300+
Quebec City – Montréal	3 hr 09 min	1 hr 49 min	1 hr 26 min
Montréal – Ottawa	1 hr 55 min	1 hr 11 min	0 hr 57 min
Ottawa – Toronto	4 hr 36 min	2 hr 25 min	1 hr 50 min
Montréal – Toronto	5 hr 12 min	3 hr 38 min	2 hr 47 min
Toronto – London	2 hr 07 min	1 hr 05 min	0 hr 51 min
Toronto – Windsor	3 hr 59 min	2 hr 12 min	1 hr 33 min

Source: VIA Rail schedules for 2010; estimates by EcoTrain for F200+ and E300+ (Deliverable 7: Demand Forecasting)

7.1.3 Train Schedules

The object of train scheduling is to produce representative schedules for costing purposes. As the ridership forecast does not provide details on annual, weekly, and daily fluctuations of traffic flows the same assumptions as in the QOHSRPS have been used for developing the schedules. The main features of these assumptions are as follows.

[27] Running times based on 2010 VIA Rail schedules are average for the number of trains per day on each route.

There are two traffic periods in the year:

- Off-season during 40 weeks with ridership at 91 percent of the mean weekly annual ridership
- High season during 12 weeks with ridership at 130 percent of the mean weekly annual ridership.

Different traffic loads for the days of the week:

- Weekdays with 110 to 125 percent (Friday) of the mean daily average
- Saturdays with 65 percent of the mean daily average
- Sundays with 80 percent of the mean daily average.

The 17 to 18 operating hours of the day between about 6:00 and midnight are divided into three periods:

- Morning peak approximately four hours, from 6:00 to 10:00
- Afternoon peak approximately four hours from 14:30 to 18:30
- Off-peak periods during midday and in the evening.

The additional passengers during the high season would be mainly distributed to off peak hours and the weekend. In the main peak of high season, Friday ridership would be only about 12 percent higher than for Friday ridership in off-season. A small percentage of the additional demand would not be served, in order to avoid super-peak conditions requiring additional trainsets for only ten to fifteen days of the year.

The distribution of travel during the day was estimated as follows:

- About 50 percent of the daily trips would occur during the main peak, either the morning peak or the afternoon peak, according to the line section and the direction of travel.
- About 20 percent of the daily trips would occur during the secondary peak, either in the morning or in the afternoon, as for the main peak.
- About 30 percent of the daily trips would occur during off-peak hours.

Target load factors have been defined ranging from 60 percent (off-peak hours on off-season days) to 85 percent (main peak hours on off-season days), to a high of 95 percent (main peak hours on high season days).

Representative schedules have been developed for off-season Fridays. These schedules could be adjusted for Monday to Thursday operations with only minor modifications. Schedules were also developed for weekend service on off-season Saturdays and Sundays.

No specific schedules were developed for high season Fridays. In fact these are the 12 super-peak days of the year when an operator would operate as many trains as possible given the fleet availability and infrastructure capacity. Also specific schedules were not developed for high season Saturdays and Sundays where demand would be lower that during the week and could be easily satisfied with the available equipment and staff.

The resulting daily trainset frequencies per direction for the two representative technologies, the years 2025 and 2055 and all line segments are shown in Table 7-5.

Table 7-5: Daily Trainsets[28] per Direction, 2025 and 2055

Line Segment	F200+		E300+	
	2025	2055	2025	2055
Quebec City - Montréal	15	19	19	20
Montreal - Ottawa	20	22	20	25
Ottawa - Toronto	22	29	25	32
Toronto - London	13	20	14	20
London - Windsor	8	10	8	10

Representative schedules for off-season Monday to Friday are presented in the technical report.

7.1.4 Fleet Size

The estimation of the fleet size was based on the following assumptions:

- Service requirements were based on the standard schedule for the off-season Friday
- Average load factor for the main peak hours was assumed at 85 percent
- Approximately one hour would be needed for cleaning and catering between the arrival of a train at a terminal station and its subsequent departure
- Service reliability is of such importance that one spare trainset should be kept at each of the two hubs of the system - Montréal and Toronto – ready to be used at any time.

Maintenance spares were calculated based on an availability rate of 90 percent for the F200+ and 95 percent for E300+ trainsets. For the first years of operation, availability is 5 percent lower due to teething troubles of the trains and lack of experience of the maintenance crews with the new trains.

[28] Actual number of trains may be different as some trains would run as double trainsets.

No additional trainsets are included in the fleet to serve the super-peaks at the twelve high season Fridays. On those exceptional days, a 95 percent mean peak load factor was accepted and peak periods may begin earlier and end later than on off-season Fridays. Furthermore, train maintenance would be organized in a way that almost the entire fleet would be available for operation.

Results for the years 2025 and 2055 and for F200+ and E300+ technologies are presented in Table 7 - 6.

Table 7-6: Number of Trainsets Required

Mode	F 200+		E 300+	
	2025	2055	2025	2055
Diesel	36	46		
Dual-mode	12			
Electric		15	46	56
Total	48	61	46	56

7.2 Estimating Annual Costs for Operations

This section explains how operation costs were estimated. This has been done separately for the following major elements identified in Section 7.1.1:

- Train operations
- Customer services
- Insurances, taxes, and fees.

7.2.1 Basic Assumptions

The following are assumptions specific to the operation costs, in addition to those mentioned earlier for all annual costs.

7.2.1.1 HSR Operator

All costs were estimated under the assumption that operations activities would be the responsibility of the HSR operator and performed by its own staff.

7.2.1.2 Service Operation and Staff Working Days

The HSR would be operated 365 days a year. Therefore to calculate the number of operational staff a factor should be added to cover holidays, weekends, vacation, sickness and training:

- Weekends: 104 days
- Public holidays: 11 days;
- Vacation: 15 days;
- Sickness: 12 days:
- Training: 3 days.

The allowance for the required coverage of 365 days amounts to 66 percent. That means 1.66 equivalent employees are needed to cover a 365-day, one-shift job.

7.2.2 Costs for Train Operation

7.2.2.1 Train Crew

This major cost item included all activities related to driving trains in normal operation and to and from stabling yards. These activities required the following personnel on each trainset in service: one train driver, one chief conductor, and two conductors. When trains are operated as double trainsets only one train driver would be needed for the two coupled trainsets. Train runs to and from stabling yards require one train driver only. For the F200+ system personnel for the operation of diesel filling stations was added.

7.2.2.2 Energy Consumption

The annual quantity of energy consumed for train operation was calculated based on:

- The total (in-service and out-of-service) train-km travelled
- The number of trainsets per train
- The specific energy consumption (litres/km or kWh/km) of each representative technology.

The specific energy consumption was determined by using the DECrun train simulator. Provisions were added for energy consumed for other purposes than train traction (e.g. air conditioning, heating). The average consumption per single trainset was calculated as:

- 4.5 litres/trainset-km for F200+
- 27 kWh/trainset-km for E 300+.

The annual cost for energy consumption was calculated based on the estimated consumption and on unit costs as follows:

- The unit cost of diesel fuel per litre for F200+: $0.62 per litre
- The electrical energy rates for E300+: $0.10/kWh for Ontario and $0.073/kWh for Québec.

7.2.2.3 Operational Control Centre

This major cost item included all activities related to supervising train operation from an operational control centre (OCC).

These activities required the following personnel at the OCC, during the full period of operation:

- 4 line controllers at any time during operating hours
- 1 network supervisor
- 1 OCC manager
- 2 information controllers
- 2 security managers
- 2 power controllers
- 1 crew controller.

Taking into account the number of shifts per day, number of workplaces, allowance for full year operation, and an additional reserve of 10 percent for stand–by, a total of 66 employees would be needed to operate the OCC for the entire corridor.

7.2.3 Costs for Customer Services

7.2.3.1 On Board Service Staff

This cost item included all activities related to providing on-board services (food and beverage supply, newspapers, etc.) to passengers. These activities required two passenger service agents per trainset.

7.2.3.2 Station Operation

This major cost item included all activities related to: ticket sales at counter; providing information to travellers; servicing ticket vending machines; providing security in the station; supervising platforms; and cleaning. These activities required personnel in every station: sales personnel; information agents; ticket machines servicers; security agents; platform supervisors; and cleaning staff.

The number of hours of work required for each of those activities was estimated for each station, based on minimum service standards, hours of operation, and passenger traffic levels and distribution by time (peak and off peak hours).

The total volume of tickets sold (and their distribution by origin station) was based on ridership forecasts and the total number of ticketing transactions was based on an assumed proportion of return tickets sold. The number of sales counters was calculated for each station using the percentage of sales at counters (18 percent), the percentage of return trips (80 percent), and a 4-minute average processing time at counter.

7.2.3.3 Telephone Sales

This cost item included all activities related to ticket sales via telephone. This activity required personnel at a call centre. The number of hours of work required was based on the percentage of sales via telephone (10 percent), the percentage of return trips (80 percent), and an average processing time at the telephone (four (4) minutes).

7.2.3.4 Ticketing and Reservation System

This major cost item included all activities related to ticketing and reservation system, whether tickets would be sold by third parties, on the HSR operator's own website, or in stations by automatic ticket machines or at the counter. For the calculation, the following percentages of ticket sales were assumed:

- 12 percent of sales by third parties (with a commission of 11 percent per ticket)
- 35 percent of sales via Internet
- 25 percent of sales via automatic ticketing machines.

Based on calculations for 10 million trips per year the operating cost for a ticketing and reservation system would amount to $2 CAD per trip. About 80 percent of all tickets would be purchased using credit cards, for which an average charge of 2.5 percent per transaction would be taken into account.

7.2.3.5 Advertising

Following the results of the QOHSRPS, the advertising budget was set at two percent of passenger revenues.

7.2.4 Costs for Insurances/Taxes/Fees

7.2.4.1 Insurance and Property Taxes

Following the results of the QOHSRPS, the allowances for insurance and property taxes were set at respectively 4 percent and 3 percent of the overall O&M costs.

7.2.4.2 Right-of-Way and Track Usage Fees

Because HSR would not run within its own right-of-way on several segments of the line, rights of way and track usage fees must be paid to the owners of the rights of way. Under present conditions, this would include: CN, CP, QGR, VIA Rail, and GO Transit.

Assuming that the entire infrastructure is completely built new and O&M costs would be paid by the HSR operator, these costs were estimated as a property lease for land based on:

- The average cost of new RoW acquisition
- An average Canadian interest rate
- An average width of existing lines RoW of 30 m.

This leads to a fee of $40,000 CAD per year per track km.

7.3 Estimating Annual Costs for Maintenance

This section explains how maintenance costs were estimated. This included the following major cost items:

- Track
- Power supply and distribution
- Signals and telecommunications
- Stations and shops
- Rolling stock.

Costs were estimated under the assumption that maintenance activities (as defined in this section) would be the responsibility of the HSR operator and performed by its own staff or by third parties under contract.

All HSR maintenance would be performed from permanent bases that could carry out maintenance of tracks, earthworks, bridges and other structures, power supply and distribution, catenary, signals and telecommunications in one facility. Number, size and spacing of these bases would depend on location of stations and crossovers and calculated reaction times, as well as the maximum snow clearing time on the line. For the purpose of this study, a reaction time of about 30 to 40 minutes has been assumed, and the number of maintenance bases has been determined accordingly.

7.3.1 Costs for Maintaining Tracks, Earthworks, and Structures

This major cost item included all activities related to inspecting, servicing, and maintaining tracks, earthworks, bridges and structures, and rolling stock and equipment. These activities were mostly related to track.

An extensive maintenance program would be required to keep the tracks in good and safe condition, so as to minimize failures that could impede train operations. This program would include the following main activities:

- Regular track inspections to evaluate track conditions with respect to their specified conditions
- Track servicing to maintain track conditions within specified limits
- Track maintenance to restore tracks to their specified conditions if current conditions differ from specified conditions.

In total 76 persons, including head office maintenance staff and staff at the 19 maintenance bases, would be required for the track work maintenance for the entire HSR from Quebec City to Windsor.

7.3.2 Costs for the Power Supply and Distribution System

7.3.2.1 For the F200+ System

Costs included the maintenance of low-voltage equipment (e.g. elevators, escalators, lighting equipment, electrical switch heaters, etc.). In total 76 persons, distributed between 19 electrical maintenance bases, would be required for the maintenance of electrical equipment for the entire HSR from Quebec City to Windsor.

7.3.2.2 For the E300+ System

Maintenance of the overhead catenary system included all measures to preserve the planned status and to determine and restore operating equipment and installations if required. As the HSR would be one of the only two electrified rail systems in Eastern Canada, all maintenance of catenary and substations would be performed by the HSR operator. Furthermore, this staff would handle all kinds of emergencies. Also included was the maintenance of low-voltage equipment (e.g. elevators, escalators, lighting equipment, electrical switch heaters, etc.). Maintenance activities included inspections, diagnostics, and corrective maintenance consisting of fault repairs, defect correction, and full repair.

In total 277 persons, distributed between 5 maintenance centers and 14 maintenance units, would be required for the maintenance of power supply and electrification of the entire line from Quebec City to Windsor.

7.3.3 Costs for the Signalling and Telecommunication System

For signals and telecommunications (S&T), preventive maintenance would be performed to reach a very high reliability and performance level of the entire system and minimize technical failures. An extensive maintenance program would be required to keep the S&T system in as good and safe condition as possible.

In total 76 persons, distributed between an S&T maintenance head office, located at the OCC, and 19 S&T maintenance bases would be required for the maintenance of S&T for the entire HSR from Quebec City to Windsor.

7.3.4 Costs for Maintaining Stations and Shops

Two employees would be needed for the maintenance of each workshop and each major station. One person would be sufficient for minor stations. Material costs were calculated as a portion of capital costs distributed over 30 years of operation.

7.3.5 Costs for Rolling Stock Maintenance and Cleaning

7.3.5.1 Maintenance

The work required for and costs associated with maintaining rolling stock differed for each representative technology. The estimation approach was essentially the same for each technology. Maintenance included all activities related to conducting the necessary and planned controls, inspections, and maintenance interventions, as well as unscheduled repair, as listed in Table 7-7.

Table 7-7: Rolling Stock Maintenance Requirements

	Activity	Frequency: every
By operator, in HSR shops in Montréal and Toronto		
a	Bogies, brakes, and train control	4,000 km
b	Overall inspection	20,000 km
c	Maintenance level 1: b + air conditioning, interior	80,000 km
d	Maintenance level 2: c + bearings and couplers	240,000 km
e	Maintenance level 3: d + compressors and transformers	480,000 km
f	Revision level 1: e + change of bogies	1,200,000 km
By manufacturer in his shops		
	Revision level 2: f + other main components	2,400,000 km
	Painting	5-8 years
	Retrofit: interior, converters (in the middle of life time)	15-20 years
	Component refurbishing	

The number of hours of work required for each of those activities (which would vary from year to year depending on kilometres travelled by the different trainsets) and the corresponding costs were estimated based on experience with comparable technologies. Comparable unit costs have been derived from German rolling stock maintenance facilities for:

- Personnel cost per train-km
- Material cost per train-km
- Cost for heavy maintenance per train-km (overhaul usually done by manufacturer)

The following provisions and allowances were added:

- As a proportion of work hours required, for unscheduled maintenance and irregular train arrival patterns at the maintenance shops
- As a proportion of personnel costs, for the cost of supplies and materials used (office material, telephone, etc), and for operational management.

7.3.5.2 Cleaning

This major cost item included all activities related to:

- Cleaning the interior of each train after each run
- Cleaning the interior of each train at the end of each service day
- Cleaning the exterior of every train in service every three days.

These activities would require cleaning staff in stations and in yards, and train drivers to move trains through train wash installations.

7.4 Updated Cost Estimates

Table 7-8 presents foreseeable O&M staff and costs for a full year of operation (2025) for both F200+ and E300+ technologies according to the following categories:

- Train operation
- Customer services
- Rolling stock and equipment maintenance
- Infrastructure maintenance
- Other costs.

It also shows the ration of O&M costs for E300+ compared to F200+ system for each of these categories. All costs are in million CAD (2009) per year.

Table 7-8: Updated O&M Cost Estimates for Representative Services, 2025

	F200+			E300+			E300+ / F200
	Staff			Staff			
Train operation							
Train Crews	283	29.9	6.1%	302	32.0	6.1%	106.9%
Energy Consumption		45.0	9.2%		43.0	8.3%	95.5%
Control Centre	55	4.8	1.0%	66	5.6	1.1%	116.7%
Transportation Administration	47	5.0	1.0%	52	5.4	1.0%	108.9%
Sub-Total for Train Operation (M$/yr.)	*385*	*84.7*	*17.2%*	*450*	*86.0*	*16.5%*	*101.5%*
Costumer Services							
On-board Service Staff	125	7.9	1.6%	140	8.8	1.7%	112.0%
Personnel in Stations	333	21.3	4.3%	333	21.3	4.1%	100.0%
Ticketing and Reservations Transactions	102	61.0	12.4%	105	67.2	12.9%	110.2%
Telephone Counter Sales	24	1.1	0.2%	26	1.2	0.2%	108.8%
Advertising		22.8	4.6%		25.5	4.9%	111.9%
Customer Service Administration	93	9.8	2.0%	97	10.1	1.9%	103.4%
Sub-Total for Customer Services (M$/yr.)	*677*	*123.9*	*25.2%*	*700*	*134.2*	*25.8%*	*108.3%*
Equipment Maintenance							
Routine Maintenance – Labour	387	32.8	6.7%	353	29.9	5.8%	91.1%
Routine Maintenance – Material		47.8	9.7%		29.9	5.8%	62.7%
Major Maintenance (contracted out)		16.4	3.3%		13.3	2.6%	81.0%
Cleaning	157	7.3	1.5%	170	7.8	1.5%	107.5%
Maintenance Administration	60	6.3	1.3%	58	6.0	1.2%	96.1%
Sub-Total for Equipment Maintenance (M$/yr.)	*604*	*110.6*	*22.5%*	*581*	*87.0*	*16.7%*	*78.7%*
Infrastructure Maintenance							
Routine Maintenance	264	20.3	4.1%	465	35.4	6.8%	174.1%
Purchased Services		11.8	2.4%		11.8	2.3%	100.5%
Materials		15.7	3.2%		33.5	6.4%	212.8%
Maintenance Administration	63	6.7	1.4%	112	11.7	2.3%	176.1%
Sub-Total for Infrastructure Maintenance (M$/yr.)	*327*	*54.5*	*11.1%*	*577*	*92.4*	*17.8%*	*169.6%*
Other Costs							
Executive Administration, Marketing	197	20.7	4.2%	225	23.6	4.5%	114.2%
Insurance and Claims		16.4	3.3%		17.6	3.4%	107.3%
Property Taxes		12.2	2.5%		13.1	2.5%	107.3%
Usage Fees		24.0	4.9%		18.8	3.6%	78.3%
Contingencies		44.7	9.1%		47.3	9.1%	105.8%
Sub-Total for Other Costs (M$/yr.)	*197*	*118.1*	*24.0%*	*225*	*120.5*	*23.2%*	*102.0%*
Total	2 191	491.8		2 502	520.2		105.8%

All amounts in million 2009 Canadian dollars, for a full year of operation and maintenance costs in 2025.
Unless mentioned or implied otherwise, costs shown include salaries, salary costs, and supplies.

8 SOCIAL AND ENVIRONMENTAL IMPACTS

This section discusses environmental and social issues associated with implementing a High Speed Rail (HSR) system in the Quebec City – Windsor Corridor. As such it is a summary of the technical report for Deliverable 9, Social and Environmental Impacts.

8.1 Context and Objective

Development of HSR service from Quebec City to Windsor would have impacts on the natural and social environments. The present section identifies issues that should be considered when analyzing the feasibility of HSR based on the representative technologies, routes and alignment options presented in earlier sections of this report.

8.2 Changes in the Environmental Evaluation Since 1995

8.2.1 Trends in Environmental Evaluation

The following changes to the environmental assessment process and evaluation intervened since 1995:

- An integration of environmental concerns early in the project development process
- A greater level of participation and consultation with local stakeholders during the project planning process
- The need to harmonize provincial and federal environmental assessment processes.

Environmental issues would influence the design of projects, while related studies would provide the opportunity to foresee environmental effects so that required appropriate mitigation could be integrated into the project design.

Public engagement at an early stage in the environmental assessment process could reduce and resolve potential issues that stakeholders and/or agencies might have with the project. Community members, First Nation groups and agencies can contribute local knowledge relating to the natural and social environments and offer new perspectives on the project. This increased community involvement and integration of local knowledge could help to define the major issues to be faced and resolve potential project-related conflicts within the community. Consultation with the public and agencies has become a critical component of the environmental assessment process.

Environmental assessment (EA) procedures have been developed by different levels of government in order to meet their respective requirements. Depending on the project, it may be necessary to meet the EA processes of multiple levels of government. Recently, it has become common to harmonize the processes to ensure that information presented is consistent between the different jurisdictions and promotes project efficiency. Agreements between various authorities have been developed to allow for such harmonization.

8.2.2 Evolution of Social Trends on the Environment and HSR

Social perceptions of environmental issues have changed since the mid-1990s in Canada. A study completed by Statistics Canada in 2000 indicated that nine out of ten Canadians rate the environment as one of their top concerns and eight out of ten Canadians believe that environmental protection should be given priority over economic growth. Environmental issues and sustainability have become more prominent for Canadians over the past ten years. Both industries and private citizens in Canada are becoming more conscious of environmental issues. This heightened importance of environmental issues and sustainability has been reflected in amendments to federal and provincial legislation.

8.3 Legislative Framework

The legislative framework in Canada, Ontario, and Quebec identifies the statutory requirements for the development of a large-scale rail project. Since the completion of the QOHSRPS in 1995, legislative changes have been enacted at both the federal and provincial levels. The purpose of the legislative review was to identify the changes in applicable legislation and their potential effects on the feasibility of the HSR project.

8.3.1 Federal Environmental Legislation

The following federal environmental legislation, which has been enacted or amended since 1995, was reviewed to identify their implications on the project and the permits and/or authorizations potentially required. Selected relevant guidelines and policies were also reviewed.

- Canadian Environmental Assessment Act (Enacted: 1995; Latest Amendment: 2005)
- Canadian Environmental Protection Act (1999; 2007)
- Species at Risk Act (2002; 2009)
- Navigable Waters Protection Act (1985; 2009)
- Kyoto Protocol Implementation Act (2007; 2007)
- National Capital Act (1985; 2007)

- Indian Act (1985; 2009)
- Canada National Parks Act (2008)
- Fisheries Act (1985; 2009)
- Migratory Birds Convention Act (1994; 1994)
- Noise Assessment (Health Canada Guidelines)
- Federal Policy on Wetland Conservation.

The legislation reviewed was not expected to impact the feasibility of HSR. However, upon further investigation (see Section 9, Impacts on the Transportation System in the Corridor), requirements of the above legislation and applicable regulations, including specific assessments, hearings, authorities, and/or permits, should be satisfied on a case by case basis.

8.3.2 Federal Rail Legislation

For Federally regulated railways, the development and enforcement of policies and programs relating to rail transportation is the responsibility of Transport Canada and the Canadian Transportation Agency. The following federal railway legislation was reviewed:

- Canada Transportation Act (1996; 2008)
- Railway Safety Act (1985; 2008)
- Railway Relocation and Crossing Act (1985; 1999)
- Canadian Expropriation Act (1985).

The legislation reviewed was not expected to impact the feasibility of the HSR. However, upon further investigation, requirements under this legislation and the applicable regulations including specific assessments, hearings, authorities, and/or permits, may need to be satisfied on a case by case basis.

In addition to Federal rail legislation, there are a number of regulations that may impact the implementation of HSR. It was not expected that these regulations would affect the feasibility of HSR, as they are more applicable to its operation phase. However, during the preliminary engineering stage the requirements of these regulations would need to be addressed.

8.3.3 Ontario Legislation

The Ontario Ministry of the Environment (MOE) is the provincial authority responsible for establishing and enforcing environmental policy and regulations in Ontario. The Ontario Ministry of Municipal Affairs and Housing (MMAH) has also established policies for the protection of the natural environment in Ontario through the implementation of the Greenbelt Act, 2005 and the Oak Ridges Moraine Conservation Act. The following Ontario legislation in relation to the environment and railway development was reviewed:

- Environmental Assessment Act, (1990; 2006)
- Environmental Protection Act (1990; 2009)
- Endangered Species Act (2007)
- Niagara Escarpment Planning and Development Act (1973; 2009)
- Bridges Act (1990; 2006)
- Ontario Heritage Act (1990; 2006)
- Shortline Railways Act (1995; 2006)
- Conservation Authorities Act (1990; 2009)
- Greenbelt Act (2005; 2009)
- Places to Grow Act (2005; 2009)
- Oak Ridges Moraine Conservation Act (2001; 2006)
- Provincial Policy Statements (2005)
- Ontario Regulation 23/108 under the Environmental Assessment Act for Transit Projects and Greater Toronto Transportation Authority Undertakings.

Although the review showed that there were no policies that would specifically limit the feasibility of the project, requirements set out in the Acts and Regulations, including specific assessments, hearings, authorities, and/or permits, may need to be satisfied on a case by case basis.

8.3.4 Quebec Legislation

The Ministry of Sustainable Development, Environment and Parks (Ministère du Développement durable, de l'Environnement et des Parcs MDDEP) and the Ministry of Natural Resources and Fauna (Ministère des Ressources naturelles et de la Faune MRNF) are the authorities responsible for establishing and enforcing environmental policy and regulations in Quebec.

The following legislation was reviewed for the present study:

- Environment Quality Act (1972; 2009)
- Natural Heritage Conservation Act (2002; 2006)
- Conservation and Development of Wildlife Act (2002; 2006)
- Preservation of Agricultural Land and Agricultural Activities Act (1978; 2006)
- Land Use Planning and Development Act (1979; 2009)
- Sustainable Development Act (2006; 2008)
- Threatened or Vulnerable Species Act (1989; 2006)
- Forest Act (1986; 2008)
- Parks Act (1977; 2008)
- Cultural Property Act (1972; 2006)
- Expropriation Act (1973; 2005)
- Railway Act (1993; 1994)
- Safety in Guided Land Transportation Act (1988; 2001)
- Noise regulations on construction sites (provincial and municipal).

Although the review showed that there were no policies that would specifically limit the feasibility of the project, requirements set out in the Acts and Regulations, including specific assessments, hearings, authorities, and/or permits, may need to be satisfied on a case by case basis.

8.4 Analysis of Environmental and Social Issues

8.4.1 Identification of Environmental Issues

Eleven environmental issues were selected, inventoried and mapped for the present study, six of them pertained to the natural environment, and five to the social environment.

The potential environmental impacts reflect those issues that were known at this level of study. The HSR routes were only representative, and could not be precisely mapped at this stage. Future studies would require detailed review, and additional impacts would be evaluated at the EA stage.

Natural Environment:

- Substantial Watercourses (includes rivers, streams, brooks, or creeks)
- Wetlands
- Natural Protected Areas
- Sensitive Fish Habitats
- Prime Agricultural Lands (Categories 1 and 2 soils as defined by Natural Resources Canada)
- Resource Extraction Areas.

Social Environment:

- Residential Areas
- Recreation and Tourist Areas
- Historical or Cultural Site and Cemeteries
- Federal Reserves, including First Nation reserves, Land Claim Settlement Lands, and military bases
- Waste Management Sites

These issues were selected based on the following criteria:

- Elements that were analyzed in previous studies;
- Issues that were associated with specific Legislation or regulation;
- Professional judgment of the potential for impact either by HSR construction or operation;
- Value given to these elements by the public;
- Data accessibility (data sources and data coherence and uniformity between Quebec and Ontario);
- Level of precision consistent with the scope of the study.

8.4.2 Results

The results of the analysis of environmental issues were presented in a series of maps that were appended to the technical report for Deliverable 9, Analysis of Environmental and Social Impacts. These maps showed the representative routes for F200+ and E300+ where[29] different environmental issues could potentially occur. These maps were complemented by a detailed discussion of the issues found on every segment of the representative routes.

[29] These are approximate locations for representative routes. Precise locations will only be known when site investigations are performed once definitive, as opposed to representative, routes are chosen.

Tables 8-1 and 8-2 summarize theses results and identify, on a segment-by-segment basis, interactions between the issues identified above and the HSR representative routes retained for analysis.

Table 8-1: Natural and Social Environmental Interactions with the F200+ Representative Route

		Segment from Representative Route						
Issue	**Measure of Impact**	**Québec to Trois-Rivières**	**Trois-Rivières to Montréal**	**Montréal to Ottawa**	**Ottawa to Oshawa**	**Oshawa to London**	**London to Windsor**	**Total**
Natural Environment								
Substantial Watercourses	Number of crossings	5	2	3	4	2	4	16
Wetlands	Number of interactions	2	5	3	12	3	1	25
Natural Protected Areas	Number of interactions	8	2	5	2	3	0	20
Sensitivie Fish Habitat	Number of interactions	0	2	6	2	16	10	26
Prime Agricultural Land	Kilometres of interactions	23	74	125	217	168	122	607
Resource Extraction Area	Number of interactions	0	2	4	10	2	1	18
Social Environment								
Residential Areas	Kilometres of interactions	9	22	32	28	103	9	194
Recreation and Tourist Sites	Number of interactions	10	7	13	16	25	13	71
Historic or Cultural Site	Number of interactions	1	6	7	5	9	3	28
Federal Reserve	Number of interactions	0	1	0	1	0	0	2
Waste Management Site	Number of interactions	0	1	1	1	0	0	3

Table 8-2: Natural and Social Environmental Interactions with the E300+ Representative Route

		Segment from Representative Route						
Issue	**Measure of Impact**	**Québec to Trois-Rivières**	**Trois-Rivières to Montréal**	**Montréal to Ottawa**	**Ottawa to Oshawa**	**Oshawa to London**	**London to Windsor**	**Total**
Natural Environment								
Substantial Watercourses	Number of crossings	5	2	3	5	1	5	16
Wetlands	Number of interactions	3	4	2	13	2	1	24
Natural Protected Areas	Number of interactions	8	2	1	2	3	0	16
Sensitivie Fish Habitat	Number of interactions	0	2	4	5	17	11	28
Prime Agricultural Land	Kilometres of interactions	21	74	110	187	197	122	589
Resource Extraction Area	Number of interactions	0	2	5	7	3	0	17
Social Environment								
Residential Areas	Kilometres of interactions	10	22	32	18	92	92	174
Recreation and Tourist Sites	Number of interactions	10	7	12	13	23	23	65
Historic or Cultural Site	Number of interactions	1	6	5	9	8	8	29
Federal Reserve	Number of interactions	0	1	0	0	0	0	1
Waste Management Site	Number of interactions	0	1	0	2	0	0	3

8.5 Additional Natural and Social Environmental Issues

Additional environmental issues that could not be mapped at the scale of this project are identified below. These issues would need to be taken into consideration during the design, engineering, construction and operation stages of the HSR project, when identifying specific locations for these issues would be obtained through detailed site investigation, which could not be undertaken as part of the current review, given the limited scope of the study.

The importance of the impacts associated with these issues and corresponding mitigation measures would need to be evaluated later as part of detailed engineering studies. In addition, coordination with the appropriate provincial and federal ministries would need to be carried out to ensure that the project does not negatively impact the existing natural and social environments.

8.5.1 Natural Environment

8.5.1.1 Erosion and Slope Instability

Potential impacts to surface water quality may result from the construction activity on the HSR line (e.g. grading, which removes vegetation, exposing soil to wind and water erosion).

Erosion occurs in areas with a combination of erosive soil types and steep slopes. This could result in sedimentation that ultimately flows into surface water.

8.5.1.2 Drainage and Storm Water Management

Existing storm water drainage conditions would need to be evaluated and mapped at the preliminary engineering stage to determine if they could become an issue and how to address them.

Construction activities of the HSR as well as vehicular traffic and use of heavy machinery could affect the natural drainage of the work site through soil compaction and limited water circulation.

8.5.1.3 Surface and Groundwater Quality

Surface water quality and groundwater contamination could occur during construction activities and project implementation. Traffic and use of heavy equipment during site preparation activities, as well as construction and operation activities, present a risk of surface or groundwater contamination through the infiltration, leaching or runoff of polluting substances in the event of accidental or uncontained discharge.

8.5.1.4 Soil Contamination

During construction, vehicular traffic and the use of heavy equipment for site preparation present a risk of soil contamination through the infiltration of polluting substances in the event of accidental or uncontained discharge. Furthermore, if any contaminated soils (or the appearance of it) were found during construction, they should be managed in compliance with the appropriate regulations and procedures.

8.5.1.5 Flora and Fauna (including Species at Risk)

Flora and fauna refer to the indigenous plant and wildlife species found in a particular geographic region. Detailed analysis of the plant and wildlife species that exist along the representative HSR corridor would need to be undertaken later at the preliminary engineering stage.

For safety reasons, fencing should be erected on both sides of the RoW, as a mitigation tool to reduce the number of animal and human fatalities. Fencing should provide animal passes to prevent the isolation of wildlife habitat and/or animal accumulation in a specific area. Secondary effects could occur as a result of the primary effects, including increased pressure on the vegetation and forest regeneration.

8.5.2 Social Environment

8.5.2.1 Land Use

Effects on existing land use, land use compatibility and potential changes in land use as a result of HSR implementation should be considered as part of future Environmental Assessment (EA) approvals. One way to estimate potential impacts on land uses would be to look at land uses that typically are found in the vicinity of railways and assume that similar land uses would occur along the future HSR RoW. The HSR would have different impacts on sensitive land uses as opposed to urbanized or open space.

The implementation of HSR in a new RoW may promote changes to land uses over time. Due to noise and nuisance issues, sensitive land uses may slowly relocate further from the HSR corridor. In addition, cities and towns with a HSR station may experience different growth patterns than other cities and towns, and this impact may extend to suburban areas along the future HSR RoW.

8.5.2.2 Demographics and Socio-Economic Effects

The implementation of HSR could have effects on residents living close to the rail line or stations. Both positive and negative effects should be considered in terms of the existing demographics, social, and economic conditions.

Demographic data would include:

- Population characteristics
- Income distribution
- Employment.

Social and economic effects would include:

- Increases or decreases in property value
- Property displacement and acquisition
- Job creation and loss
- Loss or gain of connectivity and access

- Nuisance effects (noise, vibration and dust) during construction and during operation
- Visual effects.

8.5.2.3 *Property Impacts*

Property impacts would be examined in further detail during the evaluation of the various alternatives at the EA stage. Extensive public consultation would be conducted with property owners and the EA would document property impacts for the preferred alternative.

8.5.2.4 *Infrastructure and Public Utilities*

A detailed EA study along the selected HSR alignments should consider both above and under ground infrastructure and public utilities and their potential effects on HSR development. Utilities to take into consideration are water mains and sewers, high-voltage electric line, communication systems, and natural gas and other pipelines. The alignment should be designed, where possible, to avoid major infrastructure components and/or incorporate linear infrastructure into the design of the HSR alignment.

8.5.2.5 *Electromagnetic Fields*

Electromagnetic fields occur naturally within the earth and as a result of human activity, including electricity generation, transmission and local distribution, appliances, communication systems, and industrial processes. In the context of the HSR, there are potential safety concerns associated with the interactions between the trains and catenary with overhead electrical utilities. If electromagnetic levels from these two sources reach or exceed safe levels, this could present health risks.

8.5.2.6 *Elimination of Grade Crossings*

For safety reasons, both HSR representative technologies would require the elimination of all grade crossings, whether road-rail or rail-rail crossings. In order to maintain traffic flows across the HSR, grade separation structures should be built to replace grade crossings. Social and environmental effects are anticipated as a result of the elimination of grade crossings.

The elimination of grade crossings should be addressed in both rural and urban areas as there may be different and significant effects in these two environments. A preliminary assessment of the elimination of grade crossings has identified the following potential issues.

Road Network and Traffic Issues:

- Impacts of frequent and long-duration road closures necessary during construction
- Ability of local road network to absorb additional traffic during construction and in the event of permanent re-alignment of roads
- Special traffic requirements that may be impacted (i.e. large trucks and haul routes)
- Impact on existing railway services such as commuter rail in Montreal and Toronto and VIA Rail.

Emergency Response Issues:

- Impacts on fire, police, and medical routes
- Potential increases in emergency response times
- Changes to the existing emergency evacuation routes.

Residential Land Use Issues:

- Potential land acquisition requirements in residential areas
- Creation of an unattractive pedestrian and cycling environment and loss of connectivity
- Loss of snowmobile, bicycle and multi-use crossings
- Impacts on the potential for future residential development
- Increased neighbourhood traffic during construction phase and road re-alignment
- Increased congestion and decreased access to services such as schools, community centres and municipal services.

Commercial Land Use Issues:

- Temporary and permanent loss of access to businesses
- Impacts on the potential for future commercial development
- Land acquisition in commercial and industrial areas.

Agricultural Land Use Issues:

- Farm Severance
- Agricultural land acquisition
- Elimination of private road and farm crossings.

8.5.2.7 *Elimination of Private Crossings*

Private grade crossings are privately owned and are neither open to public traffic nor maintained by a public entity. The HSR project would result in the loss of private crossings in agricultural areas where these crossings are especially important because they often provide access from one piece of a farmland to another piece on the other side of the RoW. The impacts of the elimination of private crossings and potential mitigation measures should be considered in greater detail during the EA stage.

8.5.2.8 *Farmland Severance*

Farmland severance is defined as the division of one farmland parcel into two or more farmland parcels through the erection of a barrier across the land. Farmland severance along the corridor would impact private landowners at a variety of points where new RoW would be acquired and where existing grade crossings would be eliminated. Some of the potential impacts on private agricultural landowners are as follows:

- Loss of direct access to main roadway network and severed portion of land during construction and permanently
- Loss of private crossings (reduced access)
- Loss of agricultural lands that would be occupied by the rail RoW
- Loss of property values due to physical separation of the lands
- Disturbances to the drainage works during construction phase and permanently
- Disturbances to electricity sources
- Impacts on farm facilities
- Increases to long-term fixed and variable operation costs due to the decreased access.

The EA study would identify which landowners throughout the corridor would be affected by farm severance, the magnitude that the impacts would have on farm operation and value, and specific mitigation measures.

Additionally, the EA study should determine the quality of the lands lost or severed and the necessary compensation that would need to be given to the owners. Costs associated with ensuring that property owners are appropriately compensated were included in the updated estimates of construction and operating costs.

8.5.2.9 Specialty Crop Areas in Ontario

Specialty crop areas are to be highly protected. They are defined in the Ontario Provincial Policy Statements as areas where "specialty crops such as tender fruits (peaches, cherries, plums), grapes, other fruit crops, vegetable crops, greenhouse crops, and crops from agriculturally developed organic soil lands are predominantly grown". Currently, Ontario has three specialty crop areas (i) Niagara's fruit and wine region, (ii) the Holland Marsh, and (iii) apple production in Grey and Simcoe counties. The EA study would determine whether the HSR may encroach on any specialty crop areas.

8.5.2.10 Archaeology

Archaeological information was not included as part of the environmental and social impact analysis because archaeological resources need to be identified at a much smaller scale.

8.5.2.11 First Nations

The Supreme Court of Canada and many lower courts have stated that governments and private companies have a 'Duty to Consult' with aboriginal people whenever there is a possibility that rights under Section 35(1) may be infringed. The EA study would determine whether the HSR encroach on any First Nations land areas.

8.5.2.12 Public Issues / Perceptions

Public issues and perceptions in both Ontario and Quebec were important elements of the HSR project and need to be addressed throughout all phases. At this early phase of the project, according to a poll conducted by the Railway Association of Canada (RAC) in 2008, the Canadian public opinion of HSR was satisfactory in all age cohorts. Additionally, RAC, in consultation with EKOS, conducted another poll in 2009 to gauge public perceptions on HSR in general. The poll found that the Canadian public overwhelmingly supports HSR. Eighty-six percent of the respondents surveyed believed that the federal government should provide the upfront funding for capital investment in HSR, and they should also provide additional ongoing investments for maintenance and operations. Also, 68 percent of Canadians polled stated that they believed that all levels of governments should provide funding to the project in order to make it feasible.

Additionally, 81 percent of respondents felt that HSR would help to stimulate the economy and create thousands of jobs in a time when economic stimulus was needed. Furthermore, 78 percent of respondents felt that HSR would strengthen the economy through allowing the public to move through the country at a quicker pace. Negative perceptions revealed through the poll indicated that members of the public felt that HSR would only benefit people in populated areas, the cost would be excessive, and track construction would be a significant undertaking that would be complex.

This would suggest that early and meaningful public participation and consultation with local stakeholders at the onset of the Environmental Assessment is essential to the success of the HSR project.

8.5.2.13 Removal of Conventional Rail Service and Effects on Rural Communities

This report was based on the agreed assumption that conventional rail service throughout the corridor would be replaced by HSR services. The representative routes and station locations would not provide rail access to the same communities as the existing VIA Rail services. This is because the HSR representative routes would lie within a combination of both new and existing RoW and, due to the proposed speed, it was not feasible to provide the same number of stops as conventional rail. During the environmental assessment process, the socio-economic effects associated with the removal of conventional rail service in these rural communities should be assessed in detail. In addition, alternative modes of transportation to these rural communities should be considered in order to provide transportation access and to ensure that the communities were not negatively affected. Potential effects as a result of the loss of conventional rail could include decrease in tourism and the associated economic effects, as well as loss of accessibility to surrounding communities or major urban centres.

8.6 Safety

As part of this analysis of environmental and social impact issues, safety was the subject of a specific review. The goal of that review was twofold:

- To estimate how many fatalities and injuries would be saved as a result of the implementation of HSR in the Quebec City - Windsor Corridor;
- To estimate the economic value of those savings, as this is a benefit to be considered in the economic analysis.

8.6.1 Sources of Increased Safety due to HSR

The implementation of HSR in the Corridor would reduce the number of fatalities and injuries as follows:

- Fatalities and injuries at grade crossings, due to collisions with trains, whether freight, VIA Rail, or commuter, would be eliminated through the proposed replacement of grade crossings by grade separation along the HSR route.
- Fatalities and injuries related to air travel, bus travel, rail travel (excluding grade crossing accidents, accounted for above) and auto travel would be reduced, due to some of their passengers having decided to switch to HSR, a safer mode.

8.6.2 Methodology

8.6.2.1 *Base Data*

Data on fatalities and injuries for the air, rail and road modes in Ontario and Quebec were obtained from various sources including the Transportation Safety Board of Canada (TSB), Transport Canada (TC), Ontario Ministry of Transportation (MTO) and Société de l'Assurance Automobile du Quebec (SAAQ). These data were adjusted as required for consistency.

8.6.2.2 *Economic Equivalence*

The economic equivalence of the expected reductions in fatalities and injuries was determined based on the value of a statistical life (VSL), which is a measure of the benefit of preventing a fatality or injury. VSL base values of $4.96 million CAD (2009) for fatalities and $318,000 CAD (2009) for injuries were used in this analysis. These VSL figures were based on values suggested in the Transport Canada report Estimates of the Full Cost of Transportation in Canada.

8.6.3 Projected HSR Safety Impacts

Table 8-3 summarizes the number of fatalities and injuries in 2031, with and without HSR between Quebec City and Windsor, as well as the corresponding reduction in the associated economic losses (in 2009 CAD) and the percentage reduction from the existing (2005) conditions.

Table 8-3: Reduction in Fatalities and Injuries due to HSR, 2031

	Ontario						Québec					
	Without HSR		With F200+		With E300+		Without HSR		With F200+		With E300+	
	Numbers	Value	Reduction	Value	Reduction	Value	Numbers	Value	Reduction	Value	Reduction	Value
Road												
Fatalities	203,0	$1 008	11%	$114	12%	$124	78,9	$392	11%	$44	12%	$48
Serious Injuries	430,1	$137	11%	$15	12%	$17	321,6	$102	11%	$12	12%	$48
Rail												
Fatalities	16,5	$82	88%	$72	88%	$72	10,0	$49	70%	$35	70%	$15
Serious Injuries	14,8	$5	87%	$4	87%	$4	10,0	$3	60%	$2	60%	$35
Air												
Fatalities	0,1	$0	26%	$0	30%	$0	0,3	$1	26%	$1	30%	$1
Serious Injuries	0,2	$0	26%	$0	30%	$0	0,2	$0	26%	$0	30%	$0
Total												
Fatalities	219,6	$1 090		$186		$196	89,1	$442		$80		$64
Serious Injuries	445,2	$142		$20		$21	331,8	$106		$14		$83
Economic	Loss:	$1 232	Loss Avoided:	$206	Loss Avoided:	78,9=G16+G15	Loss:	$548	Loss Avoided:	$93	Loss Avoided:	$147

Values are in million 2009 Canadian dollars

8.7 Noise and Vibration

As part of this analysis of environmental and social impact issues, noise and vibration were the subject of a specific review. The goal of that review was twofold: to determine the types of noise impacts that HSR would create and identify possible mitigation measures.

However evaluating the need for local measurements of ambient noise, identifying locations where the most severe impacts would be felt and what specific mitigation measures would be necessary, were beyond the scope of the present study.

8.7.1 Sources of HSR Noise

There are typically three noise sources related to the operation of HSR. At low speeds, propulsion sounds are the predominant sources emitted from a train. As speed increases, mechanical noise sources largely govern total noise level, including wheel-rail interaction and guideway structural vibrations. When a train reaches approximately 290 km/h, aerodynamic sources dominate the radiated noise levels. Much of this noise is caused by the boundary layer flow separation of the air flowing over the train. Due to the nature of these sources, aerodynamic noise increases much more rapidly with respect to speed than propulsion or mechanical sources.

Another characteristic of the noise from a HSR train is the onset rate of the sound. The rapidly approaching train results in noise that very quickly reaches its maximum levels. This could have a greater impact and lead to nuisance effects for surrounding receptors as a result of the noise as compared to a slower train that would slowly reach its maximum levels.

8.7.2 Changes in Noise Impacts Due to HSR

The major changes in noise impacts resulting from the operation of HSR would vary depending on the environment.

8.7.2.1 In Urban Areas

In the seven metropolitan areas in the Corridor, HSR would be travelling, at reduced speeds (rarely above 150 km/h and often slower) and on lines where there already are various types of conventional trains. At those speeds HSR trains would be quieter than freight trains or VIA Rail trains.

8.7.2.2 In Open Country

Depending on the location and route segment, 25 to 50 trains per day (in both directions) would be travelling at high speed, replacing 10 to 20 much slower VIA Rail trains. At those speeds, HSR trains are noisier than all other trains, but given their speed, would take less time passing a given point: 2.4 seconds for F300+, 3.6 seconds for F200+, compared to 3.4 seconds for a 5-car VIA Rail train and to 57 seconds (given its 1-mile length) for a freight train travelling at 100 km/h.

8.7.3 Mitigation for Significant Noise Impacts

8.7.3.1 Mitigation Measures Available

Noise mitigation techniques can be subdivided into three sections according to the location where they are implemented:

- The first treatment location is at the noise source

- The second is along the source-receiver propagation path
- The third is at the receiver.

8.7.3.2 Mitigation at the Source

Mitigation measures at the source are numerous due to the wide range of noise sources on a train.

Wheel-rail interaction produces a large amount of mechanical noise. One method of minimizing this is through the use of resilient and damped wheels. These are particularly effective. Since an accident on the ICE was partially caused by the use of resilient wheels at high speed, care should be taken when considering this option as a noise mitigation measure. Another method of dramatically lowering wheel-rail noise is to use a spin-slide control system, which assists in maintaining a wheel's roundness and avoiding localized flat spots on a wheel. To further reduce wheel-rail noise, different treatments could be applied to the track, including stringent tolerances and movable-point frogs.

The use of disc brakes on the ICE and the TGV allows them to operate at 300+ km/h without being noisier than traditional tread-braked stock operating at 140-160 km/h. Noise caused by turbulent boundary layers has been reduced through research on the structure of the front of trains. The structural improvements also led to much quieter entry of trains at high-speeds into tunnels, which had previously been a location of concern. Also, pantograph noise has been minimized by making their structure more aerodynamic and placing fewer along the length of the train.

8.7.3.3 Mitigation Treatments along the Path from the Source to the Receiver

Noise mitigation treatments along the source-receiver propagation path and at the receiver could be very effective in lowering total sound levels. The primary example of this treatment is a sound barrier. Sound barriers are used to interrupt the propagation of a sound wave by being placed directly between a source and a receiver. To be effective, a barrier should be continuous and without gaps.

When the sound levels within a building are of concern, there are a variety of receiver treatments that could be used. Some of these include the installation of thick-paned windows or increased inter-pane spacing in windows, strategic placement of windows, and sealing of gaps in the building envelope. In addition, air conditioning systems prove to be useful in noise mitigation because it allows windows to be kept closed during the warm summer months. However, building treatments are usually not appropriate for existing dwellings and are better suited for planned developments.

8.7.3.4 *Noise Mitigation Specifications*

When designing HSR trainsets for the Quebec City - Windsor corridor, the appropriate noise emission targets would be prescribed in the performance specifications for the rolling stock. Specific mitigation measures from those mentioned above, or others, could be prescribed in technical specifications, although it might be preferable to let bidding car builders propose their own technical solutions to meet the performance specifications.

8.7.3.5 *Alignment in Residential Zones: Noise Barriers*

The implementation of additional barriers along existing or new alignments may be necessary to mitigate rail noise at nearby noise sensitive receptors. Mitigation should reduce sound levels to an appropriate level that would be technically, economically and administratively feasible.

The construction of a large barrier may have negative aesthetic impacts that may be considered greater than the noise impact of the train. This should be taken into account when considering the introduction of such barriers. The cost of implementing a representative length of noise barriers has been accounted for in the capital cost estimates (Section 6).

8.7.4 Vibration

8.7.4.1 *Vibration Produced by HSR Trains*

HSR trains, like any steel-wheeled vehicles, induce vibration in the soil under and near the tracks on which they travel. Vibrations induced by HSR would be important in number due to the frequency of service offered. As far as intensity, however, vibrations induced by HSR would be lower than those of conventional trains, due mainly to the lower axle load (17 tonnes whereas a heavily loaded freight car would have an axle load reaching or exceeding 30 tonnes), better maintenance of the rolling stock and track, and the use of continuously welded rail.

8.7.4.2 *Canada Mortgage and Housing Corporation Rules*

Structural vibrations in buildings may be perceived by occupants and affect them in various manners. Vibrations may compromise comfort, work capacity, and in certain circumstances, people's health and safety.

Contact of a passenger or freight train's wheels with track irregularities exerts dynamic loads on the ground. These loads generate constraint waves that propagate through the soil and end up in the foundations of adjacent buildings, making them vibrate. The type of soil and its stratification greatly influence the amplitude of vibrations and dominant frequencies.

The less rigid the soil, the smaller its shock absorbing capacity, the stronger the vibration is. Vibration levels decrease with the increasing distance from the track, due to the "geometric propagation" of constraint waves, their dissipation due to soil viscosity, and/or friction in the soil. Soils, however, are usually heterogeneous and stratified. Propagation schemas are as a result very complex and attenuation relationships are site-specific. Due to this, it was impossible in the present study to estimate the effect of HSR on residents living near the representative alignments.

The Canada Transportation Act (CTA) stipulates that a railway company must limit the noise and vibration produced to a reasonable level, but it does not quantify those limits.

At present, no Canadian standard can be used to evaluate the effect of vibration on buildings. Nevertheless, Canada Mortgage and Housing Corporation (CMHC), in its document entitled "Noise from road and railway traffic: its impacts on habitat" provides a warning for constructing a building less than 100 meters from a railway track. At such distances, it is possible that a high level of vibration would be felt within the building, due to vibration in the soil.

That zone should be carefully analyzed during the environmental assessment. A soil investigation program should be executed during conceptual design in order to adopt track types and track construction methods that would minimize impact to neighbouring houses.

It should be noted that vibrations induced by a new HSR train travelling on new tracks would be considerably reduced by comparison with conventional trains on conventional track.

On the other hand, where conventional trains already operate in a railway RoW, and no vibration issues have been identified, it is rather unlikely that adding a high-speed train would generate vibrations that would cause problems to residents along the track.

The potential for noise and vibration impacts from railways located adjacent to urban areas may be present. During the routing and alignment phases of the EA, noise and vibration impacts would be evaluated and mitigation measures would be incorporated in the EA document.

8.8 Atmospheric Emissions

As part of this analysis of environmental and social impact issues, atmospheric emissions were the subject of a specific review. The goal of that review was twofold:

- To estimate the reductions in atmospheric emissions that could be achieved following the implementation of HSR in the Quebec City – Windsor Corridor
- To estimate the economic value of those reductions, as this would be a benefit to be considered in the economic analysis.

8.8.1 Definitions

Atmospheric Emissions from transportation vehicles consist of Greenhouse Gases and Criteria Air Contaminants.

Greenhouse gases (GHG) are substances that trap heat from the solar radiation and human activities (building heating, goods production, energy production, transportation, etc.) inside the atmosphere. The main greenhouse gases considered in this analysis are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), as these are most susceptible to be emitted by the various transportation modes considered in the present study. Increases in GHG emissions have been recognized for a number of years as one of the major issues associated with climate change. GHG harmful effects are increasingly apparent, hence the urgency to act to identify and implement innovative projects aiming at environmental protection and reduction of GHG emissions.

Major Criteria Air Contaminants (CAC) are pollutants that can have impacts on the health of living organisms (humans, fauna, and flora) or on the quality of the environment (acid rain, dust, visibility, smog, deterioration of goods). CAC pollutants considered in this analysis include: carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOC), sulphur dioxide (SO_2) and suspended particles (PM). Atmospheric ozone (O_3) was not evaluated, as this contaminant is not generated directly by the various transportation modes. On the other hand, this chemical compound is indirectly related to the atmospheric decomposition of NO_x, SO_2, and VOC; it is also associated with the formation of photochemical smog.

8.8.2 Changes in Emissions Due to HSR

The introduction of HSR in the Quebec City - Windsor Corridor would have the following impacts on atmospheric emissions:

- Operation of the diesel-fuelled F200+ would produce emissions all along the line.
- Operation of the fully-electric E300+ would produce emissions in Ontario, at the site of power generation stations, on the assumption that electricity used by HSR in Ontario is supplied by Hydro One and produced by Ontario Power Generation from fossil fuel; minimal emissions would be produced in Quebec as electricity supplied by Hydro-Quebec is almost entirely produced from hydroelectricity sources.

- Emissions from automobiles and other light-duty motor vehicles would be reduced, as some auto travellers would switch to HSR, reducing the number of auto km travelled.
- Emissions from aircraft would be reduced, as some air travellers would switch to HSR and the number of flights would be reduced.
- Emissions from inter-city buses might slightly increase, as some VIA Rail passengers would switch to bus rather than to HSR, resulting in increases in bus-km travelled.
- Emissions from VIA Rail trains providing Corridor services would be eliminated, as these services would be replaced by HSR.

8.8.3 Approach

The analysis was done separately for F200+ and E300+. Two base years of 2031 and 2041 were considered in the current study. The first year of HSR operation was taken as 2025.

8.8.3.1 Determining Emissions Factors

Emission factors are the quantity of pollutants emitted, as a function of their energy sources consumption, by the various transportation modes involved. They were evaluated in kilograms of pollutants per litre of fossil fuel or gas consumed for conventional passenger trains, light duty vehicles, intercity buses, and F200+.

Airplane emission factors relating to the GHG emissions were evaluated using the same methodology. Airplane emission factors for CAC were evaluated as a function of the number of flights saved due to diversion to HSR, as CAC emissions impact the local environment at takeoff and landing. There are impacts due to CAC emissions at high altitude, but their effect on the communities under the flight path cannot be measured.

Emission factors for the HSR E300+ were calculated in kilograms of pollutants emitted per kW-hr of electricity used.

Values for representative emission factors were obtained from reliable sources, separately for each transportation mode and for each type of pollutant identified. Technology improvements most likely to be implemented by the reference years were taken into account.

Table 8-4: Emission Factors for Each Mode (kg per 1,000L of fossil fuel consumed)

		Grennhouse Gases			Criteria Air Contaminants				
		CO_2	CH_4	N_2O	PM	SO_2	NO_X	CO	VOC
Rail									
Conventional Diesel Trains		2,663	0.15	1.10	0.08	0.85	5.49	3.90	0.93
Auto									
Gasoline automobile	Ontario	2,289	0.52	0.20	0.01	0.03	2.34	75.13	3.91
	Quebec	2,289	0.52	0.20	0.01	0.03	2.78	94.32	5.34
Values for other type of light duty vehicles not shown									
Buses									
Inter-city Buses	Ontario	2,663	0.14	0.082	0.14	0.01	5.94	2.39	0.26
	Quebec	2,663	0.14	0.082	0.43	0.03	6.53	3.11	0.40
Air									
Emissions (kg) per take-off and landing cycle for CACs. Emissions calculated directly in CO_2e for GHG (0.172 kg/km-passenger)					0.09	0.70	3.12	32.70	29.60
Emissions (kg) per take-off and landing cycle for CACs									
HSR									
F200+	Both Provinces	2,663	0.15	1.10	0.08	0.85	5.49	3.90	0.93
E300+	Ontario	216	0.70	0.27	0.01	0.70	0.30	0.10	0.003
E300+	Quebec	7	0.02	0.03	0.00	0.01	0.05	0.02	0.001

In a given column, most numbers have been rounded to the same number of decimals to facilitate comparisons along the vertical.

8.8.3.2 Determining Fuel Consumption

Representative energy consumption was determined for every mode involved. Fuel consumption for all modes except HSR E300+ and airplanes, was measured in litres of fossil fuel consumed by vehicle-km travelled (i.e. train-km, auto-km, bus-km, plane-km, etc.). This method appeared to be the best measure for evaluating savings in atmospheric emission of pollutants. The results are as follows:

- For conventional passenger trains: 41.93 L per 1,000 passenger-km or 5.49 L per train-km, with an average of 131 passengers per train.
- For gasoline powered automobiles: 9.0 L/100 km (different values for other types of light duty vehicles)
- For inter-city buses: 39.57 L/100 km of diesel fuel for an average load of 33.6 passengers per bus
- For airplanes, fuel consumption was not used in evaluating quantities of GHG emissions, as emission factors were already included in kg of pollutants per km travelled. As for the CAC, the quantity of pollutants emitted is related to the number of take-off and landing sequences rather than the fuel consumption.
- For F200+: 4.5 L per train-km
- For E300+: 27 kWh per train-km.

8.8.3.3 *Estimating Changes in the Operation of Modes*

Changes in the use of modes were measured as changes in vehicle-km travelled: train-km, auto-km, bus-km, plane-km, as this appears to be the proper measure for evaluating savings in pollutants. Increases and decreases in vehicle-km, for every mode, were thus estimated as follows for the reference years. Results are shown in 16 detailed tables in the report for Deliverable 9, Analysis of Environmental and Social Impacts.

8.8.3.4 *Estimating Changes in the Quantities of Pollutants*

Reductions Due to Diversion from Other Modes: Changes in the quantities of pollutants were calculated in metric tons, as this appears to be the proper measure for evaluating savings in pollutants. Reductions in the quantities of pollutants were estimated for every transportation mode using the following calculation:

The mode's change (reduction or addition) in vehicle-km travelled multiplied by the mode's estimated average consumption per vehicle-km, including the use of the average number of passengers determined for each mode, and the fleet composition for the automobiles. This result was multiplied by the mode's own emission factor for each pollutant.

Increases Due to the Operation of HSR: Increases in the quantities of pollutants due to the operation of HSR were also calculated in metric tons using the following calculation: The HSR number of train-km was multiplied by the HSR technology's estimated average consumption per train-km (in diesel litre/km-passenger for F200+ and in kW-h/km-passenger for E300+), and then multiplied by the HSR technology emission factor for each pollutant.

8.8.3.5 *Economic Value of Savings in Pollutants*

To evaluate the cost of atmospheric pollution, several methods were considered (market price, reduction costs, impacts on population, cost for health care, etc.).

The method retained for evaluating the cost of GHG's refers to Canada's Action on Climate Change.

The method for the costs associated with PCA's was based on the methodology used and available data in the inventory conducted for Transport Canada by Marbek Consultants.

Unit costs for atmospheric pollution in CAD per ton of emissions are given in Table 8-5

Table 8-5: Unit Costs for Atmospheric Pollutants

Unit Cost of Atmospheric Pollution ($/Ton of Emissions)				
Pollutants				
CO_2e	$PM_{2.5}$	SO_2	NOx	VOC
40.0	21,150.0	5,600.0	5,765.0	735.5

8.8.3.6 Net Economic Benefits Resulting from Emissions Saved Due to HSR

The total positive economic values of emissions saved due to diversion to HSR (from the four other transportation modes), minus the negative values of the emissions produced by the HSR itself were calculated for every scenario, year of reference and HSR representative technology. As an overall result:

Implementation of F200+ between Quebec City and Windsor would result in a total economic benefit from the reduction in pollutants evaluated at approximately $192 million CAD (2009) with a net present value of $47.4 million CAD.

Implementation of E300+ between Quebec City and Windsor would result in a total economic benefit from the reduction in pollutants evaluated at approximately $390 million CAD (2009) with a net present value of $96.1 million CAD.

9 IMPACTS ON THE TRANSPORTATION SYSTEM IN THE CORRIDOR

The HSR corridor between Quebec City and Windsor includes a variety of public and private transportation modes. The introduction of HSR could potentially have an impact on existing transportation services that operate within the corridor including intercity bus, air, automobile, commuter rail and VIA Rail services. In addition, freight rail services may also be impacted by HSR where representative routes contemplate the shared use of corridor RoW with freight railways.

The main assumptions and recommendations utilized in assessing potential impacts of HSR on competing travel modes in the Corridor included:

- No airport like passenger screening would be considered for high speed rail
- Representative routes would not provide HSR stations at airports
- Connecting air traffic would not be a potential market in the present study
- The HSR corridor would be grade separated from all road and rail crossings for both F200+ and E300+ representative technologies
- Both representative technologies would be adapted to meet FRA requirements
- The F200+ system would be equipped with dual-mode diesel and electric engines capable of operating in the Mount Royal Tunnel and on other future electrified portions of the representative route
- HSR equipment and infrastructure would provide winter weather mitigation components for four season service reliability. This also includes the use of non-tilting equipment for both F200+ and E300+ representative technologies
- Mount Royal tunnel would be equipped with new signal system at approaches to and within the tunnel to increase capacity
- New stations at locations specified including at suburban locations would provide as much as possible, multi-modal interfaces
- Both representative technologies would accommodate 400 passengers per train
- Service frequencies would include a maximum of 28 daily trains per direction and up to 18 hours of daily service.

9.1 Direct Impacts

9.1.1 Mode Shift

The ridership demand forecasts indicate that HSR would attract ridership from existing competing modes of transportation. In the present study, the total number of trips made in the corridor that used existing modes of transportation was determined for the 2006 base year and growth projections for 2031 and 2041 were developed. The estimated HSR ridership diverted by mode, purpose and market was developed for 2031 and 2041 for both the F200+ and E300+ representative technologies and used to evaluate potential direct impacts on competing transportation modes. Induced ridership to HSR (trips made using HSR that would not have been made in the absence of HSR services) was also estimated.

9.1.1.1 HSR Ridership by Purpose, Market and Source -2031

Table 9.1 showed a similar percentage of riders diverted to HSR in 2031 for both technologies as only a one to two percent variation in ridership between technologies was observed. In 2031, it is projected that 93 percent to 94 percent of HSR ridership would be diverted from other modes and only six to seven percent of the ridership would be induced. Similar projections were noted in 2041, as shown on the following two tables:

Table 9-1: HSR Ridership by Market and by Source – 2031

2031[30]		Auto		Air		Rail		Bus		Induced		Total	
System		F200+	E300+	F200+	E300+	F200+	E300+	F200+	E300+	F200+	E300+	F200+	E300+
Primary Market	*Riders (1,000)*	4,691	5,044	803	924	2,331	2,331	-275	-237	578	718	8,128	8,780
	% Total	77%	76%	78%	78%	81%	81%	71%	69%	89%	89%	79%	79%
Secondary & Other Markets	*Riders (1,000)*	1,369	1,554	229	265	546	546	-112	-106	68	91	2,100	2,350
	% Total	23%	24%	22%	22%	19%	19%	29%	31%	11%	11%	21%	21%
Total Riders		6,060	6,598	1,032	1,189	2,877	2,877	-387	-343	646	809	10,228	11,130
Modal % of Total Riders		59%	59%	10%	11%	28%	26%	-4%	-3%	6%	7%	100%	100%

30 Source - Deliverable 7 Tables 6-7 and 6-8

Table 9-2: HSR Ridership by Market and by Source – 2041

2041[31]		Auto		Air		Rail		Bus		Induced		Total	
System		F200+	E300+	F200+	E300+	F200+	E300+	F200+	E300+	F200+	E300+	F200+	E300+
Primary Market	*Riders (1,000)*	5,124	5,504	902	1,038	2,458	2,458	-290	-253	643	798	8,836	9,544
	% Total	77%	76%	78%	78%	81%	81%	71%	70%	89%	89%	79%	79%
Secondary & Other Markets	*Riders (1,000)*	1,498	1,698	256	297	574	574	-119	-111	77	103	2,289	2,560
	% Total	23%	24%	22%	22%	19%	19%	29%	30%	11%	11%	21%	21%
Total Riders		6,622	7,202	1,158	1,335	3,032	3,032	-409	-364	720	901	11,125	12,104
Modal % of Total Riders		59%	59%	11%	11%	27%	25%	-4%	-3%	6%	7%	100%	100%

It is estimated that the greatest percentage of HSR ridership would be diverted from automobiles. Of the total HSR riders, 59 percent would be former automobile users; 11 percent would be diverted from air; 25 to 27 percent would be diverted from VIA Rail; and a total negative diversion rate for intercity bus would be observed. However, when bus ridership was observed by purpose, the business sector for both the primary and secondary markets indicated bus ridership would be diverted to HSR. Higher negative diversion rates for non-business bus riders contributed to an overall gain in bus ridership.

9.1.1.2 *Estimation of Impact of HSR on Total Mode Ridership*

The 2006 base year ridership numbers were developed by mode and market as presented in Table 9.2.

Table 9-3: Market Base Year 2006 Trips by Mode

Mode	Primary Market[32]		Secondary & Other Markets[33]		Total Market Share	
	Trips(1,000)	Share	Trips(1,000)	Share	Trips(1,000)	Share
Auto	26,147	82%	56,719	93%	82,866	89%
Air	1,962	6%	620	1%	2,582	3%
VIA Rail	1,832	6%	1,383	2%	3,215	4%
Bus	2,018	6%	2,059	4%	4,077	4%
Total	31,959	100%	60,781	100%	92,740	100%

The growth in travel without HSR for future markets in 2031 and 2041 was estimated for years 2031 and 2041 as indicated in Table 9.3 below.

[31] Source - Deliverable 7 Tables 6-9 and 6-10
[32] source Deliverable 7 Figure 26
[33] source Deliverable 7 Figure 27

Table 9-4: Growth in Travel without HSR: 2006-2031-2041[34]

Markets	Annual Trips			Total Growth		Market Share		
Primary	2006	2031	2041	2006-2031	2006-2041	2006	2031	2041
Business	10,036,000	14,909,000	16,306,000	49%	62%	31%	33%	34%
Non-Business	21,924,000	29,667,000	31,906,000	35%	46%	69%	67%	66%
Total	31,960,000	44,576,000	48,213,000	39%	51%	100%	100%	100%
Secondary & Other								
Business	12,089,000	13,682,000	14,761,000	13%	22%	20%	20%	21%
Non-Business	48,692,000	53,444,000	56,636,000	10%	16%	80%	80%	79%
Total	60,780,000	67,126,000	71,397,000	10%	17%	80%	80%	79%

In 2006 primary markets represented 32 million annual trips: they would represent 44.5 million trips by 2031, and 48.3 million in 2041. Annual Trips for secondary and other markets for 2006 were estimated at 60.8 million: they would represent 67.1 million in 2031 and 71.4 million in 2041.

In order to estimate the share of travel by mode and market without HSR, the base case market share percentages presented in Table 9.2 above were applied to the estimated annual trips in 2031 and 2041 presented in Table 9.3. Table 9.4 below, presented the derived travel without HSR by market and mode for the years 2031 and 2041.

Table 9-5: Travel without HSR by Market and Mode 2031-2041

Mode	2031			2041		
	Primary	Secondary & Other	Total	Primary	Secondary & Other	Total
Auto	36,552,320	62,427,180	98,979,500	39,534,660	66,399,210	105,933,870
Air	2,674,560	671,260	3,345,820	2,892,780	713,970	3,606,750
VIA Rail	2,674,560	1,342,520	4,017,080	2,892,780	1,427,940	4,320,720
Bus	2,674,560	2,685,040	5,359,600	2,892,780	2,855,880	5,748,660
Total	44,576,000	67,126,000	111,702,000	48,213,000	71,397,000	119,610,000

[34] As presented in Deliverable 7 Table 6-5

The HSR trips diverted from each mode presented in Table 9.1 were then subtracted from the estimated total travel by market and mode presented in Table 9.4 to derive an estimate of the overall modal traffic diverted to HSR in 2031 and 2041. Table 9.5 below provided an estimated market impact of HSR ridership diverted from other modes by market for years 2031 and 2041.

For all modes except air, only a one percent difference in ridership between the F200+ and E300+ service was observed. As air travel is extremely time sensitive, the impact of the E300+ system on diverted air travel was increased by four (4) percent over the F200+ service sample.

Table 9.5 indicated that the estimated total HSR riders diverted from auto travel would impact the total market by 6 to7 percent. In addition air markets would be impacted by 31 percent to 36 percent; 72 percent of VIA Rail ridership would be diverted to HSR and bus would gain a 6 to 7 percent total market share.

Table 9-6: Estimated Market Impact of HSR Ridership Diverted from Other Modes by Market for 2031 and 2041

Auto	Total Estimated Ridership	Diverted from Auto 2031		Total Estimated Ridership	Diverted from Auto 2041	
		F200+	E300+		F200+	E300+
Primary	36,552,320	4,691,000	5,044,000	39,534,660	5,124,000	5,504,000
% of Total Primary Market		*13%*	*14%*		*13%*	*14%*
Secondary & Other	62,427,180	1,369,000	1,554,000	66,399,210	1,498,000	1,698,000
% of Total Secondary & Other Markets		*2%*	*2%*		*2%*	*3%*
Total Remaining Ridership	98,979,500	6,060,000	6,598,000	105,933,870	6,622,000	7,202,000
% per Total Market		*6%*	*7%*		*6%*	*7%*

Air	Total Ridership	Diverted from Air - 2031		Total Ridership	Diverted from Air - 2041	
		F200+	E300+		F200+	E300+
Primary	2,674,560	803,000	924,000	2,892,780	902,000	1,038,000
% of Total Primary Market		*30%*	*35%*		*31%*	*36%*
Secondary & Other	671,260	229,000	265,000	713,970	256,000	297,000
% of Total Secondary & Other Markets		34%	39%		*36%*	*42%*
Total Remaining Ridership	3,345,820	1,032,000	1,189,000	3,606,750	1,158,000	1,335,000
% per Total Market		*31%*	*36%*		*32%*	*37%*

VIA Rail	Total Ridership	Diverted from Rail - 2031		Total Ridership	Diverted from Rail - 2041	
		F200+	E300+		F200+	E300+
Primary	2,674,560	2,331,000	2,331,000	2,892,780	2,458,000	2,458,000
% of Total Primary Market		*87%*	*87%*		*85%*	*85%*
Secondary & Other	1,342,520	546,000	546,000	1,427,940	574,000	574,000
% of Total Secondary & Other Markets		*41%*	*41%*		*40%*	*40%*
Total Remaining Ridership	4,017,080	2,877,000	2,877,000	4,320,720	3,032,000	3,032,000
% per Total Market		*72%*	*72%*		*70%*	*70%*

Bus	Total Ridership	Diverted from Bus - 2031		Total Ridership	Diverted from Bus - 2041	
		F200+	E300+		F200+	E300+
Primary	2,674,560	(275,000)	(237,000)	2,892,780	(290,000)	(253,000)
% of Total Primary Market		*-10%*	*-9%*		*-10%*	*-9%*
Secondary & Other	2,685,040	(112,000)	(106,000)	2,855,880	(119,000)	(111,000)
% of Total Secondary & Other Markets		*-4%*	*-4%*		*-4%*	*-4%*
Total Remaining Ridership	5,359,600	(387,000)	(343,000)	5,748,660	(409,000)	(364,000)
% per Total Market		*-7%*	*-6%*		*-7%*	*-6%*

9.1.2 Comparison with the QOHSRPS

9.1.2.1 Comparison of Share of Travel in Corridor by Purpose

The travel in the Quebec City – Windsor corridor by purpose was established in both studies.

Table 9-7: Comparison of Corridor Travel by Purpose QOHSRPS to Present Study

Purpose of Trip	QOHSRPS 1992	Present Study 2006
Business	21%	24%
Non Business	79%	76%

An upward trend in business travel share in the corridor between the QOHSRPS and the present study of three (3) percent was noted. This observation may be due in part to increases in fuel costs that may have slightly curtailed corridor use for non-business travel.

Table 9.7 indicated that the QOHSRPS projections in business riders for 2005 attracted to the QW-D-200 (200 km/h via Dorval) represented 35 percent of the total riders. The source of ridership for the QW-M-300 route (300 km/h via Mirabel airport) and QW-D-300 (300 km/h via Dorval) services, forecasted a ridership distribution of 37 percent business versus 63 percent non business.

The present study forecasted a 48 to 52 percent split between business and non-business riders in 2031 for both the F200+ and E300+ technologies.

Table 9-8: HSR Ridership by Purpose: 2005 and 2031

Purpose of Trip	Business Travel		Non-Business Travel	
QOHSRPS - 2005[35]	Riders (1,000)	% of Total	Riders (1,000)	% of Total
QW-D-200	3,523	35%	6,541	65%
QW-M-300	4,356	37%	7,511	63%
QW-D-300	4,731	38%	7,726	62%
Present Study - 2031				
F200+[36]	2,929	48%	3,131	52%
E300+[37]	3,137	48%	3,462	52%

[35] Table 4.10 QOHSRPS
[36] Table 6-7 Deliverable 7
[37] Table 6-8 Deliverable 7

9.1.2.2 Comparison of Share of Travel in Corridor by Mode without HSR

The existing travel in the Quebec City – Windsor corridor by mode was established in both studies.

Table 9-9: Comparison of Corridor Travel by Mode QOHSRPS to Present Study Without HSR

Mode	Existing Travel by Trips (millions)		Share of Existing Trips	
	QOHSRPS 1992[38]	Present Study 2006[39]	QOHSRPS 1992	Present Study 2006
Auto	99.1	82.9	91.2%	89.3%
Air	4.1	2.6	3.8%	2.8%
Rail	2.9	3.2	2.7%	3.5%
Bus	2.6	4.1	2.4%	4.4%
Total	108.6	92.8	100%	100%

The distribution of ridership between 1992 and 2006 indicated some slight shifts in market share however it should be noted that the QOHSRPS included connecting air trips whereas the present study did not.

9.1.2.3 Comparison of Projected Ridership Sources of HSR

There were significant differences in the projected ridership sources of HSR between the two studies.

Table 9-10: Comparison of HSR Ridership by source: QOHSRPR (2005) and Present Study (2031, 2041)

Diverted From	200 km/h riders (thousands) percentage of total			300 km/h riders (thousands) percentage of total		
	QOHSRPS QW-D-200 2005[40]	Present Study F200+ 2031[41]	Present Study F200+ 2041[42]	QOHSRPS QW-M-300 2005[43]	Present Study E300+ 2031[44]	Present Study E300+ 2041[45]
Auto	4,036	6,060	6,623	4,634	6,599	7,202
	40.1%	59%	60%	39.1%	59%	59%
Air (local)	1,273	1,032	1,158	1,613	1,189	1,333
	12.6%	10%	10%	13.6%	11%	11%
Air (connect)	536	-	-	525	-	-
	(5.3%)	-	-	4.4%	-	-
Rail	1,550	2,876	3,032	1,586	2,876	3,032
	15.4%	28%	27%	13.4%	26%	25%
Bus	814	-387	-409	827	-343	-364
	8.1%	-4%	-4%	7.0%	-3%	-3%
Induced Demand	1,856	646	721	2,681	809	902
	18.4%	6%	6%	22.6%	7%	7%
Total Trips	10,065	10,227	11,124	11,866	11,130	12,105
	100%	100%	100%	100%	100%	100%

38 Table 4.4 QOHSRPS
39 Total Market Share Derived from Deliverable 7 Figures 26 and 27
40 Figure 4.4 QOHSRPS base case QW-D-200
41 Deliverable 7 Table 6-7
42 Deliverable 7 Table 6-9
43 Figure 4.4 QOHSRPS base case QW-M-300
44 Deliverable 7 Table 6-8
45 Deliverable 7 Table 6-10

9.1.2.4 *Differences in Auto Traffic Diverted to HSR*

The present study projected a significantly higher diversion rate originating from auto (59 percent) and rail (26 to 28 percent) of the overall HSR ridership than was indicated in the QOHSRPS, 39 to 40 percent for automobiles and 13 to 15 percent for rail.

When the distribution of travel by mode without HSR (as indicated in Table 9.8) was compared for both studies, the present study reflected a 1.9 percent decrease in corridor auto traffic. This may be explained in part by higher gas prices, public awareness of the harmful environmental impacts of GHG emissions and possibly increases in time delays for corridor travel attributed to traffic congestion in the larger metropolitan areas.

9.1.2.5 *Differences in Rail Trips Diverted to HSR*

The present study indicated a 0.9 percent increase in corridor rail trips relative to the modal share described in the QOHSRPS (Table 9.9). This increase in rail ridership was supported by ridership trends reported by the Railway Association of Canada which indicated that in 1992, passenger ridership in Canada (largely made up of VIA Rail) handled 4.1 million passengers. In 2006, 4.3 million passengers were handled, representing a 6 percent increase in ridership between 1992 and 2006.

The present study indicated that 26 to 28 percent of HSR ridership would be diverted from VIA Rail. The QOHSRPS indicated between 13 and 15 percent diversion from rail. The increase in rail ridership diversion may be attributed to a higher public awareness of HSR generated by the successful implementation of high speed rail installations in Europe and the growing support for higher speed passenger rail in the United States.

The service characteristics of HSR, including frequencies and trip duration are attractive attributes for business riders, which would contribute to the diversion of business travellers from the automobile and rail sector to HSR. The increased HSR trips diverted from auto and rail may be also attributed to rising fuel costs and an increased public awareness of the environmental impacts of GHG emissions.

9.1.2.6 *Differences in Bus Trips Diverted to HSR*

The present study indicated a significantly lower rate of HSR trips originating from intercity bus and from those induced to HSR than was presented in the QOHSRPS. While the QOHSPRS indicated an overall bus ridership diversion rate of 8.1 percent with the QW-D-200 and 7 percent with the QW-M-300 services, the present study indicated a total negative diversion rate of -4 percent in 2031 and -3 percent in 2041 for both technologies.

It was observed however that intercity bus industry however would experience a loss in business ridership. For example Table 6-7 of the technical report for Deliverable 7, Demand Forecasting, estimated that in 2031, 123,000 business bus riders would be attracted to the F200+ HSR service and 509,000 non-business riders would be diverted to bus. The total bus riders diverted to HSR was -387,000[46]. In this forecast business riders made up 19 percent of the total riders diverted to HSR.

Anticipated loss in the express bus service ridership within the corridor would likely generate significant opposition to HSR implementation from the intercity bus industry. Effective integration of the two modes would be required to motivate a significant market focus shift for the bus industry away from business travel market. As interests merge it would be reasonable to expect a partial integration of HSR and bus services due to their complementary nature. Through-ticketing and joint marketing programs are examples of areas of potential service integration.

The lower bus diversion rate in the present study however indicated a positive gain in ridership for intercity bus in the non-business sector. This was attributed to the diversion of non-business VIA passengers that may exhibit a higher tolerance for trip duration and/or would be unwilling to pay anticipated higher HSR fares.

The flexibility of the bus service and the preponderance of road networks available to access impacted communities would provide opportunities to develop and promote the synergies of both HSR and intercity bus services.

9.1.2.7 Differences in Induced Trips Attracted to HSR

The present study indicated a much lower rate of induced ridership than the QOHSRPS. Where the QOHSRPS indicated that 18.4 percent of the ridership for the QW-D-200 service would be induced, only 6 percent of the HSR ridership in the present study was induced. The present study however indicated that of the total induced traffic, 90 percent would be for business travel. The difference in the total induced ridership estimates between the two reports may have been influenced by the exclusion of connecting air traffic projections in the present study.

[46] Note that the fares may be the same for business and non-business bus riders, however the reduction in passenger volumes on the express routes would impact passenger/km travelled. Thus the gain to the bus industry of 387,000 non-business riders would be attributed primarily to new riders at locations no longer serviced by VIA Rail. This type of regional service would require more resources (buses, drivers, fuel, bus terminals and terminal maintenance and staff) than the current inter-city express bus service.

9.1.2.8 Differences in Air Trips Diverted to HSR

The share of air trips diverted to HSR would experience a slight decline in local traffic in the present study as indicated in Table 9.8. In the present study the 2006 primary markets and secondary and other markets accounted for 2.6 million air trips.

Of the HSR ridership diverted from air in 2031, it is anticipated that 56 percent of the total diverted air trips would be business travellers. Of the total business travellers, 82 percent would originate from the primary markets.

The QOHSRPS indicated air carriers could lose 44 percent of their projected corridor ridership by 2005; however, this share included connecting air flights. The present study estimated that the 2031 HSR ridership diverted from air would be 31 percent for the F200+ service and 36 percent for the E300+ service.

9.1.2.9 Differences in Service Frequencies

There were several differences in the service frequencies presented in the QOHSRPS and the present study. The QOHSRPS indicated higher frequencies on all corridor segments than the present study. Slight service frequency increases on the Quebec City – Montreal; and London to Windsor segments were noted while major differences in service frequencies were observed in the Montreal – Ottawa; Ottawa – Toronto; and Toronto – London segments as indicated in Table 9.10.

Table 9-11: HSR Estimated Average Daily Train Runs One Direction

Service	QW-D-200[47] 2005	F200+[48]		QW-M-300 2005	E 300+	
		2025	2055		2025	2055
Québec - Montréal	16	15	15	15	15	16
Montréal - Ottawa	23	16	18	22	16	21
Ottawa - Toronto	30	18	24	30	21	28
Toronto - London	18	13	20	17	14	20
London - Windsor	9	8	10	9	8	10

The observed differences in frequencies could be attributed to the estimated number of seats per trainset in each study. The QOHSRPS indicated that the 200 km/h system included a 282-seat trainset concept while the 300 km/h system was based on a 358-seat trainset concept. The present study applied a 400-seat trainset concept for both the F200+ and E300+ technologies.

[47] Table 4.8 QOHSRPS
[48] Table 8 eliverable 6.2

The increase in available seats per trainset in the present study permitted a reduction in trainset frequencies when compared to the service levels indicated in the QOHSRPS. The reduction in service frequencies as proposed in the technical report for Deliverable 6.2, O&M Costs would:

- Contribute to a higher seat occupancy rate per trainset
- Significantly improve line capacity
- Lessen capacity constraints at major urban station platforms
- Contribute to significant improvement in equipment utilization.

9.1.3 Use of Railway Rights of Way

The majority of existing RoW between Quebec City and Windsor are owned and operated by the freight railways. Shorter segments are owned by VIA Rail and within metropolitan areas, by commuter rail service providers.

The representative routes identified for the F200+ and E300+ technologies considered the following attributes to determine suitability of existing RoW:

- Geometric characteristics
- Routes with shorter travel times
- Construction costs
- Impacts on the natural and social environments.

9.1.3.1 HSR Tracks within Railway Rights of Way

Where portions of existing railway RoW met the above criteria, preference was afforded to the development of separate HSR tracks within the existing RoW. For 379 km of the F200+ route and 321 km of the E300+ route, the HSR would run on separate tracks located within an existing RoW.

This mode of operation presented specific concerns including:

- Access to existing and future line customers of freight services and yard facilities could require additional grade separation of services
- Available space for future freight track capacity expansion may be restricted due to HSR usage
- Sufficient space between HSR and freight tracks to protect HSR tracks from possible falling freight could further restrict future freight track capacity expansion opportunities

- Wider track spacing to ensure sufficient side clearance between freight and HSR specific infrastructure elements would further impact available land use within the RoW
- Security fencing for HSR infrastructure protection on the shared RoW would restrict access to the RoW for freight railway workers
- HSR geometry requirement could impact at grade separations at existing rail /road crossing
- Substandard geometry of existing RoW in some cases would restrict HSR speeds to levels below maximum achievable speeds.

9.1.3.2 *Shared Tracks with Other Rail Users*

In highly urbanized areas where RoW limits were constricted by existing adjacent land use and the use of central existing major stations was deemed desirable for HSR, the shared use of the RoW between HSR and other rail services was anticipated.

The service characteristics of HSR and specifically the anticipated frequencies of the service (up to 28 trains per direction daily), performance sensitivities and higher speeds, would not typically favour the joint use of tracks within existing railway RoWs by mixed rail services. Use of banking for higher speeds could result in higher maintenance costs with freight forces by causing excessive wear on the lower rail. Conversely, reducing the elevation of curves could reduce HSR speeds.

However the representative routes for both technologies identified 95 km of the HSR route within existing RoW where shared track use with other heavy rail users (commuter rail and some freight) was expected to occur due to:

- The need to access high demand passenger stations in metropolitan areas
- The provision of high degree of connectivity to other urban and regional transit services
- Restricted availability of suitable lands for the acquisition of new RoW in urban areas
- High density of land use adjacent to existing railway RoW.

The Lakeshore corridor in Toronto was indentified as a corridor segment that would present unique challenges for HSR. Presently, the existing corridor segments are owned by CN and Metrolinx. Although primarily utilized by GO Transit commuter trains, occasional local freight service is provided to customers local to the corridor. However between Burlington and Hamilton, CN operates its primary overhead freight service. The use of the Lakeshore West corridor by HSR may precipitate future investigations to consolidate some CN freight services onto portions of the CP corridor to lessen the capacity demand on joint use corridor segments or prompt future analyses into constructability of a tunnel within this segment that would permit separation of the rail services.

The time separation of HSR and freight should be further examined as overhead rail freight is also time sensitive and local freight customers along the corridor may lack the flexibility to limit freight rail service to scheduled non-HSR hours. As HSR service may include up to 18 daily hours of operation, this would only leave a 6 hour HSR free window at night for freight service use.

In addition, portions of the representative routes that would occupy existing RoW tracks may have been designated by freight railways as diversion routes to be used in instances when maintenance and capital works activities are scheduled on primary corridors or when line blockages occur.

The services of commuter rail operating within the freight railways RoW are largely concentrated during commuter peak periods, however off peak services are also provided. Future use of the Toronto Lakeshore corridor would include significant increases in traffic in both peak and off peak periods due to future planned increases in GO Transit use and the operation of the future Airport Rail Link (ARL) service that would operate within the Union Station Rail Corridor (USRC) west of Union Station. Maximum operating speeds entering and within the USRC would significantly restrict the operation of HSR as maximum speeds would be dictated by the signal and switch configuration and the proximity of Union Station to the corridor extremities (maximum speed was assumed to be 145 km/h between Oshawa and Dundas).

The corridor capacity would be further challenged by the movement of equipment trains between the GO Transit maintenance and storage facilities within the corridor. In addition, conventional regional passenger services to Niagara and Sarnia may also operate over portions of the corridor. It is anticipated that future intensification of GO commuter rail service within the Lakeshore corridor would consume the majority of available track capacity. Base on projected HSR volumes and frequencies, HSR would have a minimal impact on the use of the overall corridor capacity, as most, if not all current corridor VIA services would be replaced by HSR services. In Montreal, AMT currently operates local service, however the use of express trains in the future should not be ruled out.

It is common practice to operate “dedicated commuter/passenger windows” that restrict the freight service use during passenger intensive time periods; however this is not an exclusive arrangement. As the peak periods of commuter rail schedules become extended and the service frequencies increase, the available capacity for HSR and freight would be significantly reduced.

9.1.4 Grade Separations

The QOHSRPS assumed that existing grade crossings with the present level of protection could be permitted in areas where HSR would operate at speeds of up to 160 km/h. At existing grade crossings with improved protection, HSR trains would be permitted to operate at speeds of up to 200 km/h. of the assumptions indicated that an estimated 471 grade separations would be required and 100 rural two-lane roads would be closed.

A key assumption of the present study was that the HSR corridor for both the F200+ and E300+ technologies, would be grade separated from HSR tracks for both rail and road crossings. Table 9-11 indicated the types and quantities of grade separations required for the two representative routes.

Table 9-12: Grade Separation Installations by Representative Route

Quebec City to Windsor	Present Study[49] F200+	Present Study E300+[50]	QOHSRPS 200 km/h	QOHSRPS 300 km/h
New Grade Separations (units)	461	506	NA	471
Modifications to Existing Grade Separations (units)	133	99	NA	NA
New Farm Crossing Crossings	486	526	NA	NA
New Major Wildlife Passages	2	2	NA	NA
Capital Costs Grade Separations in million CAD	3 979	4 209	1 974*	2 878*
Public Road Closures	none	none	NA	100

Present study costs in 2009$'s
* QOHSRPS cost estimates updated to 2009 CAD using non-residential construction cost indices.

Additionally, the present study assumed that no existing roads would be closed and that new structures would be built to replace all at grade crossings along the HSR RoW.

It was anticipated that modifications to existing grade separations and the construction of new grade separations would impact the flow of roadway and rail freight traffic during construction.

Table 9-13: Distribution of Rail/Rail Grade Separations by HSR Service[51]

Route Segment	F200+	E300+
Quebec City - Montreal	4	5
Montreal - Ottawa	3	5
Ottawa - Toronto	5	12
Toronto - Windsor	16	19
Total	28	41

9.2 Indirect Impacts on the Road System

9.2.1 Road Congestion

The development of HSR would have an expected minimal impact on for the reduction of highway use demand. Although 59 percent of HSR ridership in 2031 was estimated to be diverted from autos, this was representative of only six (6) percent of the total auto trips.

[49] source Deliverable 6.1 Appendix D
[50] source Deliverable 6.1 Appendix D
[51] source Deliverable 6.1 Appendix D

On the other hand, HSR could have direct impacts on the future use of highway networks. The possible development of the HSR corridor on the North Shore of the St. Lawrence River, as illustrated in the representative routes, may require new road connections to be developed to provide access to the representative HSR stations in the vicinity of L'Ancienne Lorette and Dorval and at Trois-Rivières and, Laval. This may present a minor shift in traffic on existing bridges spanning the St. Lawrence River near future HSR stations.

New HSR stations in the vicinity of Kingston, Toronto East, Toronto West, London and Windsor would also require the establishment of new roadway connections.

The use of existing stations in the central metropolitan cities by HSR, and future planned commuter rail and transit service expansions in Quebec City, Montreal, Ottawa and Toronto would provide a high degree of connectivity with existing urban and regional transit services. It is therefore anticipated that the connectivity to the existing and future urban and regional transit services would also be utilized by HSR passengers to reach their urban stations and that HSR would not have a significant impact on metropolitan traffic congestion.

Suburban HSR stations sites would be envisioned at common locations for both the F200+ and E300+ services. The suburban stations located in the vicinity of Quebec City, Montreal and Toronto would also provide a high degree of connectivity to urban and regional services.

Representative station sites for Trois-Rivières, Kingston, London and Windsor were located far from the central business districts of these cities. For this reason it is anticipated that these stations in suburban locations would not have a significant impact on urban traffic congestion, but they could present opportunities to establish new connections to regional and intercity bus services.

As previously discussed, grade separations between the HSR line and the existing roadway network may alter current traffic flows and increase congestion on some area roads.

9.2.2 Road Construction

The overall impact of HSR on automobile travel would result in only a six (6) to seven (7) percent reduction in intercity traffic. It is not anticipated that this degree of traffic diversion would result in the deferral or elimination of planned road construction.

The construction of access roads to ingress to and egress from new HSR stations and new grade separations at the HSR corridor would have a more profound impact on regional and local roads than on major highways.

9.3 Indirect Impacts on the Rail System

9.3.1 Use of Railway Rights of Way

The following issues were examined:

- The present study assumed that the HSR corridor would be fenced on both sides. This could adversely impact access to conventional lines by freight railway employees in the absence of proper access planning.
- Where HSR trains are expected to run within existing RoW limits, the use of available space for HSR could impact the future capacity expansion opportunities for freight services.
- Where HSR trains are expected to run adjacent to existing freight RoW, the geometry of grade separation at existing grade crossings could interfere with the separation of the freight grade crossing as well.
- Where HSR trains are expected to run within or adjacent to the RoW limits of existing freight railways, freight rail sidings could require grade separation from the HSR tracks.
- During the construction of a HSR line, either within or adjacent to existing freight rail corridors, freight tracks would require constant protection which could necessitate reductions in permissible track speeds, track closures, track diversions, and/or the relocation of freight tracks.
- On segments of the HSR representative route that would deviate from railway-owned alignment currently used by VIA Rail, the withdrawal of passenger service could significantly impact the future viability of the freight line, e.g. CP Brockville Subdivision is a case in point.
- The withdrawal of passenger services could also impact the freight railways' track and signal maintenance staff and other impacted personnel allocated to the current corridor. Personnel arrangements could also be impacted by a downgrade in Class of track as defined in the Transport Canada Rules Respecting Track Safety due to a reduction in maximum operating speeds. This could result in costs to VIA for reallocation or downsizing of corridor personnel.

9.3.2 Fluidity of Freight Transportation

The continuation of rail freight operations in the Quebec City-Windsor corridor has been accommodated by the following considerations:

- The need to maintain rail freight service during construction and start up operations has been taken into account in the cost estimates in the technical report for Deliverable 6.1, Capital Costs.
- The need to maintain access to current and future rail side industries and yard facilities has been accounted for with provisions for rail-to-rail grade separations and additional tracks. These have also been taken into account in the cost estimates in Deliverable 6.1.

- In segments where HSR and freight trains would occupy the same RoW, adequate spacing between high speed rail and freight tracks has been provided.
- The assessment of access and management fees has been included in part by provisions in the technical report for Deliverable 6.2, O&M Costs.
- Provision has been made in the O&M cost estimates for maintaining the infrastructure. This is an item which is normally covered by access fees and which would be an unresolved issue to be discussed in subsequent phases of the implementation of HSR.
- Construction cost estimates included, in addition to capital construction costs, the cost of relocating existing railway lines and decommissioning of passenger specific assets on lines where conventional passenger rail service would be withdrawn and HSR would not be provided. This would also be an item usually included in right of way and track usage fees.

9.3.3 Impacts on VIA Rail

The utilization of VIA Rail's expertise and the transfer of its personnel to HSR would depend on the business development model employed. The reduction of VIA Rail staff assigned to the Quebec City - Windsor corridor directly impacted by the implementation of HSR could incur certain work force reduction payments, redeployment and training costs.

The project structure and delivery method for the implementation of HSR could include such options as design-build, design-build-finance-operate and other Public Private Partnerships (PPP). A design-build structure could permit the organizational integration of VIA Rail and HSR that would capitalize on industry expertise acquired by VIA Rail management and employees and ease the operational and functional transition between conventional passenger rail and the implementation of HSR.

VIA Rail currently operates more than 355 trains run per week in the Quebec City-Windsor corridor, carrying 80 percent of VIA's total ridership[52]. It was assumed that the implementation of HSR would eliminate the current operation of corridor conventional passenger rail services.

The future operation of other existing VIA services that connect to the corridor would require further planning consideration. The remaining conventional passenger services and use of associated infrastructure assets, in particular rolling stock assets, would be significantly diminished. Extraneous equipment currently used on the corridor and no longer required by HSR, could be cascaded to the remaining VIA Rail conventional passenger rail network or made available to other conventional rail passenger service providers.

[52] http://www.viarail.ca/en/about-via-rail; VIA Rail 2009 Annual Report

Existing station locations where conventional rail service would be replaced by HSR, would be enhanced to accommodate HSR specific requirements and to provide sufficient capacity to accommodate future HSR ridership on platforms, at station buildings and in parking facilities.

In addition, on sections of the current VIA Rail route owned by freight operators, passenger specific infrastructure facilities e.g. stations and platforms would require decommissioning. This could also cause disruption to freight operators and possibly include temporary track closures, speed restrictions and track diversions.

On segments of the HSR representative routes that would deviate from the VIA Rail owned alignment, track sections could become superfluous to VIA Rail e.g. Alexandria Subdivision and could therefore become available for transfer to another rail user or for other use.

9.4 Indirect Impacts on Urban and Regional Transit Systems

9.4.1 Commuter Rail

Extensive commuter rail services are currently provided in Montreal by AMT and in Toronto by GO Transit. These services are intensified in morning and evening peak periods with lower frequencies provided in the off peak periods. Due to surrounding urban developments and land use, the expansion of infrastructure in these corridors was largely limited to the available space within the RoW. Access to Central Station in Montreal and Union Station in Toronto for HSR may be severely constricted by the current and future commuter services provided.

The speed capabilities and limited service stops within the urban corridors of HSR could change the current rail traffic flow within the urban areas of Montreal and Toronto. While VIA Rail conventional trains currently provide service to some intermediate stations, HSR would only provide service to central urban and peripheral suburban stations at specific locations. The operation of HSR intermingled with local and express commuter trains would require a high level of coordination and a modernized signal system to ensure that capacity would be maximized and the performance requirements of all services could be achieved.

It is anticipated that the implementation of HSR could further extend the commuter shed beyond the extremities of an expanded commuter network. For example while the use of HSR was not intended as a commuter service per se, HSR passenger connections at Kingston or London could potentially provide an effective connection to stations with existing or future commuter service intermodal access[53].

[53] Deliverable 7 Table 6-2 presents HSR stations locations used to develop demand analysis and ridership forecasting.

9.4.2 Urban and Regional Transit

One of the considerations in the evaluation of future possible HSR station locations was the integration of the HSR stations with other transportation modes (both existing and planned), including possible connections to the urban and regional transit/bus services.

The HSR station locations described in the technical report for Deliverable 5, Representative Routes, provided representative and not specific locations. However in Quebec City, Montreal, Ottawa and Toronto, the existing main stations were identified as HSR stations due to their proximity to central business districts (CBD) and existing intermodal connections.

Depending on the location of the CBD in the major cities relative to the HSR corridor, it was proposed that, in addition to the main station, one or two suburban stations should be considered.

These locations would be the preferred HSR station for trips originating in that city, as a suburban station would likely be more easily accessible to a high proportion of departing passengers who would leave their homes to directly access the station.

9.5 Indirect Impacts on the Air System

9.5.1 Impacts on Airlines

National Airlines Council of Canada (NACC) representatives have stated publicly that the use of public funds to subsidize a HSR system would create a modal imbalance between air and rail that would threaten the financial stability of the airline companies and the jobs of their employees. The NACC indicated that their major concern was the policy environment and cost environment under which HSR competition could present itself to the air carriers. The implementation of HSR could therefore precipitate a policy and cost review that would be considered desirable by the air carriers.

If given the opportunity and if early in the process, airlines could choose to coordinate their services with HSR services to feed traffic to their long-haul or other regional markets not served by HSR, as has been observed in Europe.

9.5.2 Impacts on Airports

The QOHSRPS included limited discussion regarding direct impacts on airports. It did however indicate that substantial ridership to and from the airports would occur within the HSR corridor. This connecting traffic was not assessed under the present study, since HSR would not directly serve airports in Montreal or Toronto. The

QOHSRPS 300 km/h route also included a station stop at Mirabel which has been since closed to passenger traffic.

The possibility of consolidated or cancelled flights in response to projected loss of air passengers diverted to HSR, could impact landing revenues and may result in increases to airline landing fees to compensate for reductions in number of flights.

The projected ridership diversion from airlines to HSR could have a direct impact on airport improvement fees at the various airports where such fees are applied to users of the facility. This could impact both departing and transferring passengers.

9.6 Indirect Impacts on the Intercity Bus System

The parent companies of the corridor's major intercity bus operators could be advocates for the implementation of a HSR service. These companies have expertise in HSR operations in European services that would be beneficial to a Canadian application. The support of HSR by the intercity bus industry would likely be dependent on the equitable distribution of subsidies, inter-mode regulatory parity and the integration and inclusion of all modes to form a master transportation plan.

Representatives from the Canadian Bus Association (CBA)[54] have publicly stated that a HSR system should be fully integrated into a seamless transportation system supported by a public policy environment that would include air, rail and bus transportation modes and that HSR fares should be set "at levels that are reasonably compensatory in relation to the costs."[55]

[54] The CBA is a non profit advocacy group which provides representation and input into governmental issues on behalf of its membership. CBA members represent 75% of bus passenger revenues and 90% of bus parcel revenues in Canada

[55] http://www2.parl.gc.ca/HousePublications/Publication.aspx?DocId=3935511&Language=E&Mode=1&Parl=40&Ses=2

10 IMPLEMENTATION SCHEDULE AND OPTIONS

This section discusses HSR implementation schedule and options, including private sector participation (PSP). Detailed information on schedule can be found in the technical report for Deliverable 6.2, O&M Costs, and detailed information on options can be found in the technical report for Deliverables 10/11, Financial and Economic Analyses.

10.1 Project Implementation Schedule

The main purpose of the proposed project implementation schedule was to provide a cash flow for the financial analysis. It was assumed that the project would be implemented according to a conventional procurement process, as was the case in the QOHSRPS. It is EcoTrain's opinion that the schedule duration would not vary significantly, whether the project was launched under a PPP process or not; the activities preceding the detailed engineering and construction would be under complete governmental (or public) responsibility and since they account for almost ten years for environmental assessment and property acquisition, they would provide very little margin to the private sector for reducing the duration of the total schedule.

The overall schedule presented in Figure 10-1 shows that passenger service for the whole Quebec-City – Windsor corridor could begin at a minimum 14 years following the launching of the conceptual design and environmental assessment. For purposes of the subsequent analyses, it has been assumed that this decision would take place in 2011 and that the full Quebec City – Windsor corridor HSR could enter into commercial service in 2025. This schedule was based on several assumptions that should be refined at key milestones. In addition this very long timeline would require strong governmental leadership and the active participation of a large number of stakeholders, including interested private sector engineers, contractors, and financiers.

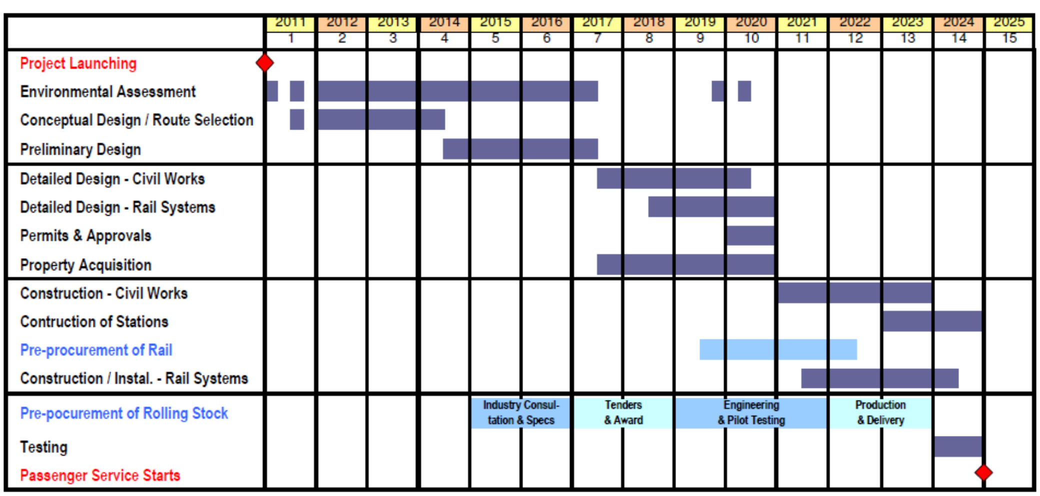


Figure 10-1: Quebec City - Windsor HSR Project Implementation Schedule

10.1.1 Environmental Assessment

Following the conclusion of the Feasibility Study and the selection of the preferred option (F200+ or E300+), the next phase would be to conduct an Individual Environmental Assessment (EA), should it be determined that an EA should proceed. Transport Canada would be the Responsible Authority for the purposes of the Canadian Environmental Assessment Act. As well, it is expected that the Ontario and Quebec Environmental Assessment processes would need to be followed. The EA would likely be completed to satisfy the requirements of all applicable EA processes and would be undertaken as an individual environmental assessment (IEA).

Permits and authorizations from the governments of Canada, Ontario, and Quebec would have to be obtained using EA procedures prescribed by those authorities. Recent agreements between the provinces and between the provinces and the federal government show a desire for harmonization in environmental assessment processes. Thus, it is suggested that a single environmental process, complying with the requirements of these three governments, would need to be developed to move the HSR project to the next stage.

There were significant concerns about the time required for conducting an IEA. In order to minimize the time required to complete the IEA, the project schedule has included a task for the development of provincial and/or federal legislation to streamline the EA process for the HSR project. During this time, the project's applicability under the new Ontario Regulation 231/08 for the Ontario Environmental Assessment Act, specifically relating to transit projects would be examined, together with other process efficiency options. Based on a streamlined EA process with the provincial and/or federal governments, it was estimated that the EA could be completed within 5 to 8 years following project launching.

This pre-construction period would include all conceptual design and preliminary engineering, environmental assessment, and early works activities such as topographical, geotechnical and hydrological surveys.

10.1.2 Conceptual Design and Route Selection

It is recommended that a conceptual design be developed for the entire Quebec City – Windsor corridor. It should start at the same time as the EA, in order to provide as soon as possible the necessary geographical and other parameters to the EA. The conceptual design should be the foundation upon which the HSR project would be built. It is important from a systems perspective that the route selection, the design criteria and the resultant horizontal and vertical alignments be developed with a single point of responsibility. It is expected that it would take six months to develop Terms of Reference and sign contracts with Consultants to undertake the conceptual design study.

A significant portion of the proposed representative routes would be adjacent to existing rail lines. However, some portions of the route would lie on green field RoW. For these portions of the routes, the conceptual design study could take a significantly longer time to develop, analyze and evaluate alternative routes.

It is expected that the conceptual design study, which would include a 1:2,000 scale functional design, would be a technical effort that could benefit from public consultations through "open door" sessions to be conducted during the EA study. It is assumed that the Consultants would need 30 months to complete the conceptual design and route selection study.

10.1.3 Preliminary Engineering

The preliminary engineering would be undertaken in conjunction with the EA. It is assumed that an additional six months from the end of the EA to the end of the preliminary engineering would be required.

10.1.4 Detailed Engineering

In a conventional project, detailed engineering is almost always undertaken by a different firm or team from the one that performed the preliminary engineering. The proposed project schedule shows that detailed engineering for civil works would start immediately after the preliminary engineering has been completed.

Detailed engineering for rail systems could begin when a significant amount of the civil works engineering has been completed. The proposed schedule indicates that the rail engineering would start one year after the start of the civil works engineering and would be completed six months after the civil works engineering would be completed.

10.1.5 Property Acquisition

Typically, property acquisition would not start until the end of the 30 percent completed detailed engineering milestone (at the earliest), and usually at the end of the 60 percent completed detailed engineering milestone. A project would not be tendered without all properties in hand, due to the risk of contractor claims for delays. A 42-month duration was proposed, slightly longer than the 36-month duration specified in the QOHSRPS, including approximately six months at the end of the task for tendering civil works. This is still optimistic since there is a minimum 18-month process time for expropriation, with hundreds of properties to be acquired. Resources would be a major constraint to the scheduling of this task.

In the QOHSRPS plan, the fabrication and installation of railway systems was not scheduled to start until two years of civil works were completed. The proposed schedule shows that the fabrication and installation of railway systems may start six months after the civil works have started.

10.1.6 Procurement

Two significant schedule risks were identified: (i) the availability of steel rail; and (ii) the on-time availability of rolling stock (due to car builder production schedules).

To address these risks, advanced procurement of rail and trainsets is recommended. This would provide cost savings due to the size of the orders and the ability to guarantee manufacturing slots well in advance of required delivery date on site. The timelines shown for the procurement of trainsets and the interim milestones have been reviewed by a major manufacturer to ensure their reasonableness.

10.1.7 Civil Works, Railway Systems and Rolling Stock

The proposed project schedule has maintained the QOHSRPS durations for general construction (civil works and stations) and fabrication and installation of railway systems and rolling stock. Station construction or modification, estimated at 24 months, would terminate just before the passenger service start-up. Fabrication and installation of railway systems would begin six months after the civil works have started in order to be completed some six months before the end of the testing activities.

10.1.8 Testing

The QOHSRPS implementation plan had the testing starting six months before the end of installation of the railway systems. The same duration and logic for testing and station construction were maintained in the proposed project schedule.

10.2 Follow-up Actions and Next Steps

To implement HSR in the Quebec City – Windsor corridor, the three Governments of Canada, Quebec and Ontario should prepare an inter-city transportation master plan, involving air, rail and bus operators, with a view of defining a sustainable plan for the next 50 years. The master plan would include an update of the ridership and economic analyses, based on the latest fares and ridership figures for the different modes in the Corridor. At the same time, EcoTrain recommends the establishment of a HSR Authority that would oversee the design and construction of the system and would operate it on a commercial basis. The HSR Authority would then assess market capacity in terms of costs and schedules and determine the proper size of sub-projects. The Authority would also test what risks could be transferred to the private sector in any PPP project, based on the observation that in the cases that were analysed as part of the present study ridership risk was usually assumed by the public sector.

One of the first tasks of the HSR Authority would be to launch the Conceptual Design of the project, which would start with a route selection and functional design phase, followed by a preliminary engineering phase.

Another task would be for the Authority to develop terms of reference for the Environmental Assessment, taking into account the environmental legislation in the three jurisdictions: Canada, Ontario and Quebec. Depending on circumstances, HSR sub-projects could be divided into several logical sections that could be procured separately through a phased approach. The successful delivery of one section or segment can sometimes play an important role in motivating industry market players and funders to get involved with the other sections.

10.3 Review of Options for Public Private Partnerships (PPP)

EcoTrain performed a review of seven HSR projects with a significant private sector contribution, in the form of PPP. This review aimed to achieve the following two objectives: (i) Gain a better understanding of these HSR projects, in terms of their size, risk allocation, contractual arrangements, payment structure, lifecycle and maintenance, financing, performance and accountability measures, key challenges, success factors and lessons learned; and (ii) Assess the relevance of these findings to the Quebec City - Windsor HSR project, in terms of risk allocation, contractual arrangements, capital structure and level of private sector contribution.

The seven projects reviewed cover six countries. They include: Poceirao-Caia Rave (Portugal); Perpignan-Figueras (France and Spain); GSM-R (France); TGV Bordeaux-Tours (France); High Speed 1 (London St-Pancras – Channel Tunnel Rail Link in United Kingdom); Taipei-Kaohsiung (Taiwan); and HSL-Zuid (Netherland).

The review was based on publicly available information and the knowledge of EcoTrain's team members.

Each project is unique in terms of size, geographic location, technical specifications, and risk profile. Still, common traits have emerged and should be considered. These considerations include the following:

- A consultation process is a very important tool to assess the technical and financial risks of HSR projects over their lifecycle.
- Public authorities would need to clearly identify and adequately assess all project risks prior to designing and structuring a procurement process. Furthermore, they would need to achieve a balanced and optimal allocation of project risks between the public and private sectors. Overly optimistic ridership forecasts by the public and the private sectors can be quite detrimental to the success of a project. This was the case with UK and Taiwan projects that had to be restructured shortly after being launched. The restructuring of these projects resulted in the public sector providing substantial additional funds or guarantees and assuming greater risks than initially planned because the private investors could not meet their financial obligations.

- The ridership risk is difficult to transfer to the private sector, especially when there is no historical information to support the demand forecasts.
- The allocation of geotechnical, land and property acquisition, or archaeological risks varies depending on circumstances. The transfer of these risks to the private sector may be quite costly.
- As for the allocation of other project risks, best value for the public funds invested should always be a key factor in deciding whether to transfer or not transfer such risks. On one hand, the Dutch Government decided to retain those risks in the HSL-Zuid project. On the other hand, the Portuguese Government opted to transfer most of these risks to the private sector, primarily because the PPP market had matured since the Netherland deal and secondly because the private sector was able to price these risks at an acceptable level.
- HSR projects require sufficient levels of equity capital to withstand the financial impacts of the risks transferred to the private sector.
- Availability based projects, i.e. PPP projects where revenues from fares or tolls are not part of a concession contract, but rather retained by the Owner, are easier to finance than projects involving a greater risk allocation to the private sector, including revenue risk. Prior to the financial crisis starting in the fall of 2008, a 90 to 10 debt to equity ratio was possible for HSR availability based projects. More recently, availability based projects have closed at a debt to equity ratio of approximately 80 to 20.
- Riskier projects where ridership risk is transferred to the private partner could require a capital structure ranging from a 70 to 30 to a 75 to 25 debt to equity ratio.
- The size and structure of HSR projects need to be assessed early in the planning phase, in line with private sector interest and financial capacity. An overly large project, both in term of size and value, could contribute to reducing the level of interest and competitiveness from the private sector, especially in new markets where such deals have not yet been made.
- Depending on circumstances, HSR projects would be divided into several logical sections that could be procured separately through a phased approach. The successful delivery of one section or segment can sometimes play an important role in motivating industry market players and funders to get involved with the other sections. This strategy was successfully achieved in the recent Rave project in Portugal. In France, the development of the TGV network was also split into phases, starting with the most viable lines.
- Public funding of HSR projects represents, in most cases, approximately half of the projects' costs. Note that in Europe, the European Investment Bank contributes to the funding of most projects, by way of loans at preferential conditions.

- Strong political leadership is an important factor in the development of major HSR projects, given the very long time required for delivering such projects and the high level of public funding required.
- It is common that agreements related to the provision of HSR infrastructure - typically through Design-Build-Finance-Maintain (DBFM) models - and to the operations of a HSR be subject to separate PPP contracts. Typical DBFM concession agreements cover periods varying between 30 to 50 years while operations agreements are for shorter periods of time and usually with national operators.
- In all deals, it is critical that the payment mechanism be clearly defined and ensure that there is sufficient incentive (financially and other) to perform in line with the projects' requirements.

11 FINANCIAL AND ECONOMIC ANALYSES

The financial and economic analyses rely on inputs from other sections of the current feasibility study. Given that the project is at an early planning stage, there is uncertainty in various parameters and inputs. Assumptions on project structure, private sector interest and capacity and financing market capacity and conditions have been developed based on EcoTrain members' knowledge of similar projects. However such assumptions have not been specifically validated through market sounding with potential project participants. Such validations are recommended for further studies.

No phasing has been assumed in this study, although it is most likely that such a project would be developed through a phased approach, to be agreed upon by the three levels of government.

11.1 Scope

The financial and economic analyses covered the following eight scenarios based on two types of representative technologies and four functional segments, as listed below:

Table 11-1: Description of Scenarios

Scenario	Functional Segment	Representative Technology
QW-200	Quebec - Windsor	F200
QT-200	Quebec-Toronto	F200
MT-200	Montreal-Toronto	F200
TW-200	Toronto-Windsor	F200
QW-300	Quebec - Windsor	E300
QT-300	Quebec-Toronto	E300
MT-300	Montreal-Toronto	E300
TW-300	Toronto-Windsor	E300

The base case scenarios consisted of the Quebec City – Windsor functional segment for both F200+ and E300+ technologies. Other scenarios with functional segments between Quebec City and Toronto, Montreal and Toronto, and Toronto and Windsor have also been examined.

The financial analysis was performed under two delivery modes, a wholly public case and a private sector participation (PSP) case.

11.2 Project Risk Profile

The Quebec City - Windsor HSR project is considered to be high risk for various reasons, including its very large size, its complexity and the lack of HSR precedents in Canada. The project risks relate to the following issues:

- Assessing the future demand of the HSR service is very complex and difficult, particularly when there is no relevant comparable to rely upon. Indeed, the potential travellers' reaction to HSR in the Quebec City – Windsor corridor is a key consideration as it would determine the level of revenue generated by the project and therefore its ability to recover the initial investment and the recurrent costs.
- Planning and design of such a large project are particularly lengthy and complex. This complexity entails uncertainty, which requires contractual and financial flexibility. Examples of pre-construction risks include the risks involved in the acquisition of the required RoW, and in obtaining the mandatory environmental approvals and permits for a multijurisdictional project.
- Construction risk is a major risk for large infrastructure projects as they typically include technical, contractual and managerial constraints which require carefully management. Construction risks relate to items such as soil condition, cost overruns and scheduling overruns, which are sometimes beyond the control of the sponsors.
- During operations, there are risks related to train operations, maintenance of the HSR system, and asset rehabilitation over the long term.
- Financing risk is high for projects involving long gestation periods, extensive construction works, large funding requirements, uncertain demand for a new service, and returns on investment over a long term period, whether borne by the public or private sector (or a mixture thereof).
- Appropriate risk allocation and governance are critical factors, no matter what the funding sources for the project are: public, private or a mixture thereof.
- Public acceptance and support is crucial for a highly visible and costly infrastructure project.

11.3 Financial Analysis

11.3.1 Objective

The objective of the financial analysis was to estimate the financial rate of return (FRR) of the project, the level of funding required by Government and the means by which the project could be financed with and without PSP.

11.3.2 Project Costs

For the purpose of the financial analysis, the project costs have been apportioned into three phases:

- A pre-construction period of 6 years for activities such as conceptual design, preliminary and detailed engineering, and environmental assessment
- A detailed engineering period of four (4) years for detailed engineering of civil works and of rail systems, early works activities such as topographical, geotechnical and hydrological surveys, as well as land and property acquisition, plus a construction period of four (4) years for activities such as earthworks, drainage, construction of tunnels, bridges and stations, laying of tracks, installation of signalling and telecommunications systems, and construction of transmission lines, power sub-stations and catenary for the E300+ system
- An operating period of 30 years starting once the construction works have been completed and approved by the relevant authorities and the system has been thoroughly tested. Costs during the operating period include annual operation and maintenance (O&M) costs, and renewal costs related to the lifecycle replacement of assets

The following table illustrates the estimated project costs for each of the eight scenarios in constant (2009) millions of Canadian dollars (CAD) before inflation.

Table 11-2: Estimation of Project Costs in Constant (2009) Dollars before Inflation

Scenario	Pre-Construction Costs (2009 M$)	Construction Costs (2009 M$)	O&M Costs (30 years) (2009 M$)	Renewal Costs (30 years) (2009 M$)
QW-200	297	18,630	16,168	6,925
QT-200	224	13,760	12,510	5,222
MT-200	141	8,926	8,840	3,345
TW-200	72	4,847	3,844	1,731
QW-300	335	20,965	16,876	8,607
QT-300	256	15,731	13,334	6,537
MT-300	173	10,778	9,476	4,658
TW-300	82	5,532	4,028	2,313

The following table illustrates the estimated project costs for each of the eight scenarios in inflated (nominal) millions of Canadian dollars (CAD).

Table 11-3: Estimation of Project Costs in Inflated Dollars

Scenario	Pre-Construction Costs (M$)	Construction Costs (M$)	O&M Costs (30 years) (M$)	Renewal Costs (30 years) (M$)
QW-200	345	26,162	30,977	15,842
QT-200	260	19,315	23,960	11,944
MT-200	164	12,534	16,930	7,601
TW-200	83	6,821	7,356	3,889
QW-300	389	29,342	32,294	19,141
QT-300	298	22,002	25,518	14,565
MT-300	202	15,050	18,146	10,348
TW-300	95	7,737	7,706	5,062

11.3.3 Project Structure Overview and Underlying Risk Sharing

EcoTrain has performed financial analyses using project structures that are representative of current market trends and methods for implementing HSR projects in other jurisdictions. Many variations to the structure are possible and could be considered in further studies.

The wholly public case assumed that the project would be delivered exclusively by the public sector under a traditional delivery method. Further, the public sector would assume all project costs and risks, including all the required financing, and would retain all project revenues and potential upsides.

The PSP case assumed that the public sector would transfer some of the project costs and risks to the private sector using a PPP framework, namely risks that the private sector is most apt at managing, up to an acceptable market level. Under this case, the private sector would inject equity into the project in exchange for a specified level of compensation required to achieve a targeted FRR.

PSP could take different risk sharing and contractual forms ranging from a wholly private sector delivery mode, such as a concession, to various types of PPP agreements for certain components of the project.

In most HSR projects, ridership and revenue risks were retained by the public sector either through a rail authority or a state-owned enterprise. Transfer of HSR ridership risk was challenging, as described above in Section 10.3, Review of Options for Public Private Partnerships. Hence, for this project, it was assumed that the public sector would bear ridership and revenue risks.

The private partner would be primarily responsible for the design, construction, financing and maintenance of certain capital components of the project. Payments to the private partner would be made by the authority or state-owned enterprise, but would be ultimately funded or guaranteed by the governments.

In terms of project components, considering the private sector interest and risk tolerance in precedent HSR projects, civil works, track, signal and telecommunication systems would most likely be delivered under a PPP framework. Other components of the project including RoW acquisition, power supply, stations, rolling stock, maintenance facilities and information technology (IT) and ticketing systems were assumed to be retained by the public sector as it would likely require higher levels of control over these components.

Based on the above and consistent with other PPP deals in Canada, the PSP case was defined as a Design – Build – Finance – Maintain (DBFM) contract for the delivery and maintenance of the civil works, track, signal and telecommunication components of the project.

It was assumed that a wholly private sector option whereby all project risks would be transferred to the private sector was not financeable, thereby unachievable due to the size and high risk profile of the project. Accordingly, this option was not considered for the purpose of the financial analysis.

11.3.4 The Wholly Public Case

The following diagram illustrates the assumed project structure and assignment of responsibilities under the wholly public case:

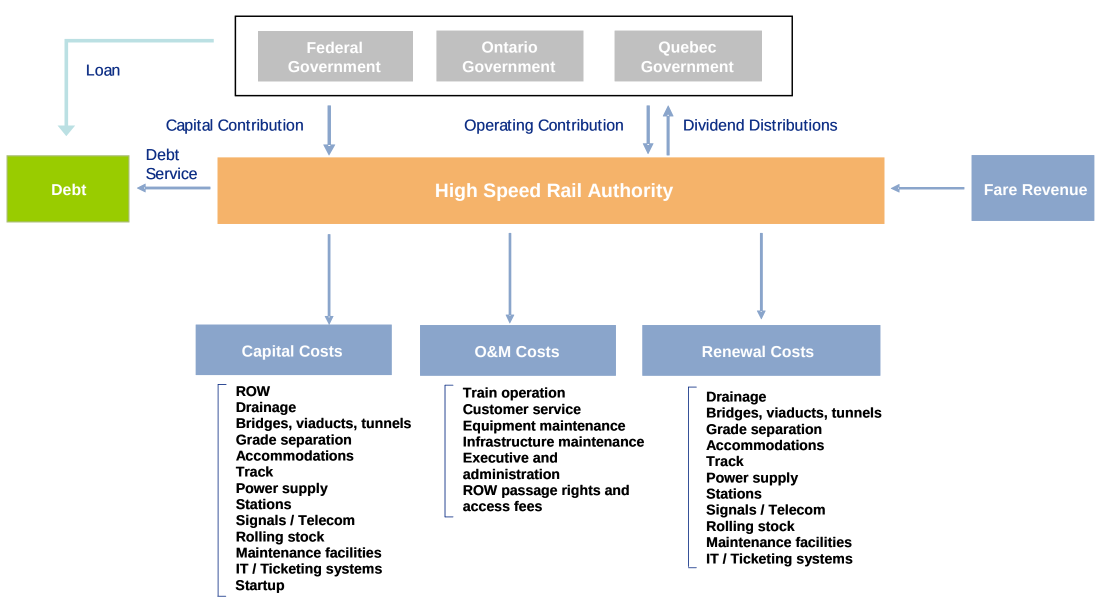


FIGURE 11-1: WHOLLY PUBLIC CASE

11.3.4.1 High Speed Rail Authority (Authority)

The HSR Authority would be established by the three levels of government – Canada, Ontario and Québec.

The Authority would have overall responsibility for the development and provision of the HSR project, and would directly finance the project, acquire RoW, build all infrastructure, acquire equipment and rolling stock, and operate and maintain all components of the system over a 30 year period.

The Authority would subcontract work and could transfer some of the project risks to suppliers of services for a price. Contrary to a PSP case, there was no equity injection from the private sector in the wholly public case.

The Authority would have access to capital provided by Government. While EcoTrain was not excluding any options, it assumed that the Government would provide a repayable loan to the Authority based on its debt capacity as determined by the amount of operating cash flow available to service interest and principal payments.

Capital costs in excess of the projected debt capacity of the Authority would be funded by the governments in the form of a capital contribution.

The Authority was assumed to be a non taxable entity. In the event that it generates excess cash at the end of a year, it would be distributed to the Government in the form of dividends. Conversely, should the Authority incur an operating deficit, it would be guaranteed by the Government, without requiring the Authority to access any other form of debt or revolving credit facility.

The interest rate on the loan provided to the Authority by the Government was assumed to be the 10-year borrowing rates of the three governments weighted according to their assumed funding share (50 percent by the federal and 25 percent by each province) which comes to 3.8 percent (July 2010). The debt would be fully amortized over the 30-year operating time horizon.

11.3.4.2 Flow of Funds

<u>Pre-construction</u>: During years 1 to 6, work performed would include activities such as conceptual design, preliminary engineering and environmental assessment studies. This work would be funded by the three governments according to the sharing agreement.

<u>Property Acquisition and Construction</u>: Starting in year 7, the Authority would use the proceeds from the loan provided by the Government to fund the capital spending required for that year. Interest on the loan would be accrued during this period.

The amount of the loan provided by the Government to the Authority would correspond to the amount that the projected net operating revenues of the Authority (before major renewal costs) could support. Capital spending requirements over this amount were assumed to be funded by the Government through capital and/or equity contributions.

Operations: Once construction was completed and rail operations begin, the Authority would operate the passenger rail service, collect fare revenue, pay for all O&M and renewal costs and make interest and principal payments on the loan obtained during construction.

If the fare revenues collected by the Authority were not sufficient to pay for all O&M, renewal and debt service costs for the year, the Authority would incur an operating deficit. It was assumed that the Government would provide an operating contribution to make up the difference. Conversely, if the Authority makes an operating profit for the year, this profit would be distributed to the Government in the form of dividends. The dividend payment would be distributed according to the contributions made by the three governments.

11.3.4.3 *Calculation of Financial Rate of Return*

Financial Rates of Return (FRR) for the wholly public case were calculated using cash outflows from the Government for capital and operating contributions: cash inflows to the Government consisting of dividends paid by the Authority: and the terminal value of the project at the end of the 30-year operation period.

11.3.4.4 *Terminal Value Calculation*

It was assumed that the investments made by the Government would have value beyond the 30 years of operation and that value was considered in the financial analysis. The terminal value was calculated using a capitalized cash flow method, a standard technique for valuation of on-going operations past the end of the projection period. This method applies a capitalization factor of 15x the normalized annual cash flow of the project in the last year of the projection period.

The normalized annual cash flow was calculated as revenue, less all operating costs less normalized renewal costs. Renewal costs needed to be normalized as they were irregular and the amount incurred in a given year may not be representative of an average year. To address this issue, the renewal costs for the project were distributed over a long period in order to arrive at an average annual spending rate.

11.3.5 The Private Sector Participation Case

The following diagram illustrates the assumed project structure and assignment of responsibilities under the PSP case:

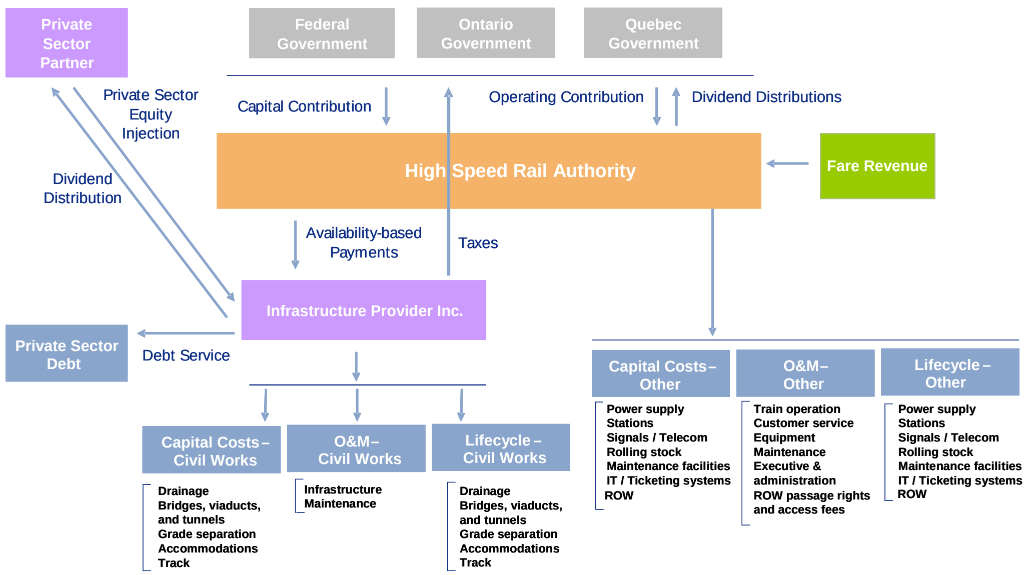


FIGURE 11-2: PRIVATE SECTOR PARTICIPATION CASE

The above project structure was a conceptual simplification used for the purpose of the financial analysis. It was assumed that there would be one DBFM contract with a private sector Special Purpose Vehicle (SPV), namely Infrastructure Provider Inc. (Infrastructure Provider).

It was likely that a project of this size would be split into multiple, and possibly phased, sub-projects and DBFM transactions. Each sub-project would likely have a financeable size of about $3 to $4 billion CAD. For simplicity, it was assumed that the Infrastructure Provider in each of these potential DBFM transactions would have the same capital structure (debt to equity ratio of 80 to 20) under the same financing and project commercial terms. Hence the various DBFM transactions could be modelled as a single group in the financial analysis.

11.3.5.1 High Speed Rail Authority

Under the PSP case, the HSR Authority would directly finance part of the project; acquire RoW, equipment and rolling stock; and operate and maintain the RoW, power supply, stations, rolling stock, maintenance facilities and IT and ticketing systems. Further, it would operate the HSR service and assume the revenue risk.

The Authority would enter into a DBFM contract with an Infrastructure Provider for financing the design, construction and maintenance of civil works. Accordingly, the Authority would make availability-based payments to Infrastructure Provider over an operating period of 30 years. The Authority would also make payments to Infrastructure Provider during the construction period in order to reduce the amount of financing required by Infrastructure Provider. This approach was commonly used in similar PPP agreements to reduce the cost of private financing and to make the transaction more financeable.

11.3.5.2 *Infrastructure Provider*

The Infrastructure Provider would be responsible for designing, constructing, financing and maintaining the civil works portion of the HSR system through a DBFM contract signed with the Authority. Civil works would include the following components: earthworks and drainage, grade separations, bridges, viaducts, tunnels, tracks, signals and telecommunications and catenary for the E300+ option.

The Infrastructure Provider would have a capital structure of 20 percent equity and 80 percent debt. This structure was consistent with similar DBFM deals occurring in the Canadian market and for international HSR Transactions.

It was assumed that no more than 50 percent of the capital cost of the project would be financed by the private sector, which was consistent with the level of financing provided by the private sector in the various HSR projects around the world. If the construction costs assumed by Infrastructure Provider exceed 50 percent of the capital costs of the entire project, the excess would be funded through construction payments by the Government.

Market sounding and benchmarking should be performed at a later date to assess the financing market capacity and validate the above noted 50 percent capital costs cap.

11.3.5.3 *Flow of Funds*

Pre-construction: During years 1 to 6, work performed would include activities such as conceptual design, preliminary engineering and environmental assessment studies. This work would be either undertaken directly by the Government or, if undertaken by the private sector, the costs would be funded by the Government in the form of capital payments.

Property Acquisition and Construction: Starting in year 7, the Government would fund all of the capital cost requirements of the Authority by way of yearly capital contributions, and a portion of the construction costs of Infrastructure Provider, by way of construction payments. Infrastructure Provider would issue debt and raise equity at an 80 to 20 debt to equity ratio to fund infrastructure components under its responsibility, not already funded by Government. Interest on debt would be paid by Infrastructure Provider during construction, and would be funded out of debt proceeds, in keeping with general practice for project finance debt. The cost of debt for the private sector was assumed to be the Base Interest Rate (a blended average of the long-term risk-free rates for the Governments of Canada, Ontario and Québec) plus a Margin Rate of 300 basis points.

As of July 19, 2010, the long term risk free rates were 3.70 percent for Canada, 4.65 percent for Ontario, and 4.74 percent for Québec, resulting in a blended average Base Interest Rate of 4.20 percent. The cost of debt to Infrastructure Provider would thus be 7.2 percent (i.e. 3.0 percent for margin plus 4.2 percent for interest rate).

Operations: Once construction was completed and rail operations begin, the Authority would operate the passenger rail service, collect fare revenue, pay for all O&M costs associated with the components under its responsibility, and make availability payments to Infrastructure Provider. If the fare revenue collected by the Authority was not sufficient to pay for all O&M costs and to make availability payments, the Authority would incur an operating deficit. It was assumed that the Government would then provide an operating contribution to make up the difference. Conversely, if the Authority makes an operating profit for the year, this profit would be distributed to the Government in the form of dividends. The dividend payment would be apportioned according to the contribution each level of government has made.

During the operation period, Infrastructure Provider would pay for all capital and operating costs related to components under its responsibility and collect availability payments from the Authority based on its performance and the availability and usability of the tracks, catenary (in the case of the E300+ technology), signals and telecommunications systems.

Availability payments would be based on the private sector's annual maintenance costs over the 30 year term, debt service costs and required FRR. Yearly operating profits would be distributed to the private sector partner or sponsor in the form of dividends. Cash returns to the private sector partner would be calculated on the basis of these dividends. Profits generated by Infrastructure Provider would be taxable at statutory federal and provincial rates.

Operating losses incurred by Infrastructure Provider would be assumed by the private sector partner as such losses would not be guaranteed by the public sector.

At the end of the 30 year term, the assets maintained by Infrastructure Provider would revert back to the governments at no cost.

11.3.5.4 Calculation of Financial Rate of Return (FRR) - Public Sector

In the PSP case, the FRR to Government was calculated using:

- Cash outflows from Government consisting of capital and operating contributions into the Authority and construction payments to Infrastructure Provider to offset a portion of the private sector's capital costs
- Cash inflows to Government consisting of dividends paid by the Authority, income taxes paid by Infrastructure Provider, and the terminal value of the project.

Sales taxes on HSR fares were not included in the financial analysis[56]. This was consistent with the treatment used in the 1995 Study.

11.3.5.5 Calculation of Financial Rate of Return (FRR) - Private Sector

The FRR for the private sector was calculated using:

- Cash outflows from the private sector partner consisting of equity injections to Infrastructure Provider during the construction and operation periods
- Cash inflows to the private sector partner consisting of dividends paid by Infrastructure Provider.

It was assumed that the FRR required by Infrastructure Provider was 13.5 percent after tax at the SPV level.

11.3.5.6 Terminal Value Calculation

At the end of the 30 year term, the assets maintained by Infrastructure Provider would revert back to Government. While there may be reasons to extend the PPP agreement, for financial analysis it was assumed that all HSR system assets would return to or remain in public hands. It was further assumed that the assets that have been maintained by the private sector would be retained in the same condition or have the same value as those in the wholly public case. Accordingly, the terminal value of the HSR system in the PSP case would be the same as the one in the wholly public case.

11.3.6 Base Case Scenario Results

For each scenario, the following key results are presented:

[56] Usually all taxes are considered a cost to be borne by a private entity. However the Goods and Services Tax (GST of the Federal Government) and the Provincial Sales Tax (PST of the Provincial Governments) are Value-Added Taxes (VAT) whose cost to an entrepreneur is offset by the amount of similar taxes that this entrepreneur can claim against any goods or services that he has acquired in the course of his business.

- Net Present Value (NPV) of Project to Government: This was the net financial investment and return to Government measured on a net present value basis using a discount rate of 4.2 percent (based on the blended borrowing rate of the Federal, Quebec, and Ontario governments).
- FRR of Project to Government: This was the financial rate of return generated by the project to Government. A positive FRR indicates that the financial returns generated by the project over the operating period to Government are greater than the upfront investments in the project. Conversely, a negative FRR indicates that the financial returns over the operating period are not sufficient to cover the cost of the upfront investments.
- Government Investment Required: This was the total value of Government contributions before operation commencement, including (where applicable) the pre-construction funding, capital contributions to Authority, loans to Authority, and construction payments to Infrastructure Provider. This amount was stated in total value (TV in inflated dollars) as well as in NPV terms.

The table below presents the results for the QW-200 and QW-300 scenarios under the wholly public case.

Table 11-4: Wholly Public Case Results for the QW-200 and QW-300 Scenarios

Scenario		NPV of Project to Government	IRR of Project to Government	Government Investment - Total	Government Investment - NPV
		(M$)		(M$)	(M$)
QW - 200	Wholly Public Case	(7,719)	0.80%	26,572	16,278
QW - 300	Wholly Public Case	(8,463)	0.92%	29,731	18,181

The QW-200 scenario would produce a negative NPV of $7,719 million. A negative NPV indicates that the FRR of the project was lower than the discount rate used. The FRR to Government was estimated at 0.80 percent. The amount of investment required from Government during the pre-construction and construction periods was projected at $26,572 million or $16,278 million in NPV terms.

Under the QW-300 scenario, the NPV of the project would be negative $8,463 million. The FRR to Government was estimated at 0.92 percent. The amount of investment required from Government during the pre-construction and construction periods was projected at $29,731 million, or $18,181 million in NPV terms.

On a comparative basis, the QW-300 scenario produced a slightly better FRR than the QW-200 scenario, but it required a higher level of Government investment and produced a lower (more negative) NPV.

The results for the PSP case for the QW-200 and QW-300 scenarios are presented below.

Table 11-5: PSP Case Results for the QW-200 and QW-300 Scenarios

Scenario		NPV of Project to Government (M$)	IRR of Project to Government	Government Investment - Total (M$)	Government Investment - NPV (M$)
QW - 200	PSP Case	(14,740)	-8.31%	13,426	8,270
QW - 300	PSP Case	(16,355)	-7.51%	15,060	9,238

Under the PSP case, the financial returns to Government would be less favourable than under the wholly public case in terms of NPV and FRR. The NPV to Government for the QW-200 scenario would produce a negative $14,740 million, which was $7,021 million below the NPV of the wholly public case. The NPV of the QW-300 scenario under the PSP case would be negative $16,355, which was $7,892 million lower than the NPV of the wholly public case. FRRs for both scenarios under the PSP case would be significantly lower than under the wholly public case.

The financial returns to Government under the PSP case would be less favourable than those under the wholly public case due to the higher rate of return required by the private sector for their investment. With the private sector requiring a rate of return that was higher than the underlying rate of return of the project, the rate of return to Government would be decreased under the PSP case.

Under the PSP case, the amount of Government investment would be reduced due to the private sector debt and equity. The total value of Government investment for the QW-200 scenario would be $13,426 million ($8,270 million in NPV terms), which was approximately 50 percent of the amount under the wholly public case. For the QW-300 scenario, the total value of Government investment would be $15,060 million ($9,238 million in NPV terms), which was approximately 51 percent of the amount under the wholly public case.

11.3.7 Other Scenarios

The financial results for the other scenarios under the wholly public case are presented below.

Table 11-6: Wholly Public Case Results for Other Scenarios

Scenario		NPV of Project to Government (M$)	IRR of Project to Government	Government Investment - Total (M$)	Government Investment - NPV (M$)
QT - 200	Wholly Public Case	(4,290)	1.86%	19,591	12,005
MT - 200	Wholly Public Case	(1,215)	3.32%	12,698	7,776
TW - 200	Wholly Public Case	(4,240)	Highly Negative*	6,965	4,258
QT - 300	Wholly Public Case	(4,753)	1.94%	22,366	13,677
MT - 300	Wholly Public Case	(2,032)	2.92%	15,336	9,377
TW - 300	Wholly Public Case	(5,146)	Highly Negative*	7,900	4,820

* Beyond the calculation limit of the @IRR function in Excel.

In the wholly public case, all scenarios were projected to produce negative NPV. The MT-200 and MT-300 scenarios were projected to produce the best financial results in terms of NPV and FRR. The MT-200 scenario was projected to have the best NPV, at negative $1,215 million, followed by the MT-300 scenario with NPV of negative $2,032 million. The scenario with the highest FRR would be the MT-200 scenario at 3.32 percent, followed by the MT-300 scenario at 2.92 percent.

The QT-200 and QT-300 scenarios generated financial results that were in between the QW-200 and QW-300 scenarios and the MT-200 and MT-300 scenarios.

The TW-200 and TW-300 scenarios were projected to produce highly negative FRRs.

The FRRs for the QW-200 and QW-300 scenarios of 0.80 percent and 0.92 percent respectively were positive because the terminal values were included. If the terminal values were excluded, the FRRs would have been negative. In the other scenarios where the FRRs were positive, if the terminal values were excluded, the FRRs would be reduced significantly.

These observations show that the project economics were such that a relatively long period would be required to achieve pay-back of the initial investment. In some scenarios pay-back was not projected to be achieved, hence resulting in a negative FRR.

The financial results under the PSP case for the other scenarios are presented below.

Table 11-7: PSP Case Results for Other Scenarios

Other Functional Segments		NPV of Project to Government	IRR of Project to Government	Government Investment - Total	Government Investment - NPV
		(M$)		(M$)	(M$)
QT - 200	PSP Case	(9,478)	-4.93%	9,917	6,109
MT - 200	PSP Case	(4,578)	-1.05%	6,431	3,958
TW - 200	PSP Case	(6,066)	Highly Negative*	3,494	2,148
QT - 300	PSP Case	(10,673)	-4.57%	11,299	6,932
MT - 300	PSP Case	(6,082)	-2.02%	7,727	4,742
TW - 300	PSP Case	(7,218)	Highly Negative*	3,964	2,426

* Beyond the calculation limit of the @IRR function in Excel.

Financial results in terms of NPV and FRR were less favourable than under the wholly public case for all scenarios. Although, the amounts of initial investment required by the government under the PSP case would be approximately 50 percent of the amounts under the wholly public case, the total public contribution required over the term of the project was much higher when considering the public sector financial support required in the on-going operations of the project.

11.3.8 Sensitivity Analysis

The following tables present the results of sensitivity analyses performed using the QW-300 scenario as the basis to explore possible outcomes in the event of changes to the key assumptions.

Table 11-8: Sensitivities on QW-300 Scenario – Wholly Public Case

Sensitivities on Scenario QW-300		NPV of Project to Government	IRR of Project to Government	Government Investment - Total	Government Investment - NPV
		(M$)		(M$)	(M$)
Base Case	Wholly Public Case	(8,463)	0.92%	29,731	18,181
Interest Rates					
Increase 1%	Wholly Public Case	(8,464)	0.92%	29,773	18,205
Decrease 1%	Wholly Public Case	(8,466)	0.92%	29,838	18,242
Revenue and Operating Cost					
Increase 20%	Wholly Public Case	(5,078)	2.49%	29,745	18,190
Decrease 20%	Wholly Public Case	(11,856)	-1.51%	29,991	18,328
Operating Cost Inflation					
CPI + 0.5%	Wholly Public Case	(10,839)	-0.81%	29,731	18,181
CPI + 1.0%	Wholly Public Case	(13,673)	-6.15%	29,731	18,181
Construction Cost					
Increase 20%	Wholly Public Case	(12,687)	-0.41%	35,723	21,844
Increase 40%	Wholly Public Case	(16,909)	-1.72%	41,623	25,454
Decrease 20%	Wholly Public Case	(4,241)	2.39%	23,784	14,545
Terminal Value					
Increase 25%	Wholly Public Case	(7,896)	1.30%	29,731	18,181
Decrease 25%	Wholly Public Case	(9,031)	0.47%	29,731	18,181
Construction Period					
Increase 1 year	Wholly Public Case	(8,476)	-1.95%	30,534	18,347
Decrease 1 year	Wholly Public Case	(7,634)	1.00%	29,557	18,273
Sales taxes on HSR fares considered as government cash flow		(4,552)	2.69%	29,731	18,181

* Beyond the calculation limit of the @IRR function in Excel.

Table 11-9: Sensitivities on QW-300 Scenario – PSP Case

Sensitivities on Scenario QW-300		NPV of Project to Government	IRR of Project to Government	Government Investment - Total	Government Investment - NPV
		(M$)		(M$)	(M$)
Base Case	PSP Case	-16,355	-7.51%	15,060	9,238
Private Sector Target IRR					
12%	PSP Case	-15,648	-6.95%	15,060	9,238
15%	PSP Case	-17,112	-8.11%	15,060	9,238
Sales taxes on HSR fares considered as government cash inflow		(12,443)	-2.59%	15,060	9,238

Based on the above tables, the most significant sensitivity appears to be on operating cost inflation. If operating costs are assumed to increase at a rate of CPI +0.5 percent and CPI +1.0 percent (instead of at CPI +0 percent as in the base case), IRR of Project to Government would decrease to -0.81 percent and 6.15 percent (from 0.92 percent), respectively. Overall, the projected annual increase in HSR operating costs in the base case was driven by a combination of assumptions on "operational" increase (approximately 0.5 percent per annum) and assumptions on "price" increase (CPI +0 percent). EcoTrain note that there was considerable uncertainty in how HSR operating costs would increase over the long term and the results should be viewed in that context.

Also, the treatment of sales taxes has a significant impact on the results. If sales taxes are included in the financial analysis as cash inflow to Government, the FRR of the project under the wholly public case would increase from 0.92 percent in the base case to 2.69 percent.

11.4 Economic Analysis

11.4.1 Objective

The objective of the economic analysis was to assess the economic viability of the HSR Quebec City - Windsor project and its contribution to the welfare of the country. Cost-benefit analysis was a method of measuring and evaluating the relative merits of public investment projects in support of sound economic decisions. It takes into consideration the effects of a project on the economy of a country as a whole and includes economic costs and benefits that were not captured in the financial analysis.

The cost-benefit analysis was first presented from the perspective of Canadian economy as a whole. It then allocates economic costs and benefits by provincial jurisdiction, namely Ontario and Québec.

11.4.2 Cost-benefit Considerations

Economic analysis considered components such as:

- Consumer surplus
- Changes in atmospheric emissions
- Public safety improvements and reduction of injuries and fatalities
- Impact of the proposed HSR service on VIA Rail
- Impact of the proposed HSR service on other transportation modes (excluding VIA Rail).

EcoTrain's analysis was based on the approach and the components used in the 1995 Study. It should be noted that alternative approaches used by other agencies and jurisdictions may consider different cost-benefit components.

The following basic principles in cost-benefit studies have been applied in EcoTrain's analysis:

- A common unit of measurement, in dollars, was used. Only costs and benefits to which a dollar value could be attributed were considered in the analysis
- Contrary to the financial analysis which used inflated dollars, the economic analysis typically uses constant dollars. This eliminates the need to inflate the various benefit and cost items
- A real social discount rate was used to calculate the NPV of project benefits and costs. If the NPV was positive, then the benefits exceed the costs, and the project was viable from the point of view of the economy as a whole
- Sales taxes applicable to construction and operating costs were not taken into account in the economic analysis
- Sales taxes were taken into account in HSR revenues to measure consumers willingness to pay for the service, since the amounts paid by consumers include sales taxes
- The source of public funding was irrelevant to the economic model from the perspective of the Canadian economy as a whole.

11.4.3 Economic Benefits

The following section examines each of the economic benefits to Canada that were associated with the project.

11.4.3.1 Operating revenues

HSR operating revenues included passenger fare revenues as determined by traffic studies and forecasts, and included sale taxes assumed at 13 percent.

The following table lists the total value (TV) and net present value (NPV), both in million of dollars CAD, of all HSR operating revenues generated by the project for each scenario studied.

Table 11-10: HSR Fare Revenue

High Speed Rail Fare Revenue		
Scenario	TV 2009 M$	NPV M$
QW-200	38,566	9,536
QT-200	31,293	7,750
MT-200	23,259	5,731
TW-200	6,136	1,508
QW-300	43,188	10,677
QT-300	35,583	8,809
MT-300	26,599	6,553
TW-300	6,252	1,536

11.4.3.2 Consumer Surplus

Consumer surplus was defined as the difference between the market price of a good or service and the highest price the consumer would be prepared to pay for that good or service. Because some consumers are willing to pay more than the price they actually paid, there was a benefit that was not captured by HSR fare revenues alone.

Another concept that was useful in understanding consumer surplus was the concept of “generalized cost”. Generalized cost was used to describe the total cost of travel including both the out-of-pocket cost of travel (such as fares) and the value of time used in the trip. When deciding which mode of travel to use, it was logical to assume that consumers would seek to minimize their generalized cost.

For the purposes of estimating consumer surplus for HSR, it was assumed that consumer willingness to pay for HSR was linked to the reduction in generalized cost by switching to HSR. Hence, for example, if the value of the time saved by a traveller by switching from bus to HSR was greater than the increase in fare (from bus to HSR), consumer surplus was generated.

To estimate the saving per trip of the original rail user, EcoTrain considered three factors:

- Decrease in the travel time spent by a traveller as a result of switching from VIA Rail to HSR
- Additional value generated to the traveller due to a more convenient schedule. This was estimated based on the increase in the number of departures per day multiplied by the value of each increased departure
- Increase in fares paid by the traveller from VIA Rail to HSR.

The combined values from the above three items were used to estimate the value of consumer surplus. The assumptions on travel time savings from VIA Rail to HSR, value of time per hour, increase in train frequencies, value of increased frequencies, and changes in fares are presented in the following tables. It was noted that

EcoTrain's calculations have been based on the top ten (10) markets in terms of ridership and the results were expanded to cover all markets. Details on sources of information and assumptions can be found in the report for Deliverable 11, Financial and Economic Analysis.

Table 11-11: Travel Time Savings

Market	Travel Time Reduction from VIA Rail to HSR (hours)	
	E300	F200
Quebec-Montreal	2.0	1.7
Quebec -Ottawa	3.4	2.8
Montreal-Ottawa	1.0	0.8
Montreal-Toronto	2.4	1.5
Ottawa-Kingston	1.5	1.2
Ottawa-Toronto	2.9	2.3
Ottawa-London	4.4	3.6
Kingston-Toronto	1.4	1.0
Toronto-London	1.4	1.1
Toronto-Windsor	2.8	2.2

Table 11-12: Value of Traveller's Time

	Business	Non-Business
Value of Time ($/hour)	50.11	22.76

Table 11-13: Increase in Daily Frequencies from VIA Rail to HSR

Market	Increase in daily frequencies from VIA Rail to HSR
Quebec-Montreal	8
Quebec -Ottawa	8
Montreal-Ottawa	6
Montreal-Toronto	6
Ottawa-Kingston	7
Ottawa-Toronto	7
Ottawa-London	7
Kingston-Toronto	1
Toronto-London	7
Toronto-Windsor	8

Table 11-14: Value of Increased Frequencies to Travellers

	Business	Non-Business
Value per additional frequency ($/freq.)	8.60	3.50

Table 11-15: Increase in Fares from VIA Rail to HSR

Market	Increase in Fares from VIA Rail to HSR ($)	
	Business	Non-Business
Quebec-Montreal	72.42	37.14
Quebec -Ottawa	121.96	65.92
Montreal-Ottawa	40.93	17.03
Montreal-Toronto	191.22	125.63
Ottawa-Kingston	35.58	15.82
Ottawa-Toronto	96.98	46.15
Ottawa-London	135.77	70.43
Kingston-Toronto	60.70	27.64
Toronto-London	33.02	10.26
Toronto-Windsor	90.17	46.09

The following table shows the TV and NPV of the consumer surplus estimated for each scenario.

Table 11-16: TV and NPV of Consumer Surplus

Consumer Surplus		
Scenario	TV 2009 M$	NPV M$
QW-200	7,030	1,741
QT-200	4,461	1,108
MT-200	2,025	500
TW-200	2,795	687
QW-300	10,757	2,665
QT-300	7,679	1,906
MT-300	4,386	1,083
TW-300	3,371	829

11.4.3.3 Atmospheric Emission

Benefits resulting from the implementation of HSR relate to reduced air pollution (lower atmospheric emissions).

An analysis was performed to identify changes in atmospheric emissions due to the implementation of HSR in the Quebec City – Windsor corridor. The analysis evaluated the impacts of the HSR project on the emission of greenhouse gases (GHG: CO2, NH4 and N2O) and Criteria Air Contaminants (CAC: NOX, VOC, CO, PM and SO2) based on the following transportation modes:

- Existing modes: conventional passenger trains, light duty vehicles, intercity buses, and airplanes
- New modes: two HSR alternatives, F200+ and E300+.

The total economic value of emissions saved due to the diversion to HSR from the four other transportation modes and of the emissions produced by the HSR project itself, calculated by functional segment, was as follows:

Table 11-17: Benefits from Reduced Emissions

Benefits from Reduced Emissions		
Scenario	TV 2009 M$	NPV M$
QW-200	191.7	47.4
QT-200	166.9	41.3
MT-200	141.1	34.6
TW-200	34.4	8.6
QW-300	389.4	96.1
QT-300	342.0	84.6
MT-300	238.8	58.6
TW-300	55.7	13.6

11.4.3.4 Public Safety

To calculate the total economic value of public safety improvements generated by the implementation of the HSR project, EcoTrain obtained annual fatalities and injuries data for Québec and Ontario from the Transportation Safety Board (TSB) of Canada and Transport Canada regarding the road, bus, rail and air transportation modes. Using the ridership data for each of these modes, the existing rates of fatalities and injuries (without HSR) in each province were determined.

Using the ridership projections for air, road (auto and bus) and conventional rail transportation under each of the HSR technology options (F200+ and E300+ systems) and the fatality and injury rates previously calculated, the expected number of fatalities and injuries for each of these modes under the HSR scenarios was determined.

The safety benefit results indicate that upon implementation of the HSR service, the number of injuries and fatalities would generally experience a significant decrease across all modes of travel, most significantly under rail transportation, where all incidents were expected to be eliminated in the Quebec City -Windsor corridor due to the elimination of all existing grade crossings, including those within cities, as stated in section 6.2.1 Capital Cost Model.

The total economic value of safety improvements generated by the implementation of the HSR project itself, calculated by segment and using Transport Canada's[57] guidance with regards to the dollar value estimated for fatalities and injuries, was estimated as follows:

Table 11-18: Benefits from Impact on Public Safety

Benefits from Impact on Public Safety		
Scenario	TV 2009 M$	NPV M$
QW-200	9,523	2,353
QT-200	8,318	2,061
MT-200	6,830	1,688
TW-200	3,042	746
QW-300	10,039	2,481
QT-300	8,869	2,198
MT-300	7,273	1,797
TW-300	2,954	724

Impact of the HSR Service on VIA Rail

The HSR service was assumed to replace the existing VIA Rail service in the Quebec City - Windsor corridor. In broad terms, the impact on VIA Rail would be a loss of fare revenues, together with savings in operating costs and capital investments.

Based on information provided by VIA Rail, the current VIA Rail service requires operating and capital subsidies from the Federal Government that would no longer be required once HSR operations start. The amount of subsidies related to the Quebec City - Windsor corridor for 2009, 2008 and 2007 were used to calculate 3-year average amounts that were used as estimates for annual subsidies going forward.

[57] Estimates of the Full Cost of Transportation in Canada, August 2008

The following table illustrates the savings in operating and capital subsidies generated by discontinuing the VIA Rail services in the Quebec City - Windsor corridor in TV and NPV terms.

Table 11-19: Savings in VIA Rail Subsidies

Savings from VIA Rail Capital and Operating Subsidies		
Scenario	TV 2009 M$	NPV M$
QW-200	4,545	1,175
QT-200	3,566	922
MT-200	3,031	784
TW-200	980	253
QW-300	4,545	1,175
QT-300	3,566	922
MT-300	3,031	784
TW-300	980	253

11.4.3.5 Terminal Value

The terminal value of the investment in infrastructure and rolling stock represents an economic benefit. This residual value used was derived from Section 11.3, Financial Analysis in this report.

The following table illustrates the terminal value in TV and NPV terms for each of the scenarios under study.

Table 11-20: Terminal Value in TV and NPV

Terminal Value		
Scenario	TV 2009 M$	NPV M$
QW-200	4,977	581
QT-200	4,652	543
MT-200	4,323	504
TW-200	-	-
QW-300	5,572	650
QT-300	5,260	614
MT-300	4,634	541
TW-300	-	-

The terminal values for the TW-200 and TW-300 scenarios were assumed to be zero as the normalized net cash flow of the project in the last year of the projected period was negative in those scenarios.

11.4.4 Economic Costs

The following section examines each of the economic costs associated with the Project.

11.4.4.1 Investment Costs

Various investment costs related to the implementation of HSR were considered in the economic analysis. They included the costs related to the construction of the rail infrastructure and the acquisition of rolling stock.

The following table illustrates these costs in TV and NPV terms for each of the segments under study. Please note that these costs correspond to the pre-construction and construction costs in Table 11-3 of the financial analysis. For the purposes of the economic analysis, the inflated (nominal) cost data based on construction inflation have been deflated to 2009 dollars using the CPI.

Table 11-21: Total Investment Costs

Total Investment Costs		
Scenario	TV 2009 M$	NPV M$
QW-200	20,121	11,291
QT-200	14,860	8,340
MT-200	9,636	5,404
TW-200	5,237	2,934
QW-300	22,546	12,622
QT-300	16,913	9,471
MT-300	11,568	6,478
TW-300	5,935	3,316

11.4.4.2 Operating and Renewal Costs

Operating costs include the costs related to the operation of the HSR service while renewal costs relate to the lifecycle replacement of various components of the HSR system.

The following table illustrates the operating and renewal costs in TV and NPV terms for each of the scenarios under study. These costs correspond to the inflated operating and renewal costs in Table 11-3 of the financial analysis but were converted to 2009 dollars using the CPI.

Table 11-22: Total Operating and Renewal Costs Over 30 Years

Total Operating and Renewal Costs (30 years)		
Scenario	TV 2009 M$	NPV M$
QW-200	23,357	5,266
QT-200	17,932	4,057
MT-200	12,311	2,819
TW-200	5,639	1,287
QW-300	25,766	5,822
QT-300	20,089	4,551
MT-300	14,277	3,233
TW-300	6,408	1,451

11.4.4.3 *Impact of the HSR Service on Other Transportation Modes*

The impact of the HSR service on other transportation modes, namely bus operators, airlines and airports, was considered in the economic analysis. To quantify the impact on other modes, EcoTrain used the following approach and assumptions:

- For airlines operators, the impact of the HSR service would translate into a reduction of profit calculated by using an estimated net (pre-tax) profit margin on the loss of fare revenues
- For bus operators, the impact of the HSR service would result in an increase in ridership, offset somewhat by an increase in operation and maintenance costs
- For airports, the impact of the HSR service would result in a loss of revenues, since passengers are charged an Airport Improvement Fee and air ridership in the Corridor would be reduced by 33 percent.

The following tables illustrate the impact of the HSR service on the airlines, bus operators, and airports in TV and NPV terms under each scenario.

Table 11-23: Impact of the HSR Service on airlines

Impact on Airlines		
	TV 2009 M$	NPV M$
QW-200	(221)	(54)
QT-200	(189)	(46)
MT-200	(175)	(43)
TW-200	(23)	(6)
QW-300	(253)	(62)
QT-300	(219)	(54)
MT-300	(202)	(50)
TW-300	(25)	(6)

Table 11-24: Impact of the HSR Service on Bus Operators

Impact on Bus Operators		
	TV 2009 M$	NPV M$
QW-200	32	8
QT-200	33	8
MT-200	35	9
TW-200	15	4
QW-300	29	7
QT-300	30	8
MT-300	33	8
TW-300	14	4

Table 11-25: Impact of the HSR Service on Airports

Impact on Airports		
	TV 2009 M$	NPV M$
QW-200	(842)	(207)
QT-200	(728)	(178)
MT-200	(687)	(168)
TW-200	(83)	(20)
QW-300	(970)	(238)
QT-300	(849)	(208)
MT-300	(799)	(196)
TW-300	(86)	(21)

11.4.5 Financial Contribution of Each Government

In both the financial and economic analyses, it was assumed that the total government contribution would be shared on the basis of 50 percent by the Federal Government and 25 percent each by the Ontario and Québec Governments.

11.4.6 Social Discount Rate

To calculate the NPV of social cost/benefits, a social discount rate was required. There was considerable variance in the social discount rates used in different jurisdictions and there does not appear to be a standard social discount rate policy or recommendation in Ontario and Québec.

According to a recent study by a university group[58], the following are real social discount rates used in various countries:

- Canada: 4.7 percent
- France: 4.0 percent
- UK: 3.5 percent
- Germany: 3.0 percent
- European Commission: 5.0 percent.

The Cirano study also suggests that the real social discount rate to be used in Québec should be 6.0 percent and should be revised every five years.

For Ontario, EcoTrain was not aware if there was a definitive position on the real social discount rate. The understanding was that both a rate based on the Province's real cost of borrowing (typically around 2.5 percent) and a real blended debt and equity rate (5.3 percent) have been used.

In view of the above, EcoTrain proposed and received agreement from the Technical Committee to use 5.0 percent as the real social discount rate for this study. Sensitivities were performed using 3.0 percent and 7.0 percent. It was noted that a rate of 8.0 percent was used in the 1995 Study.

11.4.7 Economic Cost-benefit Results for the Base Case Scenario

The economic cost-benefit results for the QW-200 scenario are presented in TV and NPV terms in the table below. Net benefits are shown as positive numbers and net costs as negative numbers.

[58] Claude Montmarquette, Iain Scott. “Taux d’actualisation pour l’évaluation des investissements publics au Québec”. Centre interuniversitaire de recherché en analyse des organisations (CIRANO), Montréal, Mai 2007

Table 11-26: Net Economic Cost-Benefit to Canada – QW-200

Net Cost-Benefit to Canada - QW-200		
	TV 2009 M$	NPV M$
Revenues	38,566	9,536
Consumer surplus	7,030	1,741
Atmospheric emissions	192	47
Public safety	9,523	2,353
Impact of the HSR service on VIA Rail	4,545	1,175
Terminal value	4,977	581
Investment costs	(20,121)	(11,291)
Operating costs	(16,168)	(4,091)
Renewal Costs	(7,189)	(1,175)
Impact on other transportation modes	(1,032)	(253)
Total	20,323	(1,376)

For the QW-200 scenario, the total value of net economic cost-benefit to Canada[59] was projected at $20,323 million (in 2009 $) and the NPV of net cost-benefit was projected at negative $1,376 million.

The project total value was positive and the NPV value was negative as in general, the benefits of the project would be generated later in the projection period while a substantial part of the costs would be incurred earlier in the same projection period. Hence when discounted (using a real social discount rate) the benefits would not fully offset the costs.

It was nevertheless interesting to note that, in NPV terms, projected revenues would be greater than operating and renewal costs.

The economic cost-benefit results for the QW-300 scenario are also presented in TV and NPV terms in the table below.

59 Note that the benefits that would accrue to the economies of Ontario and Quebec would be sufficient to compensate for the economic losses borne by the other provinces.

Table 11-27: Net Economic Cost-Benefit to Canada – QW-300

Net Cost-Benefit to Canada - QW-300		
	TV 2009 M$	NPV M$
Revenues	43 188	10 677
Consumer surplus	10 757	2 665
Atmospheric emissions	389	96
Public safety	10 039	2 481
Impact of the HSR service on VIA Rail	4 545	1 175
Terminal value	5 572	650
Investment costs	(22 546)	(12 622)
Operating costs	(16 876)	(4 284)
Renewal Costs	(8 891)	(1 539)
Impact on other transportation modes	(1 195)	(293)
Total	24 984	(992)

For the QW-300 scenario, the total value of net economic cost-benefit to Canada was projected at $24,984 million and NPV of net cost-benefit was projected at negative $992 million. Because the NPV of the net cost-benefit for QW-300 was less negative (i.e. higher) than the NPV of the cost-benefit for QW-200, the results for the QW-300 scenario were better than those for the QW-200 scenario.

11.4.8 Other Scenarios

The net economic cost-benefit results for the other scenarios are summarized below.

Table 11-28: Net Economic Cost-Benefit to Canada – Other Scenarios

Net Cost-Benefit to Canada - Other Scenarios		
Scenario	TV 2009 M$	NPV M$
QT-200	18,781	(190)
MT-200	16,835	817
TW-200	2,020	(1,039)
QT-300	23,259	257
MT-300	19,349	869
TW-300	1,174	(1,433)

The MT-300 scenario shows the best cost-benefit result with a NPV of $869 million, followed by the MT-200 scenario with a NPV of $817 million and the QT-300 scenario with a NPV of $257 million. The other scenarios produced negative NPV values.

In NPV terms, the scenarios with E300+ system show better cost-benefit results than the scenarios with F200+ system, except in the Toronto-Windsor segment.

For both technologies the rankings of the functional segments by cost-benefit NPV, from best to worst, were as follows: Montréal-Toronto, Quebec City - Toronto and Toronto-Windsor. This suggests that a possible approach to building a HSR corridor could be to start with the Montreal-Toronto segment, and gradually phase in segments to Quebec City, and then to Windsor over time. It was however beyond the scope of this report to comment on phased construction approaches, as there would be complex engineering, ridership impacts, government policy and other considerations that would need to be analyzed.

11.4.9 Sensitivity Analysis

The following tables present the results of sensitivity analyses performed using the QW-300 scenario as the basis, in order to explore possible outcomes in the event of changes in key assumptions

Table 11-29: Sensitivity Analysis of Net Economic Cost-Benefit to Canada – QW300

Net Cost-Benefit to Canada - Sensitivities		
Sensitivities	TV 2009 M$	NPV M$
Base case - QW-300	24 984	(992)
Social Discount Rate		
Use 3%	24 984	3 927
Use 7%	24 984	(3 004)
Consumer Surplus		
20% increase	27 135	(459)
20% decrease	22 832	(1 525)
Impact of HSR on other transportation modes		
20% increase	24 745	(1 050)
20% decrease	25 223	(933)
Public safety impacts (injuries and fatalities)		
25% increase	27 493	(371)
25% decrease	22 474	(1 612)

The sensitivity analyses indicate that the choice of the discount rate would have the most impact on the economic cost-benefit results. Using a 3.0 percent discount rate, the NPV of net cost-benefit of the QW-300 scenario would be positive, at $3,927 million.

11.4.10 Economic Cost-benefit by Province

The previous sections describe the costs and benefits related to the Canadian economy as a whole.

This section provides an estimation of the economic costs and benefits by province, namely Ontario and Québec. The provincial results combine benefits and costs from the point of view of Ontario and Québec economies and the point of view of the Ontario and Québec Governments.

The following table summarizes the economic cost-benefit results of the QW-200 scenario for Ontario and Québec. Benefits are shown in positive numbers and costs are shown in negative numbers.

Table 11-30: Economic Cost-Benefit by Province – QW-200

	Ontario		Québec	
Scenario QW-200	TV 2009 M$	NPV M$	TV 2009 M$	NPV M$
Net Contribution by Government	(2 323)	(3 321)	(1 676)	(2 396)
Consumer Surplus	4 457	1 104	2 573	637
Atmospheric Emissions	147	36	45	11
Public Safety	6 540	1 618	2 983	735
Impact of HSR service on VIA Rail	2 027	524	830	215
Impact on Airlines	(164)	(40)	(57)	(14)
Impact on Airports	(625)	(153)	(217)	(53)
Impact on Bus Operators	23	6	9	2
Terminal Value	2 354	275	1 699	198
Total	12 435	49	6 188	(665)

As shown, the NPV of the cost-benefit of the QW-200 scenario to Ontario and Québec would be $49 million and negative $665 million, respectively.

The results for the QW-300 scenario are presented below.

Table 11-31: Economic Cost-benefit by Province – QW-300

Scenario QW-300	Ontario TV 2009 M$	Ontario NPV M$	Québec TV 2009 M$	Québec NPV M$
Net Contribution by Government	(2,424)	(3,673)	(1,749)	(2,651)
Consumer Surplus	6,756	1,673	4,002	991
Atmospheric Emissions	256	63	134	34
Public Safety	6,899	1,708	3,140	774
Savings from VIA Rail Subsidies	2,027	524	830	215
Impact on Airlines	(185)	(45)	(68)	(17)
Impact on Airports	(709)	(174)	(261)	(64)
Impact on Bus Operators	22	5	7	2
Terminal Value	2,635	308	1,901	222
Total	15,276	388	7,936	(494)

The NPV of the cost-benefit of the QW-300 scenario to Ontario and Québec would be $388 million and negative $494 million, respectively. The economic cost-benefit results seem more favourable in the QW-300 scenario than in the QW-200 scenario.

The economic cost-benefit results for the other scenarios are summarized in the table below.

Table 11-32: Economic Cost-benefit by Province – Other Scenarios

Cost-Benefit by Province	Ontario		Québec	
Scenario	TV 2009 M$	NPV M$	TV 2009 M$	NPV M$
QT-200	10,697	362	6,173	(132)
MT-200	9,548	779	5,114	116
TW-200	3,198	62	(662)	(691)
QT-300	13,168	661	8,052	108
MT-300	11,467	983	5,754	80
TW-300	3,103	(49)	(1,162)	(878)

In Ontario, the MT-300 scenario would generate the highest cost-benefit NPV, at $983 million, followed by the MT-200 scenario with a NPV of $779 million and the QT-300 scenario with a NPV of $661 million. The only scenario with a negative cost-benefit NPV would be the TW-300 scenario, with a value of negative $49 million.

In Québec, the highest cost-benefit scenarios would be the MT-200 with a NPV of $116 million, the QT-300 with a NPV of $108 million and the MT-300 with a NPV of $80 million. The other scenarios would generate negative NPV.

A description of the allocation methodology was provided hereafter.

11.4.10.1 Provincial Contribution to the HSR Project

Total Government contribution corresponded to the net of capital investment, operating costs and fare revenues at the project level.

To perform a cost-benefit analysis from a provincial perspective, EcoTrain used the following approach and assumptions to allocate the total Government contribution to the HSR project by province:

- Funding for the project was assumed to be provided by the Federal, Ontario and Québec Governments on a 50/25/25 basis
- The contribution by the Federal Government was allocated to each province based on the share of federal income tax revenues generated in each province. The amounts allocated to Ontario and Québec represent "indirect" contribution by the two provinces. Based on Statistics Canada data for the period 1981 to 2007, the average share of federal income taxes collected from Ontario and Québec was 44.6 and 18.3 percent, respectively. These percentages were used to allocate the indirect contributions to Ontario and Québec.

On that basis, the net Government contribution allocated by province was as shown below.

Table 11-33: Allocation of Net Government Contribution by Province

Allocation of Net Government Contribution to Ontario and Québec		
	Ontario	Québec
All Scenarios	47.3%	34.1%

The total allocated percentages of Ontario and Quebec were below 100 percent as a portion of the funding provided by the Federal Government was allocated to other provinces.

11.4.10.2 Consumer Surplus

The consumer surplus benefits were allocated to Ontario and Québec based on HSR trip origin and destination locations. For example, for HSR trips in the Montréal-Toronto segment, 50 percent was allocated to Québec and 50 percent to Ontario. For HSR trips in the Quebec City - Montreal segment, 100 percent was allocated to Québec. The allocated HSR trips from all segments were added together to calculate the overall allocation percentages for the Quebec City - Windsor corridor. This method was intended to be a proxy for the residency of HSR travellers.

The consumer surplus allocation by province was as follows:

Table 11-34: Consumer Surplus Allocation by Province

Consumer Surplus	Allocation to Ontario and Québec	
Scenario	Ontario	Québec
QW-200	63%	37%
QT-00	54%	46%
MT-200	74%	26%
TW-200	100%	0%
QW-300	63%	37%
QT-300	55%	46%
MT-300	74%	26%
TW-300	100%	0%

11.4.10.3 Atmospheric Emissions and Public Safety

The net economic impacts of changes in atmospheric emissions and public safety improvements have been developed separately for Ontario and Québec. Hence, no allocation was required.

11.4.10.4 Impact of the HSR Service on VIA Rail

The federal subsidies provided by the Federal Government were allocated to Ontario and Québec based on their respective share of the Canadian income tax base.

11.4.10.5 Impact of the HSR Service on Other Transportation Modes

The impacts of the HSR service on other transportation modes were allocated to each province based on the location of the origin and destination of the diverted trip, similar to the method used to allocate consumer surplus. The allocated trips from all segments were added together to calculate the overall allocation percentages for the Quebec City - Winsor corridor.

The table below shows the percentages used to allocate the impact of the HSR service on other transportation modes to Ontario and Québec.

Table 11-35: Allocation of Impacts on Airlines and Bus Operators

	Allocation of Impact on Airlines		Allocation of Impact on Bus Operators	
Scenario	Ontario	Quebec	Ontario	Quebec
QW-200	74%	26%	73%	27%
QT-200	71%	29%	69%	31%
MT-200	74%	26%	67%	33%
TW-200	100%	0%	100%	0%
QW-300	73%	27%	75%	25%
QT-300	70%	30%	70%	30%
MT-300	72%	28%	67%	33%
TW-300	100%	0%	100%	0%

11.4.10.6 Terminal Value

Terminal value allocation was based on the direct contributions made by the three governments, i.e., 50 percent for Canada and 25 percent each for Ontario and Québec. The allocation of terminal value was based on the approach used for allocating contributions by Government to HSR service.

12 SUPPORTING POLICIES

As part of the present study, a review of transportation policies in countries with an existing HSR system was performed to identify their consistencies and inconsistencies, success factors and lessons learned. This Section was thus a summary of the technical report for Deliverable 8, Review of Transportation Policies in Countries with HSR, which the reader should consult for more detailed information.

A policy was defined as a deliberate plan of action to guide decisions and achieve rational outcome(s). The term may also be used to denote what was actually done.

12.1 Countries of Reference

France, Germany and Spain were selected as countries of reference for the purpose of this review. Key criteria used to select these three countries were:

- Long standing experience in the development and operation of HSR networks
- Availability of information sources
- Relative comparability of urban development, demographics and living conditions to those conditions found in the Corridor.

Given that the EU has increasingly guided the development and operations of HSR systems in these three countries, the development of EU policies, initiatives and framework were also reviewed.

The United States (US) was not considered as a country of reference. Notwithstanding the recent announcement in April 2009 of President Obama's vision to build a network of HSR corridors, HSR was at an early stage of development in the US. Other than the Boston to Washington HSR service, the US does not have a corridor with rail service operating at a speed higher than 180 km/h. In fact, in March 2009, the United States Government Accountability Office[60] recognized that: "there was currently no federal high speed rail policy."

12.2 Approach

This review of policies was carried out as follows.

- Selection of the three countries of reference and identification of key stakeholders in each country and within the EU

[60] United States Government Accountability Office, High Speed Passenger Rail, Report No. GAO-09-317, March 9, 2009 (page 6)

- Desk research and consultations with numerous leading specialists from governments, railway companies and universities to identify and validate relevant information available as of September 2009 in each of the three countries, as well as in the EU
- Preliminary findings were discussed with members of EcoTrain and representatives of Transport Canada, Ontario Ministry of Transportation, and Ministère des Transports du Québec, which led to verifications and complementary research.

12.3 Findings

This section was a summary of Section 6 of the technical report for Deliverable 8.

12.3.1 Consistencies

- HSR networks: Primarily developed to increase passenger transport capacity, relieve road congestion and revitalize the rail industry.
- HSR policy objectives: Focused mainly on reducing travel times and upgrading the quality of public transport in terms of frequency, reliability, comfort and safety.
- HSR services: Considered of higher quality than conventional rail services, mostly as a result of achieving the above stated objectives, and priced accordingly.
- Organizational structure: The three countries of reference have implemented an organizational structure that separates the management of rail infrastructure and operations, in line with EU directives. Following the implementation of such reforms, state-owned limited liability companies own and manage HSR networks: RFF in France, DB Netz in Germany, and ADIF in Spain. Separate organizations own and manage HSR operations: SNCF in France, DB Mobility Logistics on Germany, and RENFE in Spain.
- Open access to competition: Following EU directives, the railway infrastructure owners and managers in Europe now provide open access to competition by new operators of international rail passenger services and rail freight services.
- Interoperability and connectivity: To ensure interoperability and connectivity throughout Europe, HSR networks are electrified, use standard gauge, and will eventually use the European Rail Traffic Management System (ERTMS) for signalling.

- Intermodality: Authorities increasingly recognize the importance of inter-modality in developing efficient transport systems, particularly with regard to long distance air and rail transport. As a result, the three countries have high speed lines with stations that are also used by other transit systems and/or connected to international airports. Moreover, many high speed rail lines have stations in city centres, facilitating interconnectivity with other transport modes.
- Transport mode shift: HSR was both a substitute and a complementary service to other transport modes. While HSR has become a substitute to air transport on competing routes, it was also starting to be considered as complementary to air services due to increasing connections between major airports and HSR stations or networks. With regards to road transport, HSR was generally viewed as complementary rather than a substitute, except on routes where HSR service can be provided at door-to-door travel times and with similar costs to cars.
- Users: The majority of users are non-business travellers. In Germany, business travellers represent between 40 and 45 percent of the users, the highest percentage in the three countries evaluated. In France, HSR was a transport for the masses and, according to SNCF, 30 percent of its 2007 revenue came from business travellers.
- Energy: While it was not a key factor in the development of HSR networks, the need to reduce dependency on fossil fuels as the main source of transportation energy and the availability of nuclear based electricity nonetheless led to the selection of electrical traction technology for HSR.
- Fares: HSR fares are not subsidized, except for regional services targeting commuters or designated users who can benefit from social fares (i.e. ware veterans, pensioners, students). The pricing of long distance services was market based and primarily determined by competition from airlines and by commercial goals, with a view to making HSR operations profitable.
- Taxation: There are no comprehensive taxation policies aimed at facilitating a transport mode shift. Operators pay usage charges to rail infrastructure providers and managers. Usage charges can take various forms, including charges for the right to access the infrastructure and to reserve capacity (or the availability of routes), as well as for the actual use of train paths, railway infrastructure and platforms.
- Environmental concerns: They were no major environmental factors in the initial stages of development of HSR networks however such factors are becoming increasingly relevant in the decision making process. Nowadays, additional steps are taken to minimize the negative environmental impacts related to the development of HSR lines or networks. Areas of interest include, among others, the environmental assessment of new rail lines, reduction of noise level and use of environmentally friendly sources of

energy. These additional steps, however, contribute to extended design and construction periods and to increases in infrastructure and O&M costs.

- The impact of HSR operations on the localization of economic activity: In research data, localized economic activity has not been isolated from other transportation and economic factors. Still, governments view HSR as an instrument to strengthen or revitalize regional economies, and regions eagerly promote linkages to HSR to increase mobility and promote their local construction businesses.

12.3.2 Inconsistencies

- Integration of HSR and conventional rail networks: France and Germany see their HSR networks largely as an extension of their conventional rail networks: high speed trains use both the specially built lines and conventional networks. In Germany, conventional trains sometimes use the high speed network. In Spain, with the exception of the gauge-convertible Talgo and CAF trains, high speed trains only run on the HSR network with standard gauge, whereas conventional networks use the different Iberian gauge.
- Network structure: The country's demography was a determining factor in the development of the structure of the HSR networks. In Germany, given the integration of HSR and conventional networks as well as the large number of rail lines and stations, users often have to change trains. In France and Spain, HSR networks are based on a radial model linking their national and regional capital cities. Given this structure and the geography of these countries, this implies longer distances between destinations (for instance, the Madrid-Barcelona, Madrid-Seville, Madrid-Zaragoza high speed lines are all over 500 km in length).
- Master planning: The three countries differ in their approach to master planning. The first high speed lines developed in France and Spain were planned as projects rather than as part of HSR networks or transportation master plans. In Germany, the HSR program was developed as a part of an overall transportation master plan, which also included issues related to regional and town planning. With time, there has been a growing consistency in terms of the approach and level of master planning.
- Fares: In France, due to the radial structure of the HSR network, fares are based on destination rather than km usage. This was mostly due to the fact that seats can rarely be sold more than once during a trip. In Germany, fares are based on km usage and are competitive with other transport modes. In Spain, fares are market based and are competitive with airlines for long distance trips.
- Energy sources and costs: In France, HSR was powered by electricity sourced mostly from the French electricity network and energy costs are invoiced to the operator separately from usage charges. In Germany, DB ML operates high speed trains with electricity sourced mostly from DB Netz's power grids and the German general electricity network, and the energy costs are invoiced to operators as part of

usage charges, primarily based on actual consumption. Spain was dependent on external electricity sourced from the Iberian market and energy costs are fully included in the usage charges with no linkage to actual consumption. Note that in the fully liberalized European energy markets, train operators in the three countries can enter into procurement contracts with any European electricity network.

- National industry support: In France, SNCF developed its own HSR program and technology. The benefits of this HSR program extended to many manufacturers and suppliers, which have become world leaders in HSR technology. In Germany, HSR investments led to the development of HSR technology, including the Maglev technology, automatic transit systems and technical solutions. Spain used French and German technologies to start the development of its HSR network. From there, HSR investments led to the expansion of the Talgo and CAF trains (which are best known for their gauge-convertible systems) and the development of expertise in designing and building rail infrastructure which are exported to countries such as Turkey, United Kingdom, Mexico, and China.
- Private sector involvement: Except for the French-Spanish Perpignan-Figueras high speed line, which outsourced the design, construction, finance and maintenance to a private concessionaire, the French, German and Spanish networks have been developed and financed in a conventional mode. Notwithstanding the above, French high speed lines under consideration or construction are either concessions in which traffic risk was transferred to private infrastructure providers, or PPP based on availability. This approach has not yet been adopted in Germany or Spain.
- Funding of HSR infrastructure investments: While there are differences in the funding structures of the three countries, funding was generally provided by the State and the infrastructure provider through usage charges collected from HSR operators. In France, infrastructure investments are mostly funded by the State and the regions. The remaining funds come from the private sector, either directly through usage charges (concessions) or via RFF in case of availability-based PPP contracts. In Germany, infrastructure investments are mostly funded by the central government, including contributions from DB Netz, the Infrastructure Provider. Municipalities and regions sometimes contribute to the funding of HSR stations. In Spain, infrastructure investments are mostly funded by the central government and EU funds, namely the structural and cohesion funds for the 2007-2013 period.
- Funding of HSR operations: HSR services are generally provided at market based prices with a view to making HSR operations profitable, while regional services targeting commuters are provided at fares considerably lower and below break-even level. Accordingly, the operations of conventional and regional rail lines are far more subsidized than HSR operations.

- Integration of rail freight transport in HSR developments: In France and Germany, rail freight transport was an important and growing part of total rail usage. The construction of passenger high speed lines with the same destinations has somewhat contributed to freeing-up additional capacity for rail freight transport. In Germany, some HSR lines are also used for conventional freight transport (mixed-usage). In France this was not possible, due to the track design, namely banking installed on curves. In Spain, freight was traditionally considered far less important than in France and Germany. Accordingly, some conventional rail lines were dismantled after the construction of same destination high speed lines. The situation has since evolved and the demand for rail freight transport was growing again. Investment in freight rail infrastructure would be required to address this increasing demand.

12.3.3 Success Factors and Lessons Learned

France

Success factors of the French HSR system include:

- High quality service, with a particular focus on speed and time saving
- Master plan providing an overall HSR vision
- Institutional reform and reorganization of the rail sector
- Interoperability and European connectivity
- Intermodality, including airport connections and integration with the conventional rail network
- Reduced fares representing nearly 45 percent of the TGV total revenue
- Development of technology and expertise
- Private sector funding
- Political support; involvement of stakeholders in the development and funding of HSR projects, including the development of business relationships with air stakeholders.

Lessons learned from the French HSR system include:

- Ambitious master plans are not always matched by funding commitments
- Separation of rail infrastructure and operations management opened the rail freight and passenger markets to competition by new operators
- Intermediate stations need better connections with other transport modes
- Non-integrated taxation policy was developed to achieve a balance in transport mode ratio
- Environmental concerns are increasingly considered in the development of new high speed lines

- Development of a high speed line was not a guarantee for economic growth by itself
- Rail freight transport was currently a growing business that was not given full consideration in the development of HSR network.

Germany

Success factors of the German HSR system include:

- Master plan integrating all transport modes and spatial planning
- HSR development accompanied by additional measures for regional and town planning
- Integration of the HSR network within the conventional railway network
- Integration of HSR and freight, as some HSR lines are also used for conventional freight transport (mixed-usage)
- Interoperability and European connectivity; intermodality, particularly with the public rail mass transit system
- Development of technology and expertise
- Involvement of the stakeholders in the development and funding of HSR projects.

Lessons learned from the German HSR system include:

- Master planning was not a solution to everything but a tool
- Deficient planning led to long term capacity restrictions
- Initial master planning decisions resulted in an overall lower speed in comparison to other countries
- Non-integrated taxation policy was developed to achieve a balance in transport mode ratio
- Separation of rail infrastructure and operations management opened the rail freight and passenger markets to competition by new operators.

Spain

Success factors of the Spanish HSR system include:

- High quality service, with focus on speed, travel time, comfort, reliability and safety
- HSR stations in city centres, facilitating interconnectivity with other transport modes
- Interoperability and European connectivity, with the use of standard gauge
- Strong political support.

Lessons learned from the Spanish HSR system include:

- Top-down decision-making process attracted criticism from local authorities due to the lack of transparency and coordination
- Deficient planning resulted in delays on the Perpignan-Figueras high speed line
- Transportation master plan facilitate the successful development of a HSR network
- Low quality of conventional rail network limits integration and interconnectivity
- Rail freight transport was currently a growing business that was not given full consideration in the development of HSR network
- Separation of rail infrastructure and operations management opened the rail freight and passenger markets to competition by new operators.

12.4 Relevance to the Quebec City - Windsor Corridor

The relevance of the observations noted in the previous section and how they could be applied to the Quebec City - Windsor Corridor would vary depending on various demographic, market, infrastructure, transport, regulatory, environmental, political and other considerations. Given that these observations were closely related, comments are provided hereafter by theme.

It should be noted however that given the limited scope of the mandate, EcoTrain has not performed a systematic review of the transportation policies in the three jurisdictions concerned with the project. Accordingly, these comments were primarily based on the experience and knowledge of EcoTrain's team members.

12.4.1 Reducing Travel Times and Upgrading Quality

Policy objectives that focused mainly on reducing travel times and upgrading the quality of public transportation in terms of frequency, reliability, comfort and safety, were considered as success factors, particularly in France and Spain, and to a lesser extent in Germany.

Users of a HSR service in the Quebec City - Windsor Corridor would seek to access the same service options and characteristics. In fact, the ability for users to make daily return trips between many city pairs and half-day return trips on shorter intercity distances within the Corridor, in a reliable and comfortable environment, would be key to the success of the project.

The decision to develop a line dedicated to HSR would allow for the provision of a reliable high speed service to users, as delays and other problems related to the conventional rail services would not interfere directly with the operation of the HSR service. It should not be forgotten that too many stops reduce speed, increase travel time and limit the inherent benefits of HSR.

12.4.2 Master Planning

In the countries reviewed, the development of transportation and HSR master plans has proven to be an essential step in developing a HSR network. This was relevant and would certainly be beneficial to all parties involved in the development of the Quebec City - Windsor Corridor.

The development of master plans in the early inception of a HSR network would be useful for maximizing the benefits of a HSR service, through the development of a comprehensive HSR vision; integration of transportation modes; development of a multi-modal approach; and spatial planning.

Master plans should be developed in line with the financial means and the potential funding commitments of the three jurisdictions concerned.

Joint or coordinated planning between the federal and provincial governments, as was the case of the present study, and other stakeholders such as the regions, cities and other transportation modes would benefit the decision making process and ensure that the benefits arising from such a project can be maximized.

Industry benefits would be generated through Canadian engineering and construction firms, rolling stock and railway equipment manufacturers, and others. The development of industry policies aiming to maximize local economic impacts derived from such a major project (for instance, minimum percentage of local content required) should be considered. Steps should also be taken to ensure that the development of industry expertise by local firms may eventually be leveraged in the upcoming developments of the US HSR network.

Strategic intelligence should be obtained from and discussions should be held with key representatives of the US HSR plans to take account of potential requirements or issues related to the need for connectivity between the Quebec City - Windsor HSR and the US HSR network. Current efforts to fund the construction of a new tunnel between Windsor and Detroit were one example where interconnectivity between the Quebec City - Windsor Corridor and the US HSR network may be of interest.

12.4.3 Inter-modality and Interconnectivity

Inter-modality with the conventional railway network and connectivity of HSR stations with other modes of transport, including rail transit, buses and airports, were considered as success factors in France, Spain and Germany.

In this regard, the following was relevant and applicable to the Quebec City - Windsor HSR to facilitate connectivity and reduce total travel time:

- Strong interface, where demand warrants it, between HSR and conventional rail lines, as both usually arrive and depart from the same stations
- Selection of HSR stations that provide quick access to city centres
- Development of intermediate stations or other means that provide connectivity to other modes of transport
- Development of other light rail or commuting services connected to the Québec City - Windsor HSR, for instance a rail link between the Montreal-Trudeau international airport and Montreal's downtown.

12.4.4 Rail Freight Transport

Considerations should be given to making adequate investment to maximize the use of rail freight capacity. Given the upward trend of rail freight transport in the three countries reviewed, this may become one of the key elements of a transport master plan and an economic development plan in Canada. Notwithstanding the above, one must recognize the existence of an inverse relationship between rail freight transport and rail passenger transport when comparing Canada to Europe, particularly due to the greater importance of rail passenger transport in Europe.

As the development of the Quebec City - Windsor HSR would require building new and dedicated HSR tracks, this could free up capacity for rail freight traffic on existing conventional lines.

Except for high speed trains travelling at lower speeds on existing tracks when approaching stations, sharing tracks does not seem to be a viable option. Slower freight trains would reduce the capacity available to high speed trains and prevent them from travelling at their maximum operating speed. Further, freight trains might damage HSR tracks due to the higher axle load and their length.

12.4.5 Strong Political Support

Strong political support was important for any large project, even more so in the context of an innovative project. The Quebec City - Windsor HSR would be the first project of its kind in Canada requiring strong political support at the provincial and the federal levels of government.

Public consultation and involvement were usually required for large and innovative projects, such as for Environmental Assessment hearings.

Appropriate public sector funding would also be required as 100 percent private sector financing was unlikely to be available for the development of the Quebec City - Windsor Corridor.

12.4.6 Institutional Reform

In all three countries reviewed, reforms were implemented to separate the ownership and management of rail infrastructure and operations, in line with EU directives. Prior to these reforms, both the railway infrastructure and operations were owned and managed by state railway agencies. In the Quebec City - Windsor Corridor, the situation differs in that the majority of the railway infrastructure has already been privatized and was currently owned by private sector companies that mostly operate freight trains and enjoy priority access rights. Passenger railway operators such as VIA Rail and commuter railway operators in Montreal and Toronto have negotiated access rights to the rail infrastructure. EcoTrain believes that an institutional review should be undertaken to ensure that the benefits targeted by the reforms implemented in France, Spain and Germany would be maximized in Canada.

12.4.7 Integrated Taxation Policy

In the three countries reviewed, the developed comprehensive taxation policies aimed at transport mode shift were not developed. Transport infrastructure investments required over the long term, environmental objectives and trends, and socio-economic considerations should nevertheless be reviewed carefully to assess the need for an integrated taxation policy aimed at achieving transport modal shift, a balanced transport modal ratio and desired levels of self-financing for upcoming HSR projects.

12.4.8 Environmental Concerns

Environmental concerns were not major factors in the initial stages of HSR network development in Europe but they have now become key considerations in the development of new HSR projects across the world. This would also be the case in the Quebec City - Windsor Corridor.

Nowadays, additional steps are taken to minimize the negative environmental impacts related to the development of HSR lines or networks. Areas of interest include the environmental assessment of new rail lines, the reduction of noise levels and the use of environmentally friendly sources of energy. These additional steps, however, contribute to extended design and construction periods and to increases in infrastructure and operation costs.

The selection of traction technology and the access to transportation energy remain key considerations in the development of HSR projects in Europe and elsewhere in the world. Accordingly, the long term access and dependency on energy sources should be given due considerations at the planning phase of the Quebec City - Windsor Corridor.

12.4.9 Interoperability

Interoperability was a major EU policy objective, which reflects the high level of integration of the EU communities. In the planning phase of the HSR network, careful considerations should be given to the development of compatible networks within Canada and North America. EcoTrain recognizes that opportunities for interoperability represent a longer term consideration as the high speed lines now planned in the US would not interconnect.

12.4.10 Funding

In the three countries reviewed, the funding of HSR infrastructure investments was generally provided by the State and the infrastructure provider, through usage charges collected from HSR operators. On the other hand, HSR services are usually provided at market based prices with a view to making HSR operations profitable, while regional services targeting commuters are provided at fares considerably lower and below break-even level. Accordingly, the operations of conventional and regional rail lines are far more subsidized than HSR operations. The context prevailing in the Quebec City - Windsor Corridor should be further reviewed to assess whether similar approaches could be adopted with regards to the funding of HSR infrastructure and operations.

EcoTrain would like to acknowledge the contribution of the Steering Committee members and Technical Committee members, whose collaboration ensured the successful completion of the Updated Feasibility Study of a High Speed Rail Service in the Quebec City – Windsor Corridor.

STEERING COMMITTEE MEMBERS

TRANSPORT CANADA

Helena Borges
Associate Assistant Deputy Minister
Policy-Gateways & Infrastructure

Annette Gibbons
Director General
Surface Transportation Policy

MINISTRY OF TRANSPORTATION OF ONTARIO

Scott Thompson
Assistant Deputy Minister
Policy and Planning Division

Linda McAusland
A/Director
Transportation Policy Branch

MINISTÈRE DES TRANSPORTS DU QUÉBEC

Jean-Pierre Bastien
Assistant Deputy Minister
Policy and Safety

André Meloche
Director
Marine, Air and Rail Transportation

Josée Hallé
EcoTrain's Contract Manager
Head of Rail Transportation Department
Marine, Air and Rail Transportation

TECHNICAL COMMITTEE MEMBERS

TRANSPORT CANADA

Kevin Lawless
Senior Policy Advisor
Rail Policy – Policy Group
Transport, Infrastructure and Communities

Richard Laferrière
Senior Policy Advisor
Economic Analysis - Policy Group
Transport, Infrastructure and Communities

MINISTRY OF TRANSPORTATION OF ONTARIO

Iris Fawcett
Transportation Policy Branch

Reg Clarke
Senior Policy Analyst
Policy and Planning
Transportation Policy

Toni Memme
Goods Movement Policy Office
Transportation Policy Branch

MINISTÈRE DES TRANSPORTS DU QUÉBEC

Louis-Olivier Gervais
Socio-Economic Reseach and Planification Agent
Direction of Marine, Air and Rail Transportation

Serge Routhier
Rail Analyst
Direction of Marine, Air and Rail Transportation
Rail Transportation Department

Josée Hallé
EcoTrain's Contract Manager
Head of Rail Transportation Department
Marine, Air and Rail Transportation