A Preliminary Feasibility Study about High-Speed Rail in Canada

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1. Introduction

The first high-speed train in North America, Acela Express, started its service in December 2000. 37 years has passed since Shinkansen was introduced in Japan. The earliest Shinkansen is 515 km in length, and links Tokyo with Osaka in 3 hours 10 minutes. France's TGV began its operations in 1981, which linked Paris with Lyon in 2 and a half hours. Italy's Direttissima got partly open in 1988, German's ICE in 1991, Spain's AVE in 1992, and Eurostar through Channel Tunnel in 1994. Moreover, some Asian countries, South Korea, China and Taiwan have subsequently been following. Now bullet trains are operated in almost every developed countries.

Canadians may believe their only transportation options are either airlines or highways, because of low population density. This belief certainly has some merit. For example, it is surely not a realistic plan to build a new rail from the east shore to the west or from the midland to the Arctic Circle. However, it could be a practical project to provide a bullet train service in the corridor from Montreal to Toronto, because this area has enough population to realize.

The aim of this paper is suggesting the argument about a potential of high-speed rail in Canada through a comparative study, mirroring Japanese high-speed rail experiences.

2. The social background of Shinkansen in Japan

Shinkansen started running just before the 1964 Tokyo Olympics. As Japan was swiftly growing in economy at that time, Tokaido line that was partly open in 1872 and links Tokyo with Kobe through Yokohama, Nagoya, Kyoto, and Osaka was tight to carry many passengers and freight. In 1956, the number amounted to

366(Tokyo-Yokohama) or 541(Kyoto-Osaka) trains per day. There were no room for additional trains. So, it was decided that a new line should be constructed, which would link Tokyo with Osaka in 3 hours. It had been under construction in 1959 and got open 5 years later. Then some extension projects were started and a high-speed rail network almost 2,000 km (Fig.1) was constructed up to now.

Shinkansen lines were owned by Japan National Railway (JNR). However, they were built with full borrowings, because the earliest Shinkansen was very successful. Thus, construction fund for Shinkansen was raised from the Treasury Investments and Loans, of which money was supplied by Postal Bank, Postal Life Insurance, the Welfare Pension, and the National Pension. The interest was set to high, because we believed the economic growth would sustain for a long time. In other words, our government expected to collect money not only via tax but also via Shinkansen fare. The business was going well, but the interest was too high to pay back. JNR's debt had begun to grow, because the government revenue via tax was automatically

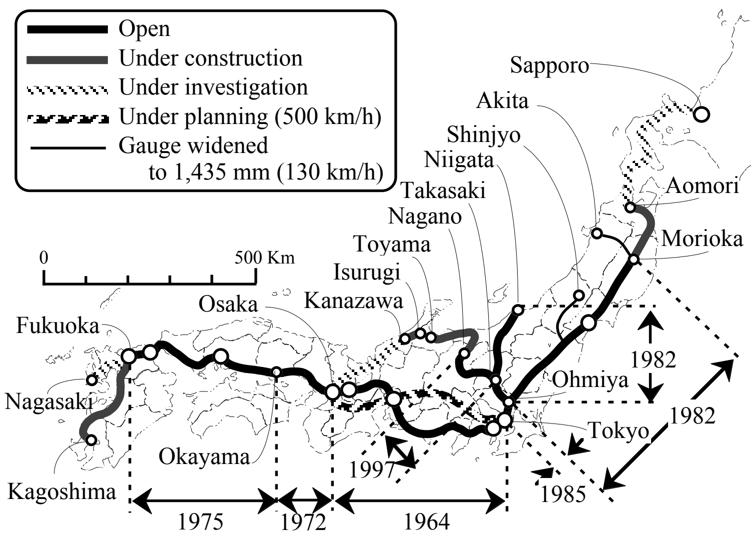


Fig.1 Shinkansen network in Japan (2001)

reduced when economy was not so brisk, on the other hand, the amount of paying back was fixed. At last, the Shinkansen extension projects could not help being frozen.

In 1987, JNR was changed over to Japan Railway (JR) companies whose stockholder is the Government. The unbelievable huge debt was cleared up, and it was decided that tracks shall be provided by public and bullet trains shall be operated by JR. The extension projects were restarted in 1989, and Hokuriku Shinkansen (Tokyo to Nagano) got open under this scheme just before the 1998 Nagano Winter Olympics. Now, over 600 km lines are under construction, over 700 km under investigation, and MAGLEV that links Tokyo with Osaka in 1 hour is under planning.

3. Benefits of introducing high-speed rail (case of Japan)

a) Good profits

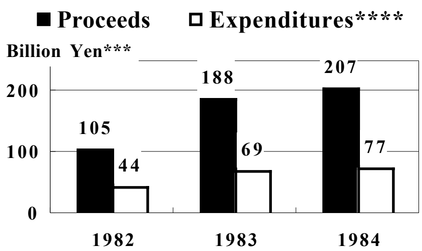
If a high-speed rail is provided on the equal term as other public undertakings without loans, it can beget a good profit every year as Fig.2.

b) Proper investment

Fig.3 is a comparison of annual G.R.P. (Gross Regional Products) with building cost of a new Shinkansen line under construction or investigation, which is almost 1,000 km in length. The annual building cost is less than 1% of GRP, thus, a high-speed rail project is not a huge investment compared with G.R.P.

c) Ecology

Fig.4 is a comparison among several transportations about discharge amount of CO_2 per 1 km and per 1 person. According to



* Based on the audit report of JNR in 1984.
** Tohoku and Jyoetsu Shinkansens
** Numerics are not adjusted with inflater.
*** 100 billion yen=$1,250 million($1=80yen, Jan. '
**** Excluding payingment back

Fig. 2 Annual Proceeds and Expenditures of Shinkansens

this, high-speed rail is a good transportation for environment, but private car or airplane is not so good.

d) Safety

Fig.5 is a comparison of mortality rate. According to this, high-speed rail is very safety. Airplane is also safety, but if an accident was made it will be not so safety. Needless to say, private car is the worst transport.

e) Effective

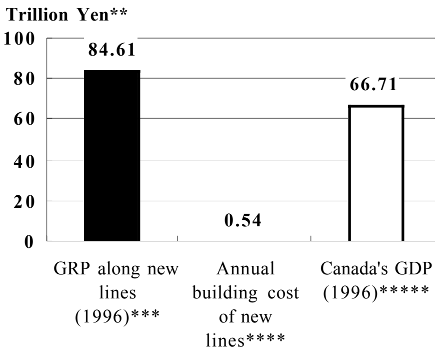
Introducing a high-speed rail is an effective method for reducing CO_2 or persons killed by accidents. As Fig.6, a Shinkansen line carries as many persons*km as a subway in Tokyo.

f) Nations' favor

Shinkansen is a nations' favorite transportation. At 200 - 500 km range in Fig.7, it has a strong competitive power against other modes. Even at 400 - 800 km range, it is used as much as airline.

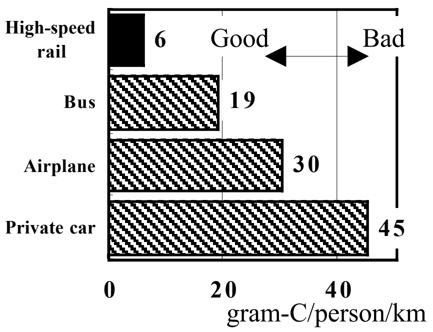
g) User benefits

User benefits per person per kilometer of Shinkansen lines



* Tohoku,Hokkaido,Hokuriku,Kyushu Shinkansens
** 10 trillion yen=$125 billion($1=80yen, Jan. '01)
*** Total of prefectures' GRP along 4 lines
**** 15 years installments ***** Statistics Canada

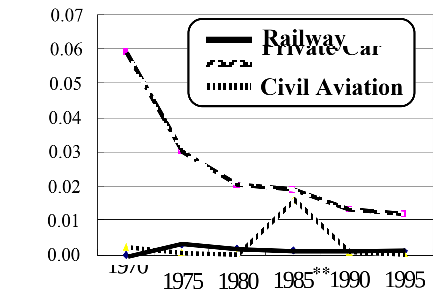
Fig. 3 Comparison of annual GRP with building cost*



*Based on the Japanese M.L.I.T.'s data

Fig. 4 Discharge amount of CO_2 per 1 person per 1 km*

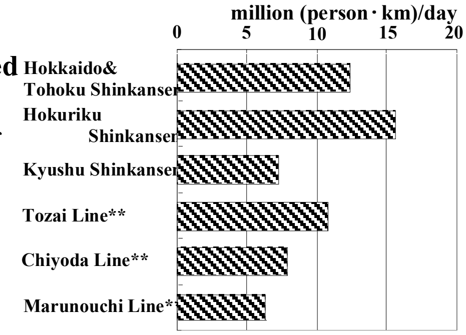
under construction are estimated as followings: decreasing of traveling hours (from slow rail or car) is 16.7 yen, decreasing of fare (from airline) is 5.9 yen, decreasing of fare (from old slow rail) is minus 3.27 yen, and decreasing of fare (from private car) is minus 3.9. Decreasing of car traffic is 830,000 (cars･km)/day, and saving life from accidents is 4.8 persons/year.



* Base on the Japanese M.L.I.T.'s data in 1999.
** 520 passengers were killed by the JAL123 accident.

Fig.5 Railway is a very safety mode.*

鉄道
自動車
航空



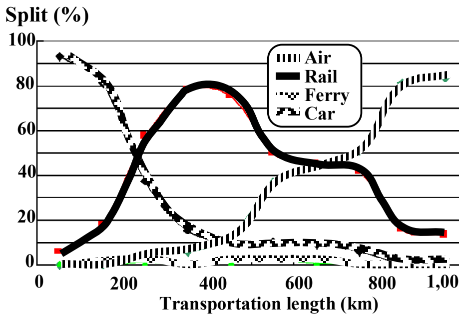
* Based on annual statistics report of railways in 1997
** Subways in Tokyo.

Fig.6 High-speed rails carry effectively*

4. Features of high-speed

Only trainsets often capture most of public attention when high-speed rails are discussed. But total system is much more important. For example, Acela Express train is operated with expensive trainset, which has powerful locomotives for running at 240 km/h and tilting mechanism for passing faster at curves. Unfortunately, they does not have exclusive tracks designed for high-speed trains, it takes the train 3 hours 18 minutes to run 368 km from New York to Boston, of which average speed is only 112 km/h. And 2 hours 43 minutes to run 362 km from New York to Washington, D.C., an average is 133 km/h. On the other hand it takes Canada's VIA train No.66 or No.67 which runs between Toronto and Montreal can reach its final destination in 3 its final destination in 3 hours 59 minutes. Their average speed reaches up to 135 km/h, that is, Amtrak has barely caught up with VIA train now.

By the way, what kinds of traits does a high-speed rail system have? The followings are peculiarities of Japan's Shinkansen system. Others in Europe may have the similar points.



* Inter-prefecture OD in Japan

Fig.7 Split of each mode*

a) separated track from any other slow trains
b) no road crossing (overpass or under pass)
c) 30~70 km apart from each stations
d) fewer switch rails and no grade crossing
e) gentle curve (R>4,000 m) and gentle slope (< 1%)
f) high-powered trainset (16 electric cars with total 11,860 kwh motors)
g) well-designed trainset (air suspension, small current collector, and so on)
h) cab signal (with automatic braking system)
i) Centralized Traffic Control (all signals and switch rails on whole line are controlled at only one center)
j) Computerized traffic management
k) heavy track with maintenance under rigid standard
l) track maintenance with machines

5. Distribution of population in Canada

The density of population in Canada is 3.0 persons/km^2, so it seems to be impossible to success in high-speed rail project. However, more than 7 million peoples live in a small area which is 100 km wide and 1,000 km long, located in Quebec and Ontario from Montreal to Windsor, of which density is over 70 persons/km^2. There is a interesting fact that the density of this area is more than Hokkaido, which is a northern island of Japan, of which population is 5,644 thousand, of which density is 67.6 persons/km^2, where the 1972 Sapporo Winter Olympics was held, which is a granary in Japan, and where a Shinkansen line is under investigation to construct.

Fig.8 is a comparison about city location and scale along some high-speed rails. German's ICE has been already open, and other 3 lines in Japan are under construction or investigation, and also a virtual line of Canada is added. According to this figure, if a new rail is built from Montreal to Toronto via Ottawa, the average density along this will be as almost the same level as that of ICE, Hokkaido Shinkansen, and so on.

6. Why do Canadians use cars so much ?

Then, why do Canadians use their own private cars in spite of such enough population density ? The followings are kinds of answers based on 1-year-observation made by Non-Canadian (me).

a) Highway

It is more comfortable to drive a car on highways in Canada

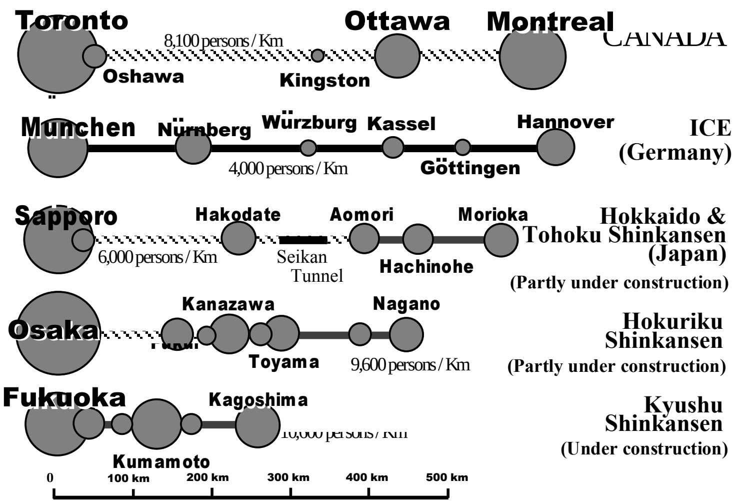


Fig. 8 City location and scale

than in Japan. Drivers don't have to pay at each time. There are fewer congestions, plenty of parking lots even in large cities. Moreover, drivers can reach their destinations almost on time. It's a very useful and economy transportation for Canadians.

b) Airline

Using airline is the best method to get destination in short time. But it's also the most expensive. If a person lives in Toronto must make a return trip to Montreal tomorrow, he may be bothered with the so complex fare system. After a while, he will find he have to pay $760 as return fare. Next morning at the airport, he may find his flight canceled by pilots' strike or any other reason, and have to join a long line to rebook or have to try to call to the reservation center again and again. If he is lucky enough to get on, the plane may arrive at Dorval Airport on "revised" schedule.

c) Railway

VIA train is a kind of economy and comfortable methods to move inter-urban. Train ticket of coach class is reasonable, but more expensive than bus, and sometimes sold out. A train runs as fast as it can, but its speed is just a little bit faster than a private car. Trains depart only a few times a day, the frequency has become fewer and fewer year by year. Delaying 30 minutes is a daily work without any apology. Overall, whoever enjoy travel itself can use trains.

d) Inter-city bus

Bus is the most economy transport. Its depots are located at downtown. In spite of traffic congestions, it can arrive almost on time. But unfortunately, it is slower than a car even on timetable.

e) Conclusion of observation

For these reasons as above, private cars are the most favorable mode for Canadians except businessmen who can use airplanes at business expense, travelers who can enjoy travel itself, and persons who cannot use cars.

7. Traveling time from Montreal to Toronto

a) how to read a chart

Fig.9 is a chart of changing traveling time of inter-city transportation. It indicates changing traveling time (vertical axis) from a city to another depending on starting hours (cross axis). Public transports depart several times a day, and each departure is displayed on a chart as a small circle mark. If a person wants to start his travel on a moment different from a departure time, he have to wait for it. So, his traveling time from a city to another will be transportation's duration plus waiting time. Thus, the changing traveling time depending on starting hours is shaped like teeth of saw, and the true distance between these cities is estimated as the average of this notched chart

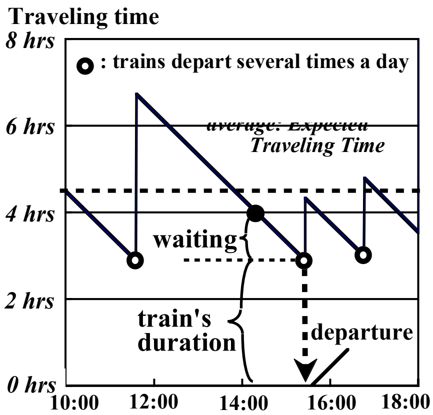


Fig. 9 Traveling time depending on starting hours

b) traveling time from Montreal to Toronto

Fig.10 is a chart about traveling time of each main transportations from Montreal to Toronto. Traveling time includes access and egress to/from airports and so on. One of private car is assumed as constant. According to this chart, airline is the best mode to get destination at any moment, because of its speed and frequency. Private car is the second best almost anytime, because anyone can start travel anytime. Trains can run a little bit faster than private car, but passengers have to wait for train departures, thus an average time including duration and waiting time is longer than car. Inter-city bus is the slowest method to reach destination anytime except some moments.

8. Settings of Canadian high-speed rail

If Montreal is linked with Toronto via Ottawa by high-speed rail the estimated traveling time will be 2 hours 32 minutes. Fig.11 is a result of regression about a relation between distance of 2 stations and duration. Using this result, the estimated traveling time is displayed as Table 1. If train stops for 2 minutes at each station, total travel time

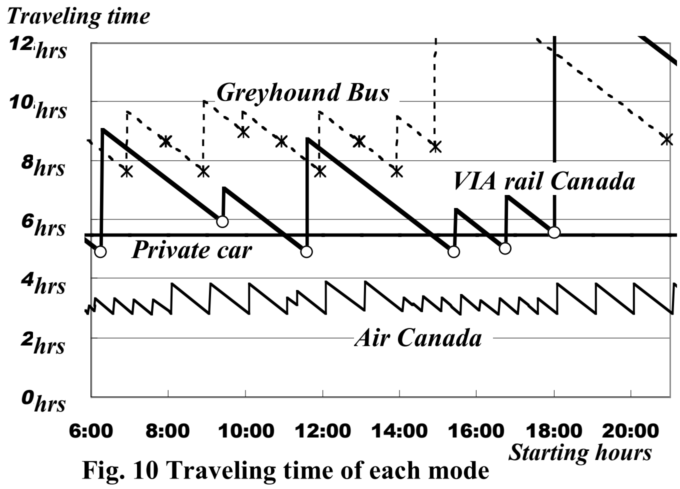


Fig. 10 Traveling time of each mode (Montreal to Toronto, summer ,2000)

will be 2 hours 32 minutes, and an average speed will be over 260 km/h. This speed is not an over estimation, because Shinkansen or TGV built in recent years has almost the same record.

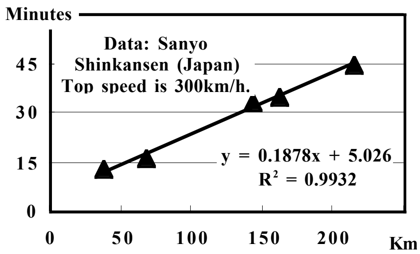


Fig. 11 Distance of stations and duration

9. Existing travel demand and estimated travel demand

a) VIA rail Canada

On a weekday, 5 trains run on each way between Montreal and Ottawa, 5 trains between Ottawa and Toronto, and 7 trains including 1 night train between Montreal and

Table 1. Estimated duration

Section			Km	Minutes
Toronto	-	Oshawa	51	15
Oshawa	-	Kingston	203	44
Kingston	-	Ottawa	191	41
Ottawa	-	Dorval	168	37
Dorval	-	Montreal	19	9

Toronto. The same train sets is used in these operations except some. Trainsets may be added passenger cars on busy days, and two trains are operated with different type cars, however, it is assumed that each trainset consists with 3 second class car (216 seats) and 1 first class car (56 seats). It is assumed that VIA trains will be fully replaced to the high-speed rail. In the end, total number of existing seats on VIA trains is estimated as 3,264 seats/way/day (Table 2).

b) Air Canada and Canadian Airlines

A large part of passengers from Montreal to Toronto are carried by Air Canada group. The numbers of provided seats in the corridor are indicated on Table 3. Other carriers are ignored, because their passengers are small in number.

According to the share data about airline of inter-prefecture OD in Japan as Fig.12, if a high-speed rail service is fully provided at an OD,

Table 2 Existing seats of VIA trains (weekday, winter, '00-'01)

Montreal->Ottawa->Toronto: 272 seats * 5 trains = 1,360 seats
Montreal -> Toronto: 272 seats * 7 trains = 1,904 seats
Total: 3,264 seats/way/day

Table 3. Existing seats of Air Canada(weekday, winter, '00-'01)

(from\to)	Ottawa	Toronto	London	Windsor
Quebec	159	483	-	-
Montreal	311	4,872	-	37
Ottawa	-	3,364	118	-
Kingston	-	195	-	-

(seats/way/day)

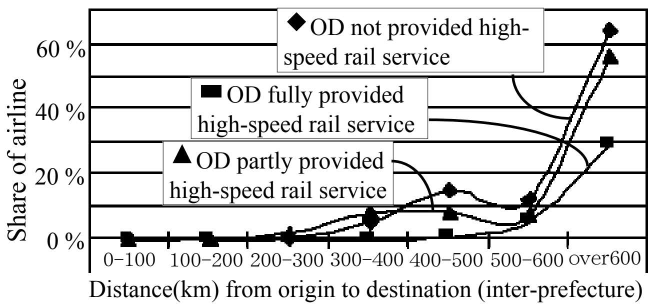


Fig.12 Airline ratio of inter-prefecture OD in Japan

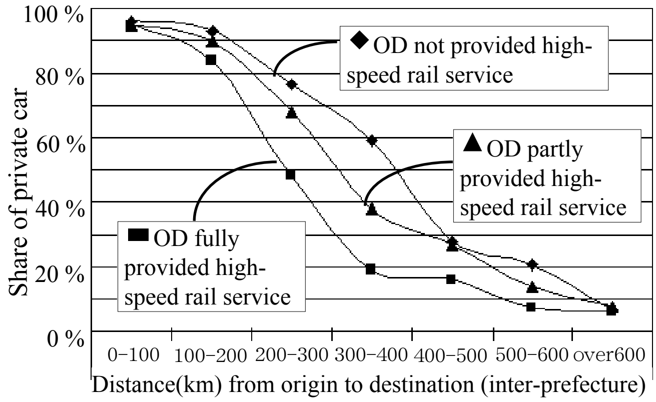


Fig.13 Private car ratio of inter-prefecture OD in Japan

a share of airline will be reduced to almost half. If a distance of OD is less than 500 km, railway will win an overwhelming victory. If partly provided, a share will be reduced from about 65% to 55% at over 600 km range, that is, almost 15% will shift to rail. At 400-500 km and 500-600 km ranges, almost half will shift to rail. At last, it is estimated that passengers on 6,523 seats will shift from air to high-speed rail.

c) Private car and bus on highway

According to the share data about private car as Fig.13, if high-speed rail service is provided at an OD, a share of private car will be reduced at least 8% (maximum 60%). But private cars are ignored in this paper, because it is not clear that Canadians driving cars return to rail or not. Buses are also ignored, because passengers' needs can be different from train or airplane.

d) Canadian high-speed rail

The Canadian high-speed trains will carry 3,264 seats on existing VIA train and 6,523 seats from airline per way per day. If a trainset is designed as the same capacity as Acela Express (301 seats) 9,787 seats/way/day should be provided by at least 32 trains/way/day. Canadian high-speed trains have to depart at Montreal or Toronto station every 30 minutes from 6 o'clock in the morning to 9 o'clock in the evening. Thus, this line will be as busy as many European or

Japanese high-speed rails (Fig.14).

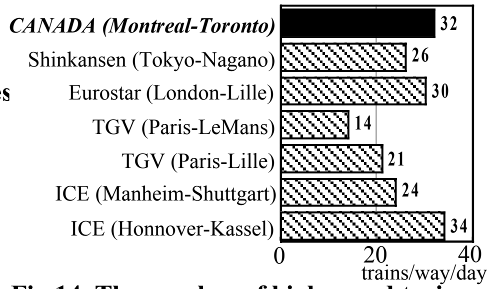


Fig.14 The number of high-speed trains

10. Comparison with res on other reports

There exist 2 reports about Canadian high-speed rail as far as I know. One is reported in by SOFERAIL which is a subsidiary company of SNCF. I could get only a result as Table 4.

On the other hand, a result in this paper is shown as Table 5. Both are different from each other, however, considering the length of line and the result of latter indicated by "seats", they are not so different each other.

Another is presented in a study by Forinash and Koppelman. This is studied using nested logit models and the results are as Table 6. Using the data on Table 2, I can convert above to Table 7. This is almost the same result as Table 5. I think the study by Forinash and Koppelman is a underestimation, because of a train average speed. 10

Table 4. SOFERAIL's estimation

Line	: Quebec-Montreal-Ottawa-Toronto-Windsor (1,215 km)
Speed	: 300 km/h (top speed)
Result	*: 10 million passengers/year*

Table 5. Estimation in this paper (2001)

Line	: Montreal-Ottawa-Toronto (632 km)
Speed	: 300 km/h (top speed)
Result	*: 9,787 seats/way/day =7.1 million seats/year*

Table 6. Estimation by Forinash and Koppelman (1993)

Line	: existing lines	
Speed	: speed up from 100 km/h to 160 km/h (average)	
Results	*: Toronto-Montreal*	*+215%~+250%*
	Toronto-Ottawa	*+206%~+297%*
	Ottawa-Montreal	*+65%~ +97%*

Table 7. Seat amount (conversion from Table 6)

Toronto-Montreal	:1,904*(100+215)(%)=5,998 seats
Toronto-Ottawa	:1,360*(100+206)(%)=4,162 seats
Total: 10,160 seats/way/day = 7.4 million seats/year	

Table 8. Construction cost of Canadian high-speed rail

wetland	:$77.8 million/km *200 km=$15,560 million	: near Ottawa
urban area	:$16.1 million/km * 90 km= $1,449 million	: 30 km*3 cities
other	:$8.65 million/km *342 km= $2,958 million	
	Total: $19,967 million	

years ago, an average speed of TGV or Shinkansen was 160 - 170 km/h, but it has grown up to over 260 km/h now. Canadian high-speed train will be able to run at faster than 160 km/h.

11. Break-even point of Canadian high-speed rail

Referring to Shinkansen's history in Japan, it is very clear that if Canadian high-speed rail is constructed with full borrowings it will surely fail. But provided without any interest, it can be success.

a) construction cost

Construction cost of TGV line in recent years (Nord Europe line) is FF 40.1 million/km (=C$8.65 million/km), and one of Canadian high-speed rail will be almost the same level, because both are through areas with low population density. But in urban areas, cost will be higher. Cost of TGV line near Paris (La Jonction en Ile-de-France) is FF 74.8 million/km (=C$16.1 million/km).

On the other hand, Canadian high-speed rail may have to run through wetlands with soft ground in east Ontario. This section may cost as much as Japan's Shinkansen. Shinkansen track made in recent years costs up to 6,220 million yen/km (= C$77.8 million/km), because of high land price, intricate geographical features, soft ground, and preparations for earthquakes. So, total cost of Canadian high-speed rail is estimated as Table 8. It can be overestimation.

b) fare

Canadian high-speed train will have enough competition power against airlines, so its fare can be higher. A fare system of an airline is so complex, however, as far as I know, the cheapest return fair from Montreal to Toronto under some conditions is around $300. Thus, Canadian high-speed rail fare can be $150 one way. According to data of East Japan Railway company, income is 26.4 yen/km, and expenditure is 10.03 yen/km, thus, net proceed is 62.0% of income. Using this ratio, $93 of $150 can be put to redeem for construction.

c) break-even point

If Canadian high-speed rail is constructed without any interests and the cost is redeemed in annual installment of 40 years the break-even point will be calculated as a following:

*$19,967 million / 40 years / 365 days / ($150 * 62%)=14,705 persons*

The number of provided seats is 9,787 seats/way/day, that is, 19,574 seats/day. So, Canadian high-speed rail can be realized, because 14,705 persons can sit on 19,574 seats. If over 75.1% of seats are occupied, Canadian high-speed rail can even go into the black.

12. Considerable features in Canada

a) a role of high-speed rail as a pivot of rail network

If an existing VIA train is smoothly connected with a Canadian high-speed train, a passenger lives along low-speed rail can be received benefits from the high-speed rail. If ignoring a role like this, the high-speed rail will be underestimated.

b) coexistence with airlines

To put it simply, a large part of flights in the corridor will be replaced to high-speed rail, and it may break air-network. If a station of high-speed rail is open at an airport and a train have a flight-code it can be a pivot of airline network in Canada. For example, German's Lufthansa Airport Express is a train with a flight-code of Lufthansa.

c) weather and wetland

Canadian high-speed rail may have to go through wetlands with soft ground, and it should be in operation even on a coldest day of winter. Keeping tracks rigid may be not so easy. However, some rainy or cold country may have effective answers.

13. Conclusion

Canadian high-speed rail is neither a dream nor a huge investment, but a practical project. It is also a very nature-friendly project. It saves number of Canadians' lives and a lot of hours. It will be a real "public" transport not only for businessmen but for everybody. And it can be even a profitable business.

The riches of nature still around in Canada. Thus, Canadians' transportation shall be more nature-friendly, so I hope. Luckily you have a factory for bullet trainsets. All you have to do is making a track designed for high-speed trains. High-speed rail is a trend of the world. It's time to go aboard.

14. Acknowledgements

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15. References

1. NAKAGAWA Dai and HATOKO Masatoshi, *An assessment method for Shinkansen under planning (Japanese, original: Seibi Shinkansen Hyoka Ron),* PTEC, 2000
2. Brian Perren, *TGV Handbook second edition*, Capital Transport Publishing
3. AMANO Kozo, MAEDA Yasunori and MIWA Toshihide, *Railway Engineering (Japanese, original: Zusetsu Tetsudo Kougaku),* Maruzen, 1992
4. SATOU Yoshihiko, *High-speed rail in the World (Japanese, original: Sekai no Kosoku Tetsudo),* Grand Prix Publishing, 1998
5. Edward J. Taaffe, Howard L. Gauthier and Morton E. O'kelly, *Geography of Transportation second edition,* Prentice-Hall, Inc., 1996
6. Forinash, C., and F.Koppleman, *Application and Interpretation of Nested Logit models of Intercity Mode Choice, Transportation Research Record 1413,* Transportation Research Board, National Research Council(1993), pp.98-106