



TOPIC 23
RAIL SECTOR
TRANSPORT

**SPEED UP BY THROUGH OPERATION
BETWEEN SHINKANSEN AND CONVENTIONAL
LINES: OU MAIN LINE (FUKUSHIMA -
YAMAGATA)**

TAKUYA TSUBOTA

Tohoku Construction Division
East Japan Railway Company, JAPAN

CHIYOJI KOIWA

Tohoku Construction Division
East Japan Railway Company, JAPAN

Abstract

This paper discusses the background outline and new technology concerning through operation of Shinkansen and conventional lines between Fukushima and Yamagata. In addition, it explains the methods and the results of travel demand forecasting, comparing and analysing them with the results after start up of operations.

SUMMARY OF THROUGH OPERATION OF SHINKANSEN AND CONVENTIONAL LINES BETWEEN FUKUSHIMA AND YAMAGATA

Background

Japan has been extending its Shinkansen network, the backbone of its intercity railroad system, since the enactment of Nationwide Shinkansen Railway Development Law in 1970 (Figure 1).

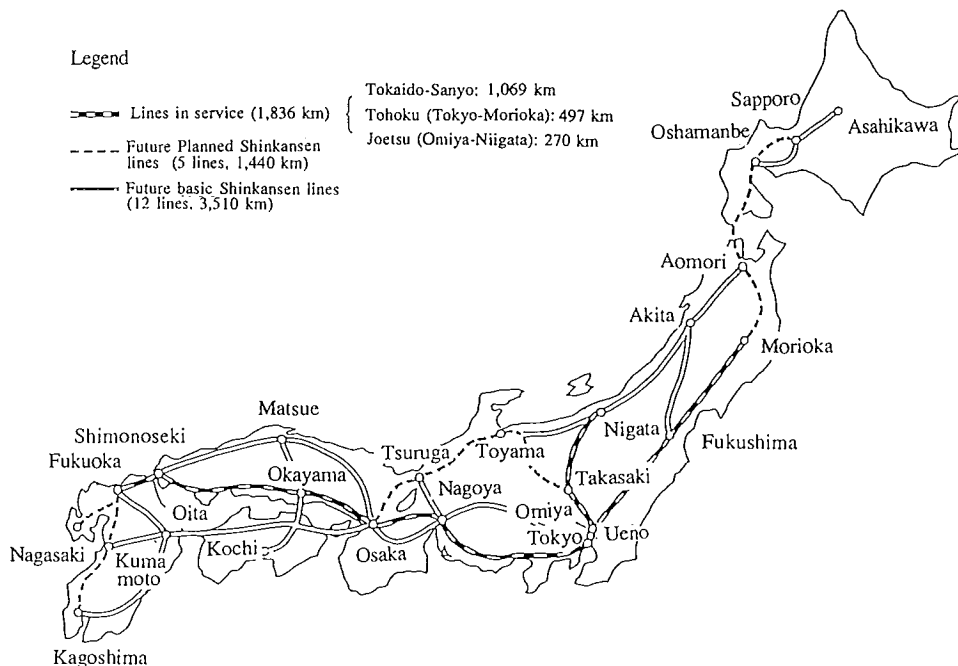


Figure 1 National Shinkansen network

At the present time, the Hokuriku Shinkansen and other planned Shinkansen are being built. There are problems, however, in securing the funds for the construction—which reportedly will cost some 7.4 trillion yen. The project will clearly require a long time to complete.

The density of the traffic for planned Shinkansen and future basic lines is much lower than on the Tokaido and Tohoku Shinkansen and other existing lines, however. The question has accordingly been raised as to whether the benefits would be commensurate with the massive investment required.

In view of the situation, a study was made of the through operation between Shinkansen and conventional lines with the aim of economically spreading the benefits of the high speed Shinkansen network to existing lines, while also decreasing the investment compared to Shinkansen of existing specifications. The first through operation between Shinkansen and a conventional line was started between Fukushima and Yamagata—a distance particularly suited to this project—in July 1992 (Figure 2).

The basic idea of this project was to lay a standard gauge track between Fukushima and Yamagata using an existing line and thereby enable through Shinkansen operation between Tokyo and Yamagata.

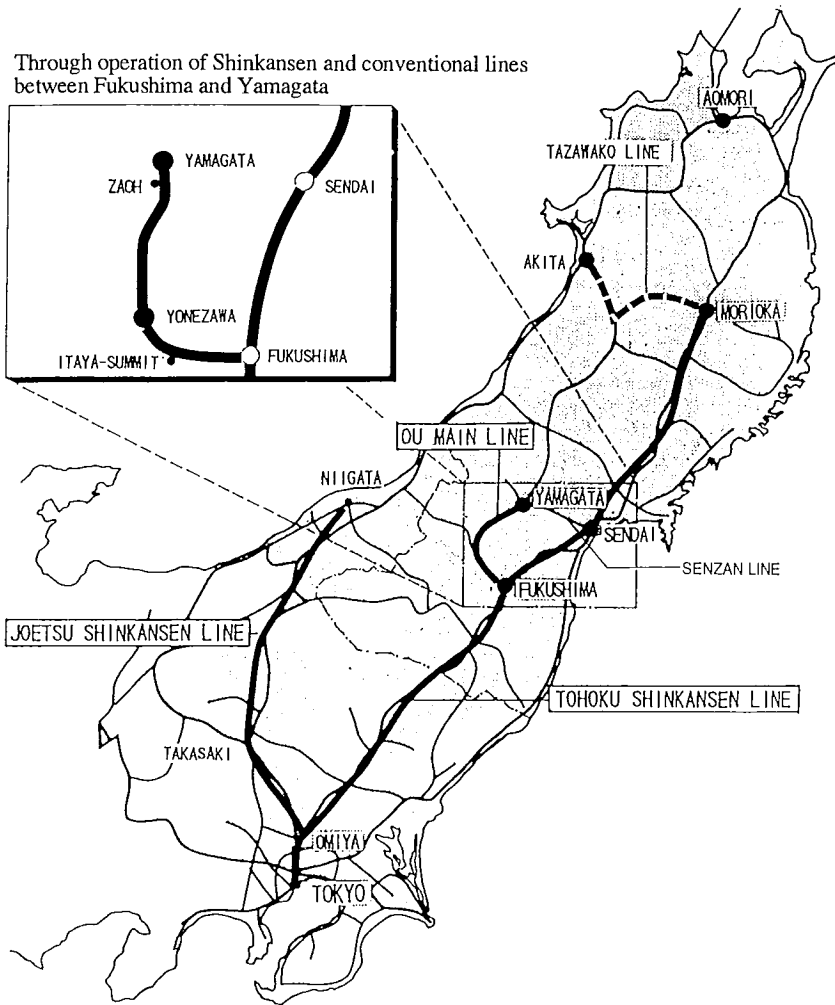


Figure 2 East Japan Railway company business area

Summary of project

The project is summarized below:

1. The narrow gauge Ou Main Line between Fukushima and Yamagata, 87.1km, was converted to standard gauge. A connectry track was installed from the Tohoku Shinkansen station at Fukushima so that Shinkansen train could use this converted line to Yamagata (Figure 3).

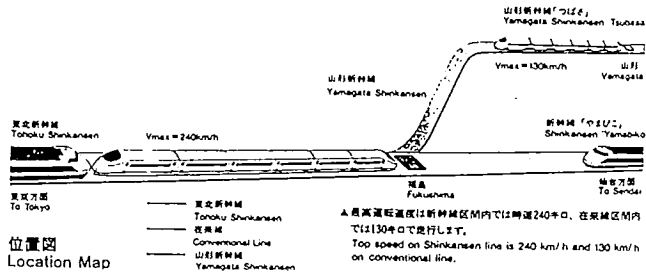
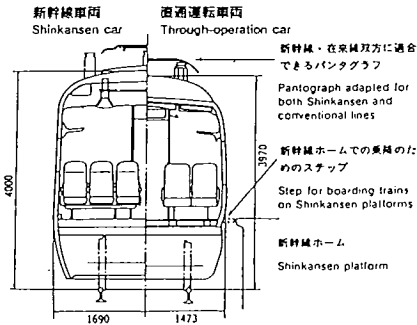


Figure 3

- The rolling stock is of the same track gauge as the Shinkansen, 1,435 mm, but was built to the same dimensions as conventional limited express cars to enable existing tunnels, bridges, platforms, and other facilities to be used (Figure 4).

●車両のイメージ
View of Rolling Stock



●直通運転の主要諸元比較
Comparative Specifications for Through Operation

項目 Item	現行 Present		直通運転 Through operation	
	特急 Limited Express 福島・山形間 Fukushima- Yamagata	新幹線 Shinkansen 上野・福島間 Ueno- Fukushima	直通特急 Through Limited Express 福島・山形間 Fukushima- Yamagata	新幹線 Shinkansen 上野・福島間 Ueno- Fukushima
営業キロ Route length	90km	265km	90km	現行に同じ Same as present figures
軌間 Track gauge	1,067mm	1,435mm	1,435mm	
車両幅 Car width	2,946mm	3,380mm	2,946mm	
電化方式 Power supply	AC20kv	AC25kv	AC20kv	
最高運転速度 Maximum speed	95km/h	240km/h	130km/h	
所要時間 Travel time	約3時間10分 about 3 hr 10 min		2時間40分台 about 2 hr 40 min	

Figure 4

3. Use was made of the existing line so as to eliminate the need for acquiring new land for the route and thereby reducing construction costs.
4. To increase the speed over the converted section, switchback tracks at four stations on the steeply graded route over Itaya-Summit, Osawa, Touge, Itaya, and Akaishi were removed so trains can pass through without stopping on the line. This was made possible by the higher performance of the new trains. Also, the turnouts at the stations were changed to allow through passage.
5. Eleven of the 91 level crossings in existence before the start of the construction were eliminated (five of these crossings were elevated or lowered) and 80 crossings were given new standard protection.
6. For freight transport, a three-rail track was laid over the 5.3 km distance between Yamagata and Zaoh.
7. The service resulting from these improvements is summarized below:
 - (i) Direct limited express service: Tokyo to Yamagata
 - (ii) Travel time: Minimum 2 hours 27 minutes (shortened 42 minutes)
 - (iii) Maximum train speed: 240 km/h on the Shinkansen and 130 km/h on the converted section (conventional maximum speed had been 95 km/h)
 - (iv) No. of trains: 14 Shinkansen trains each way per day; more at peak travel times
 - (v) Trains
 - Rolling stock: 6 cars: one “green” (first class), five ordinary
 - Passenger capacity: 335 passengers/train
 - Facilities: Facilities for both Shinkansen and converted sections (uncoupling and coupling devices, voltage switching devices), seat configuration (2 + 1 rows in first class and 2 + 2 in ordinary class), information services (passenger information display boards, telephones, etc)
 - (vi) Others: All local trains between Fukushima and Yamagata leg are standard gauge electric railcars. The “Akebono” limited express sleeper train (serving Aomori and Ueno) and freight trains were rerouted over other narrow gauge lines.

Scheme of project

Next, an explanation will be given of measures used to secure funding for Shinkansen-conventional line through operation between Fukushima and Yamagata and the scheme of the project.

Up until now, the principle followed for the Shinkansen, the mainstays of intercity transportation, has been for the users to bear the costs. Initial costs have been met by investment and financing of total costs by the national government.

With this project, however, the volume of traffic forecast was low and therefore loans could not be expected to be repaid, so it was necessary to obtain grants to ensure profitability. Further, there was repeated debate as to how the burden should be divided between the national government and local authorities, the relationship between the local authorities and East Japan Railway under the Law on the Special Measures to Promote Local Public Financial Reconstruction, etc. As a result, the following scheme was developed for this project:

1. A third sector “Yamagata JR Through Superexpress Holding Co. Ltd” was established as the implementing entity, serving to improve facilities and own the rolling stock.
2. The national government paid out about 20 percent of the expenses eligible for subsidies (from the main line revitalization fund).

3. The local authorities invested about the same amount as the national subsidy.
4. East Japan Railway invested the same amount as the local authorities.
5. The remaining costs of the project were raised by the third sector from financial institutions and are being repaid by leasing fees obtained by leasing the facilities and rolling stock to the East Japan Railway Co.

The scheme is illustrated in Figure 5.

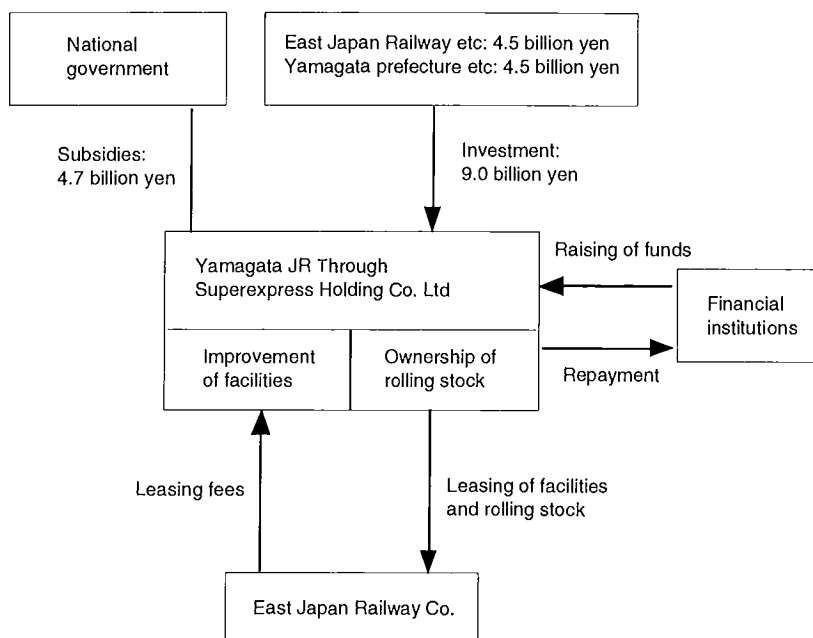


Figure 5 Type of project

The Yamagata JR Through Superexpress Holding Co. Ltd was established on May 6, 1988. Yamagata Governor Itagaki became president of the firm. The cost of construction project was approximately 32.0 billion yen, of which about 24.0 billion yen was for subsidized construction (4.7 billion yen, which accounts for 20%, is subsidies) and approximately 20.0 billion yen was spent for rolling stock.

Construction costs	32.0 billion yen
Rolling stock	20.0 billion yen
<i>Total</i>	<i>52.0 billion yen</i>

Financial resources	
National subsidies	4.7 billion yen
Capital	9.0 billion yen
Loans from Development Bank	25.0 billion yen
Loans from commercial banks	13.3 billion yen
<i>Total</i>	<i>52.0 billion yen</i>

Breakdown	
<i>Local authorities</i>	
Yamagata prefecture	3.6 billion yen
Yamagata city	0.7 billion yen
Tohoku Electric and Yamagata Bank	0.2 billion yen
<i>JR</i>	
East Japan Railway Co.	3.6 billion yen
East Japan Kiosk Co.	0.7 billion yen
Fuji Bank and Daiichi Kangyo Bank	0.2 billion yen

The project was accomplished through the above scheme. By making use of the facilities of the conventional line and establishing a through operation between a Shinkansen and an existing line, the project carries tremendous significance. It does this in two ways—by economically spreading the benefits of the Shinkansen and by establishing a precedent for national government and local authorities providing substantially equal subsidies for construction of an intercity transport link. The project therefore forms a blueprint for the future of the planned Shinkansen.

TRANSPORT

As explained above, Shinkansen-conventional line through operation between Fukushima and Yamagata began on July 1, 1992. We will look at the effects of the service based on the volume of traffic.

Trends in sectional traffic between Fukushima and Yonezawa on Ou Main Line

Figure 6 shows traffic trends on the Ou Main Line between Fukushima and Yonezawa from 1987 to the year after the start of the through service, 1993.

Due to the railway construction, however, the frequency of limited express train service between Fukushima and Yonezawa was cut from September 1990 to August 1991. Also, there was no limited express train operation from September 1991 to June 1992. Therefore, the data for 1990 to 1992 are not accurate and cannot be compared with those for other years.

A comparison of traffic in the years for which full data can be compared, 1989 and 1993, shows that there was a 31 percent increase in transport (9,441/7,214 passengers).

Figure 6 shows traffic on the Senzan Line. Since limited express train operation was cut or suspended on the Ou Main Line due to construction from September 1990 to July 1992, when the Shinkansen-conventional line through operation was started, the amount of traffic on this line increased in 1990 and 1991. This may mean that some passengers previously using the Ou Main Line between Tokyo and Yamagata switched and went by the Senzan Line.

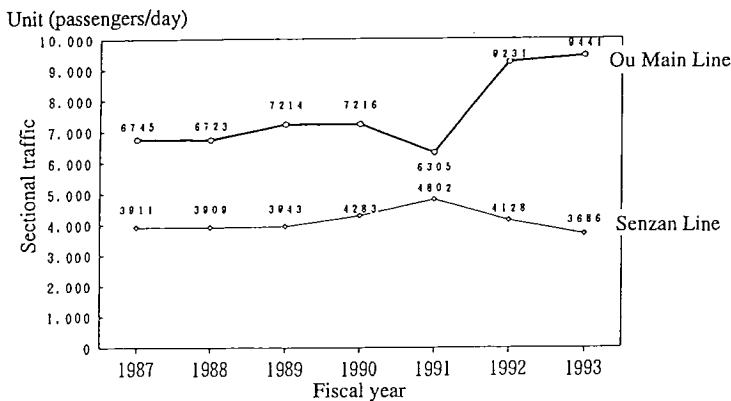


Figure 6

Trends in intercity traffic in East Japan Railway territory

To discover general trends in intercity traffic caused by socioeconomic conditions before and after the start of the Shinkansen-conventional line through operation between Fukushima and Yamagata, a study was made of the number of railway passengers traveling from Tokyo, etc., to the Tohoku region. The results are shown in Figure 7.

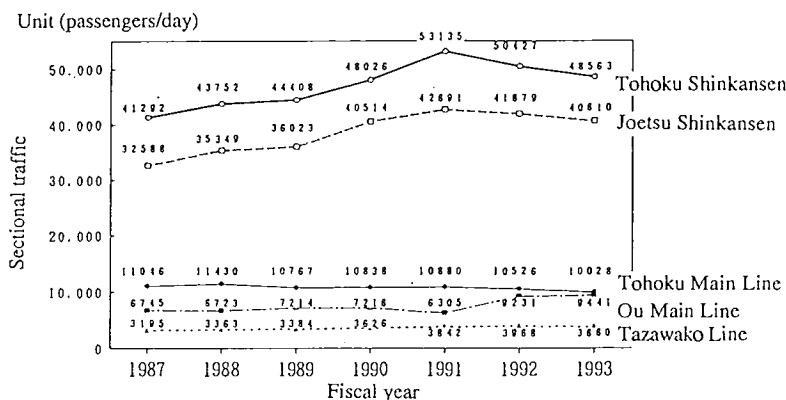


Figure 7 Railway passengers travelling from Tokyo etc to the Tohoku region

Particular attention was paid to Sendai, Morioka, Niigata, Aomori, and Akita cities.

Traffic on the Shinkansen increased until 1991, before peaking and then falling. Traffic on conventional lines remained approximately the same. Table 1 shows a comparison of traffic on several other lines in 1989 and 1993 for comparison with the Ou Main Line.

Table 1 Comparison of traffic

	1989 traffic	1993 traffic	Increase (1993/89)
Tohoku Shinkansen (Fukushima-Miyagi prefecture border)	44,408	48,563	1.09
Joetsu Shinkansen (Saitama-Gunma prefecture border)	36,023	40,610	1.13
Tohoku Line (Iwate-Aomori prefecture border)	10,767	10,028	0.93
Tazawako Line (Iwate-Akita prefecture border)	3,384	3,860	1.14

Trends in air traffic

Figure 8 shows the trends in air traffic, the major competitor of railway traffic, between Tokyo and airports in the Tohoku region, in particular, Aomori, Akita, Yamagata, and Shonai.

Despite the overall increase in air traffic, the number of passengers flying between Tokyo and Yamagata declined in 1992, the year the Shinkansen-conventional line through operation was started, and in 1993, its first full year. Clearly, this was an effect of the new service.

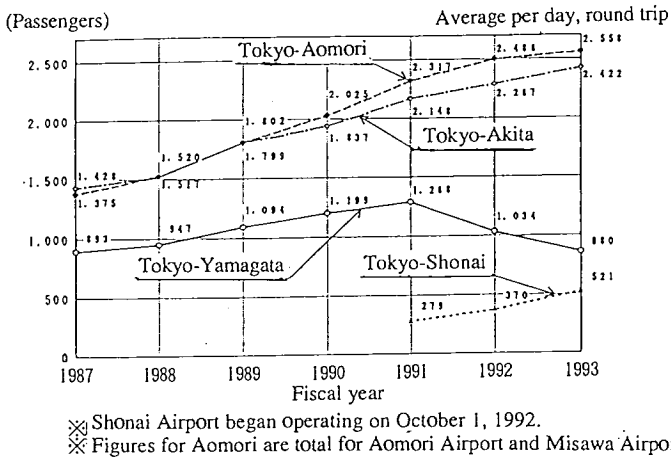


Figure 8 Trends in air passenger transport between Tokyo and Yamagata, Shonai, Akita, and Aomori

Travel demand forecasting before startup

In the process of this project, demand forecasts were made by two methods:

1. Demand forecasting by the four step estimation approach (model of Japan Transport Economic Research Center)
2. Demand forecasting by the transport resistance method

The methods of demand forecasts step estimation approach and their findings will be discussed in brief below and confirmed in accuracy by actual figures.

Method 1: Demand forecasting by four step estimation approach

1. Zoning of OD covered by forecasts

- The OD covered by the forecasts was the amount of OD traffic between the two prefectures of Akita and Yamagata and the Kanto region and areas west, in view of the range of passengers covered.
- For the zoning, Akita prefecture, Yamagata prefecture, and the Kanto region were divided into several zones in consideration of JR lines. For other regions, each prefecture was made a zone.

2. Forecast Target Year of Completion...

(1) 1992, (2) 2000, (3) 2010

3. Traffic network

- Railway line network
 - Existing lines... main railway line network
 - Future lines... Shinkansen-conventional line through operation between Fukushima and Yamagata and Ueno-Tokyo leg of Tohoku and Joetsu Shinkansen

- Road network
 - Existing roads... main roads (highways, general national roads)
 - Future roads... roads under construction or planning which may reliably be expected to open by the projected target year of completion
- Air service
 - Existing flights ... regular flights
 - Future flights... flights planned along with opening of Shonai Airport (based on Yamagata Airport)

4. Method of demand forecasting

- Use was made of the four step estimation approach based on the population frame and the estimates of the current OD.
 - Forecast of trip generation and trip attraction
 - Forecast of trip distribution
 - Forecast of trip distribution by means of transport
 - Forecast of trip distribution by railway lines

5. Establishment of population frame (night-time population)

- Forecast 1 of Institute of Population Problems, Ministry of Health and Welfare (constant net rate of movement from 1980 to 1985)
- Forecast 3 of Institute of Population Problems, Ministry of Health and Welfare (no population movement, substantially same as 4th National Development Plan of National Land Agency) (Figure 9)

6. Estimate of current OD

- OD using railways: As per *Record on Passenger Flow in Japan* (Ministry of Transport, FY1985)
- OD using airlines: As per *Record on Passenger Flow in Japan* (Ministry of Transport, FY1985) and *Survey of Dynamics of Airline Passengers* (Civil Aviation Bureau, Ministry of Transport, FY1985)
- OD using cars: As per *Road Traffic Census* (Ministry of Construction, FY1985)

7. Forecast of trip generation and attraction

- The future amount of trip generation and attraction was forecast assuming that the prime units per capita of night-time population would not change in the future.

8. Forecast of trip distribution

- Use was made of the present pattern method as it was believed that the current pattern of passengers distribution would not change too much in the future.

9. Forecast of trip distribution by means of transport

- Use was made of the disaggregate model for projecting the rates of choice of transport mode.
- Transport Mode Choice Model
 - Railways (conventional lines, Shinkansen)
 - Automobiles (passenger cars, buses)
 - Airlines

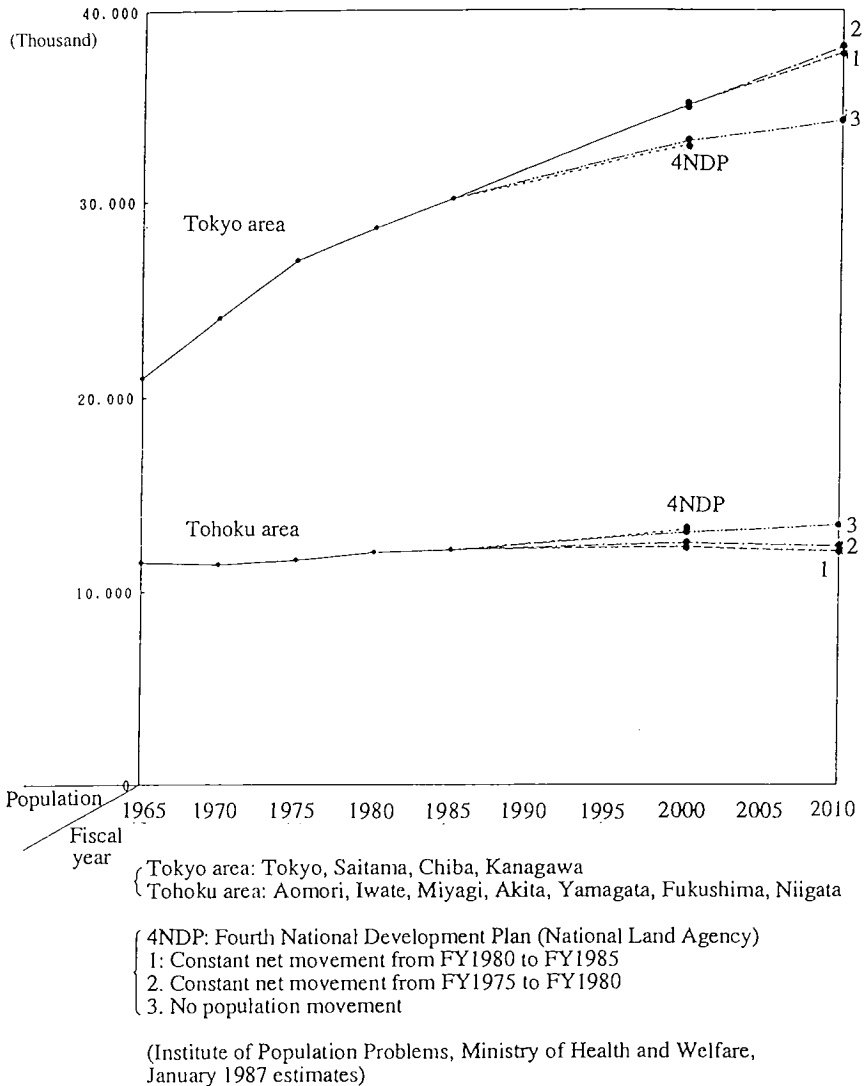


Figure 9 Trends in population in Tokyo area and Tohoku area

The probabilities of choice of transport mode were calculated as follows:

$$P_i = \frac{\exp V_i}{\exp V_R + \exp V_B + \exp V_C}$$

$$V_i = \alpha_1 T_i + \alpha_2 C_i + \alpha_3 D_i + \dots$$

where

i: Means of transport, ie i = R ... railways, i = B ... automobiles, i = C... airlines

P_i: Probability of choice of transport mode i

exp: Exponent of natural logarithm

V_i : Efficacy in case of use of transport mode i

T_i, C_i, D : Time (T_i) and fare (C_i) in case of use of transport mode i and rate of car ownership (D)

α : Parameters of descriptive variables ($T_i, C_i, D...$) at time of α_i calculation of effect

Table 2 Parameters of transport mode choice model

	Automobiles	Railways	Airlines
Trunk line time (minutes)		-0.01760198 (9.13)	
Access/egress time (minutes)		-0.008216325 (4.42)	
Total cost (yen)		-0.000220985 (3.09)	
No. of transfers	—	-0.476743 (2.42)	—
Car ownership rate	0.650012 (2.01)		—
Constants	4.215390 (6.49)	3.813387 (5.68)	—

Note:

One transfer corresponds to 27 minutes of trunk line time and 2,200 yen in total costs.

10. Railway route choice model

- The rates of selection of the conventional line and Shinkansen were forecast using the disaggregate model.

11. Assumptions in use of model

- See Table 3.

Table 3 Assumptions in use of model

	Travel time		Costs
	Trunk line time	Terminal time	
Railway	According to timetable Current: 191 minutes	Required time from center of zone to main station: 15 to 20 minutes	According to timetable
	Shinkansen-conventional line through operation: 169 minutes		
Air	According to timetable	Center of zone \Rightarrow airport	According to timetable
		Access time using bus, rail, etc. Check-in and check-out time: 30 minutes each	
Automobiles	Travel time		Average no. of passengers in passenger cars: 1.5 passengers/car Per capita gasoline + tolls
	National highways:	90 km/h	
	Metropolitan highways (city center):	60 km/h	
	General roads (suburbs):	45 km/h	
	General roads (Tokyo environs):	20 to 30 km/h	
Resting time has also been considered			

12. Results of forecasts—results of forecasts of traffic on railways (between Fukushima and Yonezawa on Ou Main Line)

- Forecast 1 of Institute of Population Problems, Ministry of Health and Welfare. The forecast gave a daily one-way traffic of 2,560 passengers in 1992 for the non Shinkansen-conventional line through operation, and an increase of 890 passengers with Shinkansen-conventional line through operation for a total of 3,450.

Note that the increase of 890 passengers breaks down as follows:

- Change from cars and airlines 600 passengers (68%)
- Change from Senzan Line 260 passengers (29%)
- Change from night trains 10 passengers (1%)
- Change from Tazawako, Kitakami, and Uetsu Main Line 20 passengers (2%)

- Forecast 3 of Institute of Population Problems of Ministry, Health and Welfare
 The forecast gave a daily one-way traffic of 2,640 passengers in 1992 for the non Shinkansen-conventional line through operation, and an increase of 920 passengers with Shinkansen-conventional line through operation for a total of 3,560.

Note that the increase of 920 passengers breaks down as follows:

- Change from cars and airlines 620 passengers (68%)
- Change from Senzan Line 270 passengers (29%)
- Change from night trains 10 passengers (1%)
- Change from Tazawako, Kitakami, and Uetsu Main Line 20 passengers (2%)

Method 2: Demand forecasts by method of transport resistance

1. Method of forecasts

- *Natural increase:* No consideration was given to any future growth in the volume of traffic. (Transport fixed at amount for FY1985)

Table 4 Flow between stations on Tohoku Shinkansen from Fukushima South and Yonezawa and Yamagata Region (Limited express passengers) (unit: passengers/day-one way)

	Yonezawa region	Yamagata region	Akita-Yokote region	Total
Ueno	414	986	649	2,049
Fukushima-Koriyama	98	77	103	278
Others	65	163	86	314
Total	577	1,226	838	2,641

Note: FY1985 OD Table (Only Daytime Limited Express)

- *Railway passengers:* Found using 20 percent increase based on figures at opening of Tohoku Shinkansen at Ueno Station in March 1985 (Effective time reduction: 23 minutes).

Table 5 Transport density of Tohoku and Joetsu Shinkansen and parallel conventional lines (passengers/day/inbound and outbound)

	FY1983			FY1985			1985/1983
	Shin-kansen	Limited express	Total	Shin-kansen	Limited express	Total	ratio
Tohoku Shinkansen (Omiya-Utsunomiya)	45,480	7,930	53,410	62,140	2,910	65,050	1.22
Joetsu Shinkansen (Omiya-Takasaki)	22,550	10,930	33,480	36,900	3,160	40,060	1.20

Note: Limited express on conventional lines

- *Change from Senzan Line*: Projections were made by preparing a model matching the current rate of usage of the Ou Line and the Senzan Line using as a representative OD the stretch between Tokyo and Yamagata, which accounts for a large proportion of the passengers between the Tokyo Metropolitan Area and Yamagata.

The model incorporated the concept of transport resistance (fares, travel time, etc), and was based on the following equation:

$$Pr = \frac{\alpha}{Rr} / \Sigma Rr$$

$$Rr = C + \omega T \beta N + \gamma$$

where

Pr: rate of selection of line r

Rr: transport resistance of line r

α : 6 (*Traffic Demand Projection Handbook* (Japan Society of Civil Engineers), based on distribution of transport of central line)

C: fare (fare as of January 1988, limited express)

T: travel time (including time for transfers)

ω : 47.5 yen/minute (time value) (*Planned Shinkansen Demand Projections* (Nomura Research Institute), based on time values of route selection model)

β : 2,157 yen/time (*Survey Study on Shinkansen-Conventional Line Through Service* (Japan Transport Economic Research Center))

N: number of transfers

γ : correction coefficient: 5,832 yen

2. Data used

- Traffic between Tokyo Metropolitan Area and Yamagata: The overall volume of traffic was calculated using the volume of traffic between the Tokyo Metropolitan Area and Yamagata using the Ou Main Line in FY1985 and the ratio of use of the Ou Main Line.
1,168 (passengers/day-one way)/0.863 = 1,353 (passengers/day-one way)

Table 6 Traffic between Tokyo Metropolitan Area and Yamagata

	Travel time		Fare
	Current	Future	
Ou Main Line	Tokyo - Fukushima - Yamagata 97 + 13 + 81 = 191mins	Tokyo - Fukushima - Yamagata 97 + 4 + 68 = 169mins	10,200 yen
Senzan Line	Tokyo - Sendai - Yamagata 123 + 19 + 79 = 221mins	Same as left	10,700 yen

3. Findings

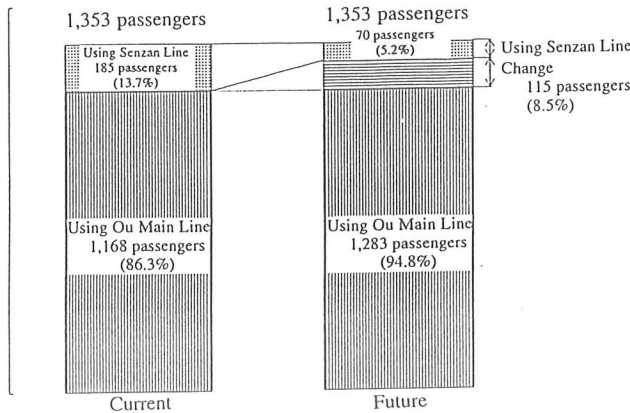


Figure 10 Findings

4. Findings

The forecast gave a daily one-way traffic of 2,640 passengers in 1992 for the non Shinkansen-conventional line through operation and an increase of 680 passengers with the Shinkansen-conventional line through operation for a total of 3,320.

Note that the increase of 680 passengers breaks down as follows:

- Change from cars and airlines 530 passengers (78%)
- Change from Senzan Line 120 passengers (18%)
- Change from night trains 10 passengers (1%)
- Change from Tazawako, Kitakami, and Uetsu Main Line 20 passengers (3%)

Comparison with actual figures

The actual figures exceeded the projections due in part to the favourable growth in traffic since 1985, the effect of privatization of the Japan National Railway, etc. When viewed in terms of the ratio of increase, however, the projected ratios were from 1.26 to 1.35 and the actual ratio was 1.37. This verifies the accuracy of the projections (Table 7).

The actual number of passengers changing from the Senzan Line may have been considered to have been 118, ie the difference between the average transport of 1,961 passengers/day (one way)

for the three years from 1987 to 1989 and the 1,843 passengers of 1993 (earlier figures used due to the reduction in transport capacity of the Ou Main Line from 1990 to 1992). This matches with the projections by the transport resistance method.

In this way, the Shinkansen-conventional line through service is considered to have generated about a 37 percent switch intercity traffic from other means of transport or new transport, including changes from other railway lines, or about 30 percent not including changes from other railway lines.

Table 7 Comparison with actual figures (passengers/day-one-way)

	No through operation (1992)	Through operation (1992)	Ratio of increase and actual increase
Four Step Estimation Approach (Base 1)	2,560	3,450 (600)	1.35 890 passengers (0.23)
Four Step Estimation Approach (Base 3)	2,640	3,560 (620)	1.35 920 passengers (0.23)
Transport resistance method	2,640	3,320 (530)	1.26 680 passengers (0.20)
Actual figures: limited express passengers (reboarding)	3,608 (1989 figures) 3,129	4,720 (1993 figures) 4,302	1.31 1,112 passengers 1.37 1.173 passengers

Note:

Figures in parentheses show number and ratio of passengers changing from cars and buses.

CONCLUSION

As seen above, the Shinkansen-conventional line through operation between Fukushima and Yamagata can be said to have accomplished its initial goal of spreading the benefits of the Shinkansen to the conventional railway network by cutting its investment cost to 1/10 that of existing Shinkansen lines.

As the second project for Shinkansen-conventional line through operation, East Japan Railway is converting tracks to permit through operation on the Morioka-Akita Tazawako Line. Operation is scheduled to begin in FY1996.

Together with planned Shinkansen currently under construction between Morioka and Aomori, and between Takasaki and Nagano (Hokuriku Shinkansen), this will complete the network of high speed railways linking Tokyo and the other major traffic hubs under the jurisdiction of East Japan Railway.

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