SPEED-UP ON THE TOHOKU SHINKANSEN AND ITS IMPACT ON REGIONAL TRANSPORT AND ECONOMY

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I. Preface

The Tohoku region which is located in the northern part of Honshu, the main island of Japan, was left economically behind for a long time.

However, the opening of the Tohoku Shinkansen* brought about many changes in this region.

This paper introduces the technical performance of the Tohoku Shinkansen, the changes brought about in the shares of the transportation means and the economical impact on the Tohoku region. This paper also refers to the future issues of the Tohoku Shinkansen.

II. The construction of the Tohoku Shinkansen and its design standard

In 1971, the Japanese government decided to construct the Tohoku Shinkansen to connect the Tokyo metropolitan area and the northern region of the Japanese main island by means of high speed trains. (Fig.-1)

Taking into consideration the operational experiences of the Tokaido Shinkansen, the first Shinkansen opened in 1964, many technical improvements were achieved for the Tohoku Shinkansen. For example,

1) The track alignment and the fixed installations were designed for the maximum speed of 260 km/h.
2) Special countermeasures against heavy snowfall were adopted.

The Tokaido Shinkansen had sometimes suffered from heavy snowfall which caused train delays of about 20~30 minutes.

Moreover, from the operational experience of the Tokaido Shinkansen, JNR engineers discovered that ballast track had snow problems when trains were operated at 200 km/h during heavy snowfall.

That is to say, when a train passes through a heavy snow section at the speed of 200km/h, small snow particles adhere to the surface of rolling stock, and they grow bigger into lumps which fall down onto the ballast.

This causes the ballast to fly up and damage the devices under the floor of the rolling stock.

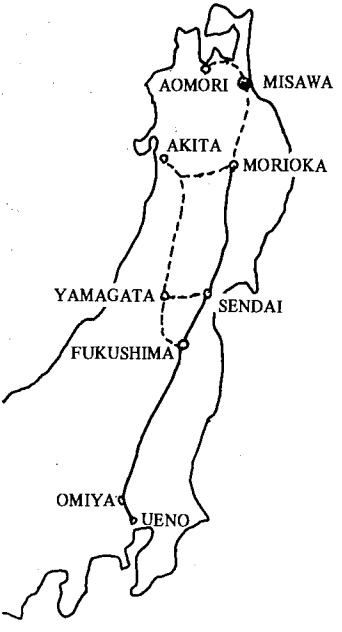

Fig.-1 Northern Region of Japan Main Island
(—— Tohoku Shinkansen
---- Connected lines)

*"Shinkansen" refers to a super-high-speed railway of standard gauge in Japan

Therefore, the following methods were adopted to counter the above problem.

The main countermeasure was the utilization of concrete slab track structure that directly connect the rails to the concrete beds by double elastic fastenings. However, as the use of concrete slab track structure was very difficult or expensive at those sections where the earth condition was not good or turnouts were installed, the ballast structure was adopted at such sections with the ballast covered by rubber net.

Furtheremore, the bottom part of rolling stock for the Tohoku Shinkansen was covered by steel plates to protect the devices from the flying ballast.

3) Infrastructures of the Tohoku Shinkansen were strengthened to withstand severe earthquakes, because train operation on the Tokaido Shinkansen would sometimes be stopped for 2 to 3 hours after an earthquake to secure the safety by inspecting the track conditions. On the Tohoku Shinkansen, when the acceleration of an earthquake is more than 120 gal, the track is checked by visual walking inspection, and is checked by a slow speed train when the acceleration is below 120 gal and over 80 gal, while on the Tokaido Shinkansen visual walking inspection is for more than 80 gal and slow-speed train inspection for between 40 gal and 80 gal.
4) The utilization of concrete salb track structure and adequate maintenance of rail surfaces have enabled wonderful riding comfort for passengers on the Tohoku Shinkansen.

Even at the speed exceeding 200km/h, a cigarette set upright on a table in the Shinkansen train keeps standing because of the very smooth riding quality.

In June 1982, the Tohoku Shinkansen was opened between Omiya and Morioka, though the 31km section between Omiya and Ueno, the northern exit of the Tokyo metropolitan area, was still under construction. Omiya and Ueno were connected by the operation of special relay trains.

In the initial stage, the maximum train speed was 210km/h because the speed was restricted on account of the noise problem of the Shinkansen trains.

In that strage, the time required from Ueno station to the major cities of the Tohoku region was reduced as shown in Fig.-2.

Section		Time Required
UENO-FUKUSHIMA	Before	3.16
	After	2.08
UENO-SENDAI	Before	4.15
	After	2.38
UENO-MORIOKA	Before	6.21
	After	3.56
UENO-YAMAGATA	Before	4.39
	After	3.47
UENO-AKITA	Before	7.52
	After	6.09
UENO-AOMORI	Before	8.47
	After	6.34

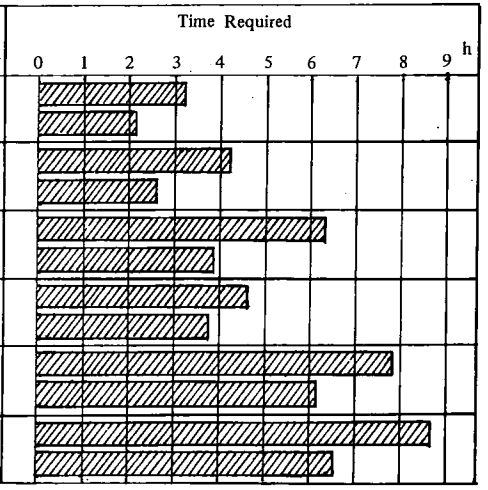

Fig.-2 Time Required from Ueno to the Cities of Tohoku Region Before and After June 1982

Even though the Tohoku Shinkansen was only partially opened in 1982 as metioned before, the fine performance such as the very punctual operation even in heavy snow or rain, and the very good riding qualitiy attracted more passengers than expected.

The number of passengers by rail between Tokyo and Sendai increased more than 40%. On the other hand, the number of passengers by airplane between Tokyo and Sendai decreased as shown in Fig.-3.

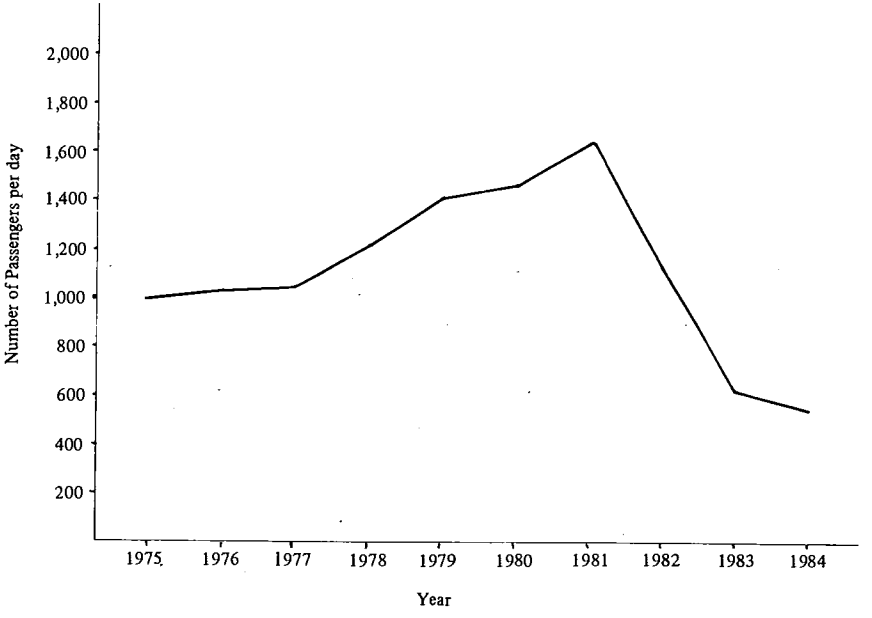

Fig.-3 Transition of the Number of Passengers by Airplane between Tokyo and Sendai

III. Decision of 240 km/h Operation

In March 1983, JNR decided to undertake research to achieve train operation at the maximum speed of 240 km/h on the Tohoku Shinkansen upon the completion of the remaining portion of the line between Omiya and Ueno.

As the result of the research, the track and the rolling stock were improved in the following technical fields,

1) Track
   (a) Maintenance of smooth rail-surface for reducing train noise by grinding the rail corrugation using specially devised equipment
   (b) Maintenance of track irregularities by long wave chord of 20m for improving riding comfort of 240 km/h operation. (Conventional maintenance was done with 10m chord.)
2) Rolling stock
   (a) Reduction of the number of pantographs to half per train to counter the noise problem.
   (b) Improvement of motor output from 185 kw to 230 kw for each motor.
   (c) Improvement of brake performance by increased capacity of rheostats.
   (d) Development of aerodynamic design rolling stock for reducing air drag.

After these improvements, JNR conducted a series of long-run tests by special test passenger

cars from September 1983 until September 1984.

The results of these long-run tests at the speed of 240 km/h were as follws:

In the context of rolling stock, wear rate of pantograph-plate was 1.5 times greater than that of 210 Km/h operation, but as far as concerns other parts there was no problem.

In the context of track, the values of vertical and lateral pressure to rails by wheels were within the permissible standards values.

Accordingly, it was confirmed that the train operation at the speed of 240 km/h was safe enough.

Furthermore, good riding quality was achieved by track maintenance using the long wave chord inspection method.

As the train noise was reduced by the reduction of the number of pantographs and by the grinding of rail corrugation, the degree of noise at 240km/h by test train became the same as that of train operation previously at 210km/h.

Considering and evaluating those results obtained from the long run tests, JNR decided to adopt the Maximum speed of 240km/h in commercial service.

IV. Inauguration of Ueno-Omiya section and beginning of 240 km/h train operation

In March 1985, construction of the section between Omiya and Ueno was completed and the new Ueno station, as the northern exit of Tokyo, was opened.

At the same time, train operation at the maximum speed of 240 km/h was commenced on the Tohoku Shinkansen.

Accordingly, Sendai, the center of the Tohoku region, was connected to Tokyo within 2 hours.

Furthermore, the number of trains operated in a day was largely increased as shown in Table-1.

The time required from Ueno station to the major cities of the Tohoku region was reduced as shown in Fig.-4

Table-1 Number of Trains per Day of the Tohoku Shinkansen (up and down, regular service)

	Ueno–Sendai	Sendai–Morioka
Before the Opening of Omiya–Ueno	50	30
After the Opening of Omiya–Ueno	76	44

This shortening of travel time and the elimination of train change at Omiya station produced additional traffic between Tokyo and northern part of Japan, a part of which was a shift from airplane to Shinkansen.

As a result, the air service between Tokyo and Sendai was closed in May 1985, and the air route between Hanamaki (near Morioka) and Tokyo was abandoned in July 1985.

Furthermore, an accident of Japan Air Line accelerated the passengers' diversion from airplane to Shinkansen in the whole area of the Tohoku region.

This fact backs up the reliance of the Japanese pepole on the Shinkansen, which has never caused a single casualty by accident, during the 21 years of its operation and has always kept on-time operation.

The transition of air passengers between Tokyo and the main airports in the Tohoku region is as shown in Fig.-5, 6, 7.

The change of the number of railway passengers between Tokyo and the Tohoku region before and after the opening of the Omiya-Ueno section is shown in Table-2.

Section		Time Required
UENO-FUKUSHIMA	Before	2.08
	After	1.27
UENO-SENDAI	Before	2.38
	After	1.53
UENO-MORIOKA	Before	3.56
	After	2.45
UENO-YAMAGATA	Before	3.47
	After	3.15
UENO-AKITA	Before	6.09
	After	4.45
UENO-AOMORI	Before	6.34
	After	5.20

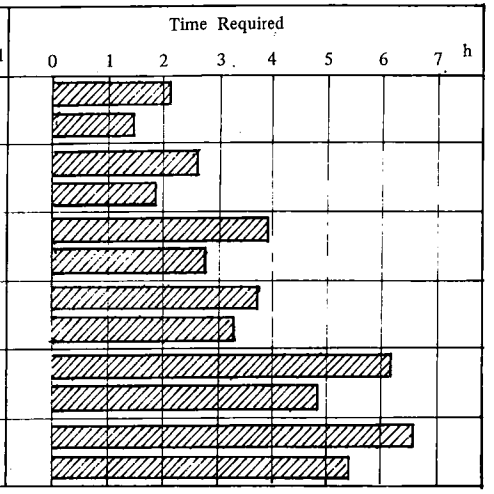

Fig.-4 Time Required from Ueno to the Cities of Tohoku Region Before and After March 1985

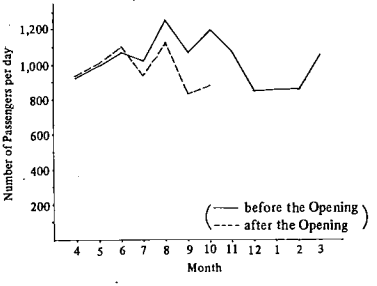

Fig.-5 Transition of the Number of Passengers by Airplane between Tokto and Yamagata before and after the Opening of Omiya-Ueno Section

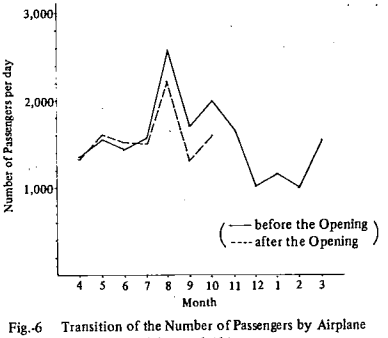

Fig.-6 Transition of the Number of Passengers by Airplane between Tokyo and Akita before and after the Opening of Omiya-Ueno Section

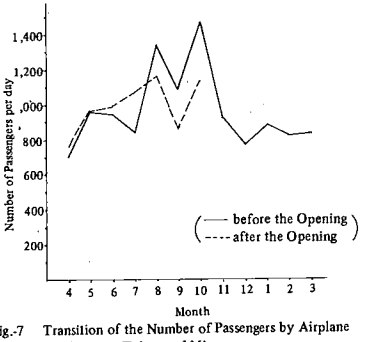

Fig.-7 Transition of the Number of Passengers by Airplane between Tokyo and Misawa before and after the Opening of Omiya-Ueno Section

Table-2 Number of Passengers per Day between Tokyo and Tohoku Region (up and down)

	Shinkansen	Conventional line	Total
Before the Opening of Omiya–Ueno (A)	41,679	10,860	52,539
After the Opening of Omiya–Ueno (B)	54,262	5,531	59,793
B/AX100	130	51	114

In addition to the shift from airplane to the Shinkansen, we can see that the opening of the Shinkansen service produced a lot of new traffic demand.

According to a study of the Sendai Bureau of International Trade and Industry, the number of travellers carried by railways from other regions into the Tohoku region is estimated to be 6.45 million in 1985.

This is an increase of 1.87 million, compared with 1981, the year before the opening of the Shinkansen. Of this increase, the contribution of the opening of the line to the new Ueno station is 0.86 million.

V. Speed-up to 260 km/h

JNR started the speed-up test for 260 km/h train operation since October 1984. Some refinements are contemplated in the brake and bogie, but the greatest problem is how to reduce the train noise. As a solution, further reduction of the number of pantographs and fitting to pantograph shields to reduce air drag are being stuided.

JNR thus intends to accomplish 260 km/h train operation in the near future.

VI. The impact on the regional economy

The operation of the Tohoku Shinkansen have made several impacts on the economy of Tohoku region. The opening of the new Ueno station, which enabled through operation of the Tohoku Shinkansen, has atracted increasing numbers of passengers from other regions, and thus brought in profits to the Tohoku region through the money they spend.

Furthermore, the operation of the Shinkansen has increased the opportunities for information and cultural exhanges as well as travel.

The results of the assessment of these effects by the Sendai Bureau of International Trade and Industry, as calculated from inter-industry relation table, are as follows;

The increase in the number of passengers has brought a direct increase in consumer expenditures such as transport, hotel and food and drink expenses, and this direct effect is estimated to be about 64.2 billion yen. This increase has induced an increase of industrial output in several industries, leading to an amount of production of about 123.88. billion yen in total. The resulting value added in the Tohoku region by this production amounted to 63.97 billion yen, and the additional number of employed was estimaed to be 24,055.

Fig.-8 is an analytical flow chart of the economic effects. Table 3 shows the results and Table 4 shows the detailed results in terms of classification of industries.

The noteworthy result is the effect of the opening of the new Ueno station. As you can see in Table-3, the amount of the induced production value, the value added and the increase in number employed has almost doubled after the opening of the direct service to Ueno.

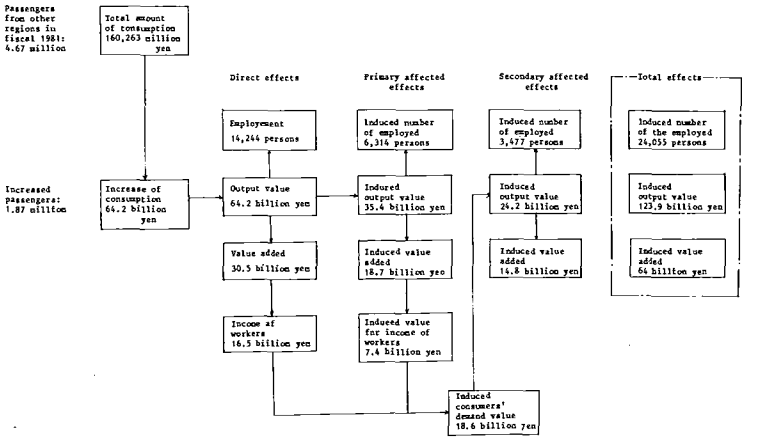

Fig.-8 Analytical flow chart of economic effects

Table-3 Economic effects induced by the increase of passengers from other regions

	Total effects	Direct effect	First stage indirect effect	Second stage indirect effect	Effect of starting service between Omiya and Morioka	Effect of starting service between Omiya and Ueno
Induced production value (million yen)	123,876	64,203	35,456	24,217	66,978	56,898
Induced value added (million yen)	63,968	30,530	18,652	14,786	31,587	29,381
Induced number of employed (persons)	24,055	14,264	6,314	3,477	13,006	11,049

Table-4 Economic effects of the increase of passengers in terms of classification of industries

Induced production value 123,876 million yen		Induced value added 63,968 million yen		Induced number of employed 24,055	
(five highest ranked industries)					
Service industries	62,214	Service industries	31,263	Service industries	13,653
Commerce	20,057	Commerce	11,536	Commerce	4,682
Financial, insurance real estate	10,553	Financial insurance, real estate	8,841	Agriculture, fisheries	3,400
Food	7,654	Agriculture, fisheries	4,437	Transportation	762
Transportation	3,032	Food	1,998	Food	466

The opening of the Tohoku Shinkansen was also accompanied by other effects that are difficult to measure. There has been more new investment, increased electric power demands because of the increase in hotel and building construction, and redevelopment of suburban cities.

Here is a brief summary of one of these effects.

In the first half of 1985, a total of 60 new industrial facilities were built in the Tohoku region. This was the highest since 1975. Out of the 60 facilities, 45 were promoted by capital from other regions.

VII. Future issues of the Tohoku Shinkansen

The opening of the Tohoku Shinkansen has been contributing greatly to the economic development of the Tohoku region, which had been relatively underdeveloped for a long time.

But also the east side of the Tohoku region, where the Shinkansen runs, enjoys the benifis of the Shinkansen much more than the rest of the region, and the people living in the rest of the region claim that the Tohoku Shinkansen has devided Tohoku into two parts, east side and west side.

To meet those claims it is necessary to expand the Shinkansen Network further.

Shinkansen construction between Morioka and Aomori will be started in the near future.

However, the tight constraints on the national budget will not permit further Shinkansen constructions.

Moreover, as the conventional lines of the JNR are narrow gauge and the Shinkansen cars are designed for standard gauge, it is impossible to operate the Shinkansen cars directly on the conventional lines, as the TGV runs in France.

Hence, I proposed a dual-gauge track design with four parallel rails[1]. which would enable us to extend Shinkansen services over the conventional lines as a measure to overcome the above problem.

For extention of Shinkansen serices over conventional lines, we could also consider the TALGO wheel-spacing change method utilized at the border between France and Spain. But in this case a delay of about 15 minutes is needed at the junction station and there is less possibility for speed up on the conventional lines. Another method worth considering is adoption of a dual-gauge track structure with three parallel rails. But in this case the difference in track centers for the Shinkansen trains and for the conventional trains causes several problems. For example, as the construction standards for the Shinkansen lines are more spacious than those for the conventional lines, there are few problems with operation of conventional trains on Shinkansen track, but if we operate Shinkasen trains on a modified conventional dual-gauge track with three parallel rails, it will be necessary to expand the cross-sections of tunnels and to modify station facilities. Moreover the catenary position will cause additional problems when high speed operation is planned.

Those are the main reasons why I recommended the adoption of dual-gauge structure with four parallel rails, which has only one track center for both Shinkansen and conventional trains. In this case the design of mixed gauge turnouts is the bottleneck, but it is possible to avoid the difficulty by designing the turnouts as part of the design of the track layout of a station.

Though there remain some problems to be solved in relation to speed-up on the conventional lines, this method will be considered to be one of the realistic methods for achieving Shinkansen service extensions with low cost, and further suvery is now under way by the Ministry of Transport of Japan and JNR.

reference 1) "Technical research on the construction of dual-gauge track employing four parallel rails" to the Journal of the Japan Society of Civil Engineering issue of Sept. 1985.

(the author was formerly a member of board of Japanese National Railways)