THE RECENT PROGRESS OF HOKURIKU SHINKANSEN AND ITS WAY TO COMPLETION

- A REEVALUATION OF THE JAPANESE CONSTRUCTING HIGH-SPEED RAIL -

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Abstract: The Tokaido Shinkansen links Tokyo with Osaka via the south coast of Honshu, and another line, the Hokuriku Shinkansen, via the north shore was planed in ‘70s. It didn’t go ahead for a long time, while a section from Tokyo to Nagano got open in 1997. The westward extension to Tsuruga was decided up, but the rest to Osaka is not fixed. In this paper, we analyzed construction cost, fare, traveling time, and passengers flow about each route of the three ideas as the final section. And then, we found out that there is some possibility for Maibara Route to be a good choice at the point of users’ benefit or convenience. While there may be another problem of the capacity of Tokaido Shinkansen, and we examined about it.

Key Words: Hokuriku Shinkansen, high-speed rail, reevaluation, routing

1. INTRODUCTION

The earliest high-speed rail, Japan’s Shinkansen, started its operation in 1964. It is 515 km in length, and had linked Tokyo with Osaka in 3 hours 10 minutes. Its success had a strong impact on SNCF, which began to develop a high-speed rail system. And then, France's TGV began to run in 1981, which linked Paris with Lyon in two and a half hours. After that, some European countries have followed. Italy's Direttissima got partly open in 1988, German's ICE in 1991, Spain's AVE in 1992, and Eurostar through Channel Tunnel between France and England in 1994. On the other hand, the first high-speed train in North America, Acela Express, started its service in December 2000, introducing TGV technology. Moreover, some Asian countries, South Korea, China and Taiwan have subsequently been following. Now bullet trains are operated in almost every developed country.

After the success of Tokaido Shinkansen, three high-speed rail projects were started in Japan, and got open until the mid of ‘80s. And furthermore, five more high-speed rail projects are planed. Hokuriku Shinkansen is one of such second-phase Shinkansen projects. But it was not going well and has not been completed yet.

The aim of this paper is suggesting the argument about a completion of Project Hokuriku Shinkansen through a comparative study on routing issue of the final section, whose layout has not exactly decided yet. First, we explain about the features of Shinkasen itself. Second, we also explain about the Hokuriku Shinkansen project. Third, we compare about 3 routes of the extension plans. Finally, we conclude this study with arrangement of some tasks to be solved before decision of the completion.

2. A BRIEF HISTORY OF SHINKANSEN

Project Tokaido Shinkansen was started in 1959 and bullet trains began to run just before the 1964 Tokyo Olympics. As Japan was swiftly growing in economy at that time, Tokaido Line, which was fully open in 1889 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 trains (on the section between Tokyo and Yokohama) or 541 trains (on the section between Kyoto and Osaka) per day. There was 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 since 1959 and got open 5 years later. Then some extension projects were started and a high-speed rail network of 2,050 km (Figure 1) will have been constructed up to the end of 2002.

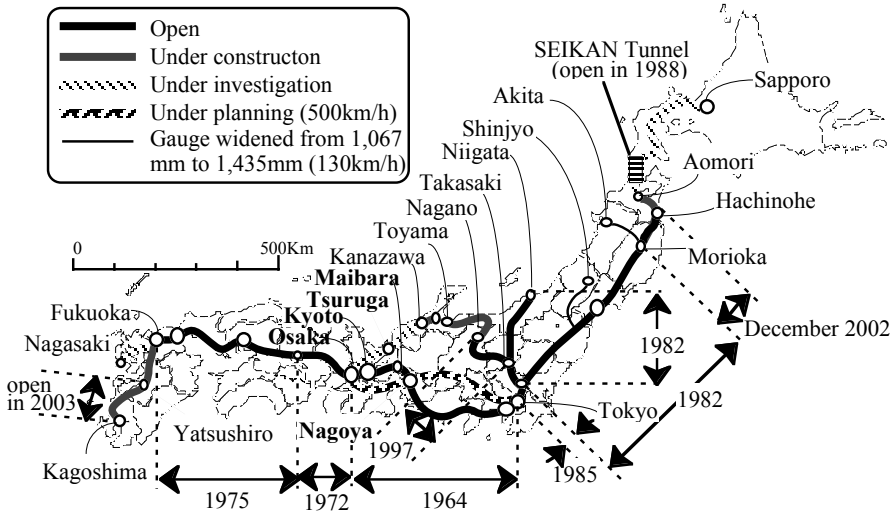


Figure 1. Shinkansen Network in Japan (2002)

Japanese National Railways (JNR) held Shinkansen lines until 1987. 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, whose money was supplied from the Postal Savings System, the Postal Life Insurance, the Welfare Pension, and the National Pension. The interest was set to high, because it was believed that the economic growth would sustain for a long time. In other words, Japanese government expected to collect money not via tax but via Shinkansen fare. The business was going well, but the interest was too high to pay back. JNR's debt had begun to grow. The reason is as followings; the government revenue via tax was automatically reduced when economy was not so brisk, but 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 was the Government. The unbelievable huge debt was separated from the new companies, and it was decided that public should provide high-speed rail tracks and the companies should operate bullet trains. The extension projects were restarted in 1989, and Hokuriku Shinkansen (from Tokyo to Nagano) got open under this scheme just before the 1998 Nagano Winter Olympics. Now, lines of over 500 km are under construction, lines of over 700 km are under investigation, and ultra-high-speed rail powered by linear-motor that links Tokyo with Osaka in almost 1 hour is at a planning stage.

3. BENEFITS OF HIGH-SPEED RAIL

3.1 Good Profits

The first stage of Shinkansen project had got bogged down because they were built with too high rate of interest. But if a high-speed rail is provided on the equal term as other public undertakings without loans, it can make a good profit every year as Figure 2.

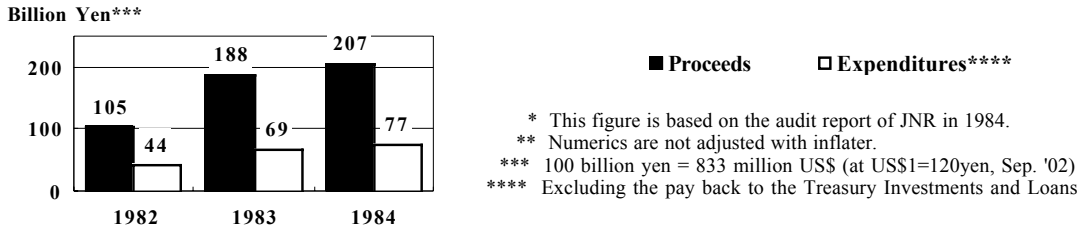


Figure 2. Annual Proceeds and Expenditures of the Tohoku and the Joetsu Shinkansens*,**

3.2 Moderate Investment

Figure 3 is a comparison chart of annual G.R.P. (Gross Regional Products) with building cost of a new Shinkansen lines under construction or under investigation, those are 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.

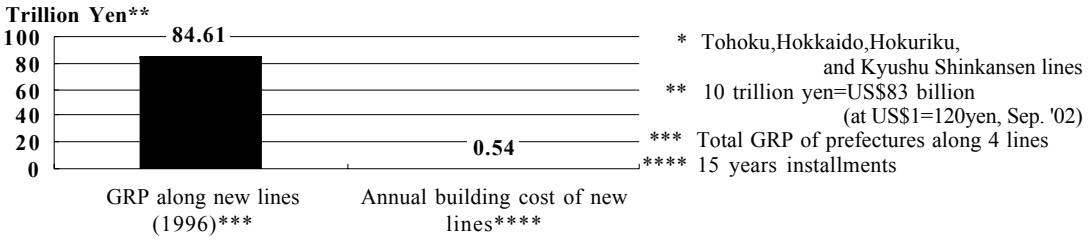


Figure 3. Comparison of GRP with Building Cost of New Shinkansen Lines*

3.3 Ecological Transportation

Figure 4 is a comparison graph among several transportations about discharge amount of CO_2 per 1 km and per 1 person. According to this figure, high-speed rail is one of the best transportations for environment, but private car or civil aviation is not so good choice.

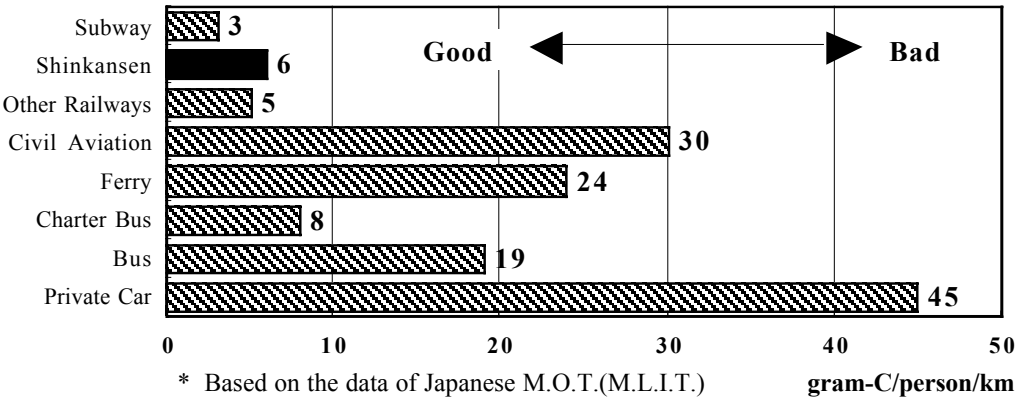


Figure 4. Discharge Amount of Carbon When Carring 1 Person for 1 km*

3.4 Safety Transportation

Figure 5 is a comparison of mortality rate among several transportations. According to this

figure, high-speed rail is very safety. For example, Tokaido Shinkansen carries more than 100 million persons every year, however its mortality rate is almost completely zero. Airplane is also safety enough, but if once an accident is made mortality rate will rise to the same level of private car. Needless to say, private car is the worst transportation.

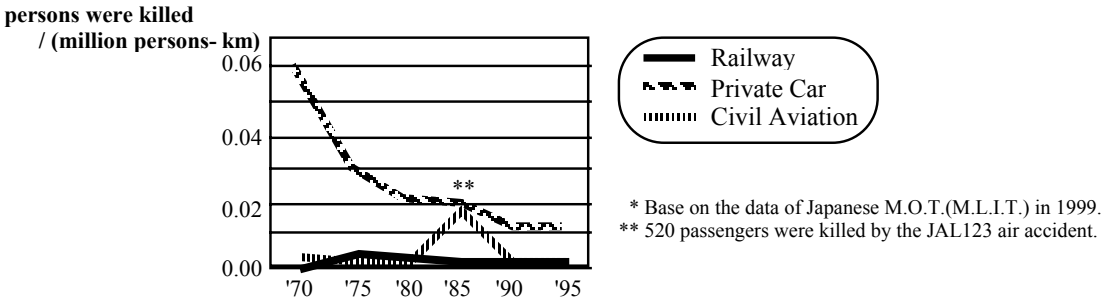


Figure 5. Motarity Rate of Transportations*

3.5 Effective

Introducing a high-speed rail is an effective method for reducing emission of CO_2 or mortality rate of passengers. As Figure 6, a Shinkansen line can carry as many persons-km as each of the busiest subway lines in Tokyo.

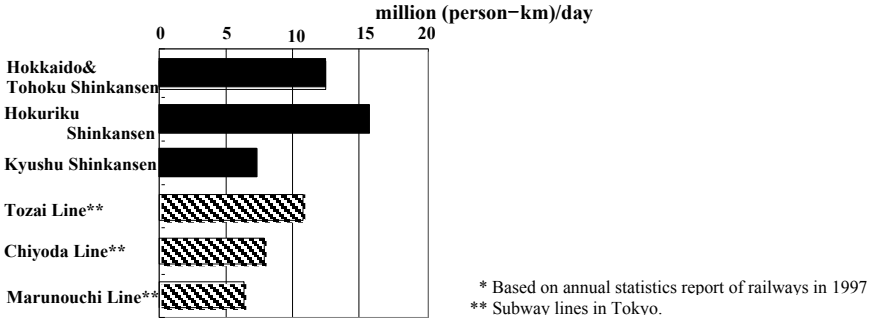


Figure 6. Efficiency of Hi-speed Rail*

3.6 Nations' Choice

Shinkansen is a favorite transportation of Japanese people. At 200 - 500 km transportation range in Figure 7, railway has a strong competitive power against other modes. Even at 400 - 800 km range, it is used as much as airline.

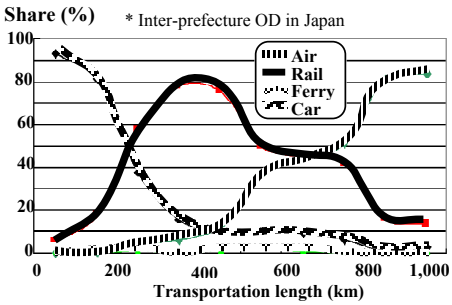


Figure 7. Share Rate of Inter-prefecture Transportation*

3.7 User Benefits

User benefits per person per kilometer of Shinkansen lines 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. If all Shinkansen lines under construction or investigation are open, it can deduce car traffic of 830,000 (cars-km)/day, and save 4.8 persons/year from traffic accidents.

4. REMARKABLE FEATURES OF SHINKANSEN SYSTEM

Only rolling stocks often capture most of public attention when high-speed rails are discussed. But total system is much more important. For example, Acela Express of US Amtrak is operated with excellent trainset powered by TGV technology, 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 a train 3 hours 18 minutes to run 368 km from New York to Boston, of which average speed is only 112 km/h. On the other hand Japan's fastest Shinkansen train named "Nozomi" can runs from Osaka to Fukuoka in 2 hours 17 minutes. Its average speed reaches up to 242 km/h. Why it can run faster than Acela Express? The followings are peculiarities of Japan's Shinkansen system. Other high-speed rail systems in Europe may have some similar features like Shinkansen.

4.1 Separated Track

Shinkansen tracks are separated from any other slow rails. There are two reasons. One is the difference of track gauges. Shinkansen trains are operated on tracks with 1,435mm gauge, but other existing trains are operated on 1,067mm gauge. Another is speed. Shinkansen runs at the twice or thrice speed of slow rails. If Shinkansen trains and snail trains are operated on the same track, they cannot carry passengers or freight effectively.

4.2 No Crossing Road

If a driver of bullet train find a car crossing on the track ahead and he breaks the train immediately, it cannot avoid a traffic accident because of its speed. So there are no roads crossing on Shinkansen tracks. All roads across Shinkansen line go through overpass or underpass.

4.3 Long Distance between Stations

As Shinkansen system is designed for only express trains, it has fewer stations than existing rails. Each distance between any adjoining stations is 30-70 km. Thus bullet trains can cruise for longer time without frequent stops.

4.4 Fewer Switch Rails

Because switch rails have gaps at just crossing of rails, trains have to reduce their speed there. So Shinkansen has fewer switch rails on the high-speed track. If switch rail is not avoidable, it is specially designed for high-speed. Needless to say, there isn't any grade crossing of main tracks between stations.

4.5 Gentle Curves & Slopes

To run at over 200 km/h, radiuses of curves are gentler than 4,000 m and rates of slopes are milder than 1%.

4.6 Trainset

Trainsets are designed with distributed traction system. A trainset consists of 16 electric cars with high-powered motors. To run at over 200km/h, it has air suspensions, small current collectors, and streamlined bodies.

4.7 Cab Signal System & ATC

If a driver of high-speed train find a red light ahead, he cannot reduce speed and stop safety short of the light. Everyone can realize a red light of only several hundreds meters ahead with our ordinary vision. But a bullet train at full speed can stop just in a few kilometers. So, all trainsets for Shinkansen have cab signal system with automatic braking system named ATC (Automatic Train Control). Signals are indicated at the train cabin as an allowed speed to run. The train break is operated automatically, if it is running faster than the directed speed. There is no signal light beside the Shinkansen track.

4.8 CTC

Locations of all the trains are informed to only one center and all train routes are controlled there. This system is named CTC (Centralized Traffic Control). When opening of Tokaido Shinkansen this system was handled by personnel, after increasing the number of trains, it is now managed by computer system named COMTRAC.

4.9 TRACK MAINTENANCE

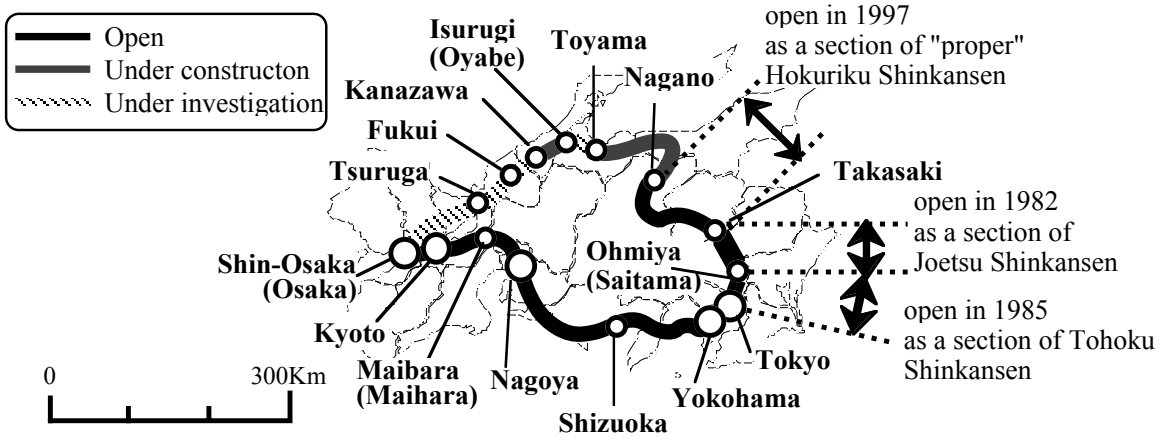
To avoid derailment or uncomfortable ride, Shinkansen tracks are well maintained with machines under rigid standard. Heavy rails are tied up to concrete sleepers or concrete slab.

5. PROJECT HOKURIKU SHINKANSEN

A lot of people lives in areas along the Tokaido Shinkansen from Tokyo to Osaka, the first bullet train project went very well. In 1965 New National Comprehensive Development Plan had started. Project Hokuriku Shinkansen shown in Figure 8 was a part of the plan. The northbound Shinkansen links Tokyo with Osaka via Nagano and Toyama along the coast of the Sea of Japan.

Some sections of the Hokuriku Shinkansen have already got open. A section from Tokyo terminal to Ueno station in Tokyo got open in 1991, from Ueno to Ohmiya in 1985, from Ohmiya to Takasaki in 1982, and from Takasaki to Nagano in 1997. The last section is the only “proper” Hokuriku Shinkansen. The sections from Tokyo terminal to Ohmiya are parts of the Tohoku Shinkansen, and the rest is a part of the Joetsu Shinkansen. Now, two sections from Nagano to Toyama and from Isurugi in Oyabe city to Kanazawa are under constuction. Two sections from Toyama to Isurugi and from Kanazawa to Tsuruga are under investigation. Those routes have been already decided, but nothing of the rest from Tsuruga to Osaka terminal is settled yet.

Policy affairs chiefs within the government and ruling parties might discuss the Hokuriku Shinkansen extension route to the westward of Tsuruga in 1999. They examined about the diversion idea of Kosei line, which is an existing narrow gauge railway, the connection idea to Maibara, which is a station on the Tokaido Shinkansen, and the basic plan of direct route along Wakasa Bay. After the meetings, no definite progress has made for 3 years. But the discussion has restarted in 2002.



The Hokuriku Shinkansen: Tokyo to Osaka via Nagano, Toyama and Fukui (upper line)
The Tokaido Shinkansen: Tokyo to Osaka via Yokohama, Shizuoka and Nagoya (lower line)

Figure 8. Location of Project Hokuriku Shinkansen

6. ROUTING ISSUE OF HOKURIKU SHINKANSEN PROJECT

6.1 Wakasa Route

The first and basic idea of the Hokuriku Shinkansen extension route to the westward of Tsuruga is Wakasa Route. It goes along the shore of Wakasa Bay, via Obama, through Tamba Highland, and reaches to Osaka terminal as shown in Figure 9. We can find this famous route in a figure, which explains Law for the Construction of the National Shinkansen established in 1973. But exactly speaking, the authority law for Shinkansen route established in 1971 simply declares that one of the railheads of the Hokuriku Shinkansen is Tokyo, another is Osaka, and passing places are Nagano and Toyama. If this Wakasa Route is selected as the extension route, the construction fund will be provided by the Japanese government and the local governments of Osaka Prefecture, Kyoto Prefecture and Fukui Prefecture. But each of the former two prefectures are under severe fiscal situations.

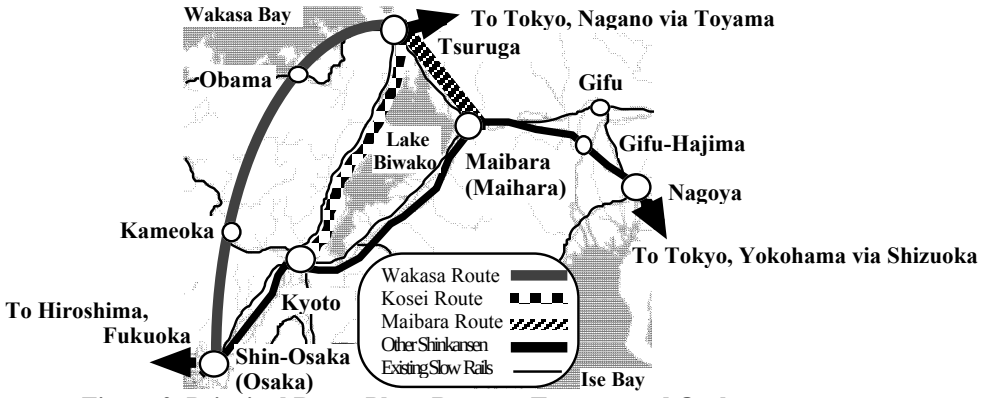


Figure 9. Principal Route Plans Between Tsuruga and Osaka

6.2 Kosei Route

The second idea is Kosei Route. It leads Kyoto by way of the west coast of Lake Biwako and gets to Osaka. Kosei Line got open in 1974, is an existing railway with narrow gauge of 1,067mm, has raised track with no crosses, and have gentler curves. Thus trains on this line

can run faster than on the other slow rails. In recent years, Gauge Changeable Train has got under development, which can cruise on both Shinkansen track with standard gauge of 1,435mm and existing track for slow trains with narrower gauge. If it get ready to run on the Hokuriku Shinkansen and Kosei Line, new track from Tsuruga to Osaka is not necessary.

6.3 Maibara Route

The third idea is Maibara Route. It goes through new track from Tsuruga to Maibara designed for bullet trains, and slides into the Tokaido Shinkansen, and reaches at Osaka terminal. The section from Tsuruga to Maibara is a part of the Hokuriku-Chukyo Shinkansen from Tsuruga to Nagoya, which is one of the third stage Shinkansen projects. We can see this idea on a map in New National Comprehensive Development Plan.

7. PRESENT STATE OF TRAFFIC FOR HOKURIKU AREA

7.1 Flows of Train Passengers

We analyzed the census data of passenger flow on national trunk lines in 1995 and drew a figure about flows of train passengers for Hokuriku Area through Tsuruga as Figure 10. The total number of passengers from Osaka Area and stations beyond is 6,500 and its share is almost half of whole passengers through Tsuruga. If adding passengers from Kyoto and its environs to this, two third passengers are using through train via Kosei-line. The number of passengers from Nagoya or Gifu Area and stations beyond is total almost one third. Passengers using through train and connecting trains go halves.

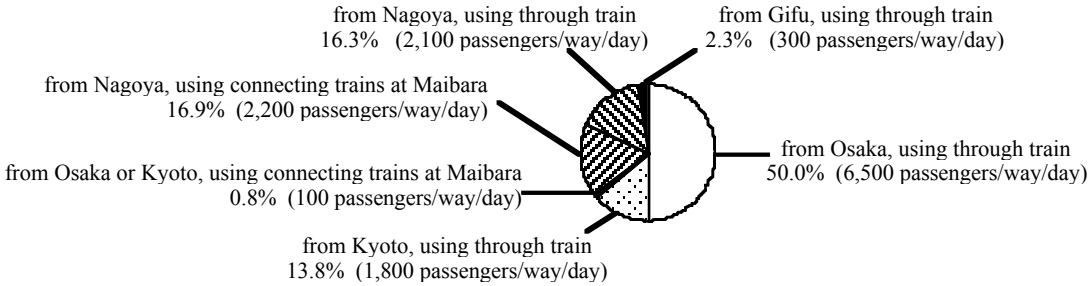


Figure 10. Percentage of Passengers for Hokuriku Area at the Point of Departure Place

7.2 Transportation Capacity

We counted up the seat capacities of express trains that run from Osaka or Nagoya to Hokuriku Area through Tsuruga and indicate them on Figure 11. The ratio of trains from Osaka to trains from Nagoya is almost three to two, while each train has different capacities and the ratio of seat amount provided is two to one. It is almost the same as the ratio of passengers.

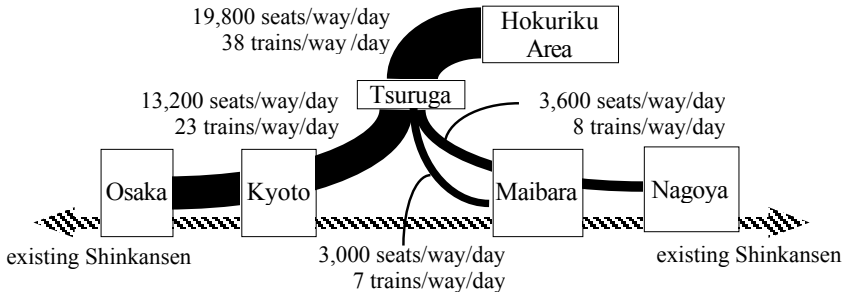


Figure 11. Amount of Provided Seats (1995)

8. CARDINAL FEATURES OF THE 3 ROUTES

8.1 Settings for Comparison

The settings for comparison in this chapter are as followings. Wakasa Route is constructed with the full Shinkansen standard. Kosei Route is using Gauge Changeable Train. It slips into existing rail of Kosei Line at Tsuruga. It runs through the Hokuriku Shinkansen, Hokuriku Line, Kosei Line and Tokaido Line before arriving at Osaka terminal. We assume that express trains can cruise on Kosei Line at the top speed of 160 km/h because of raised track. Maibara Route between Tsuruga and Maibara is constructed with the full Shinkansen standard where trains can run at the top speed of 260 km/h. Trains of this route slip into the Tokaido Shinkansen at Maibara junction. Unit cost of full track is set to 7.1 billion yen/km that is the same as the unit cost between Takasaki and Nagano. Lengths of new tracks are measured on a map.

We wrote data of distance, time required and fare from Tsuruga to Shi-Osaka, Kyoto or Nagoya station into Table 1. Time required on the full Shinkansen standard line is estimated with the schedule speed of 206km/h that is the same as Nozomi super express on the Tokaido Shinkansen, which runs 515km between Tokyo and Shin-Osaka in 150 minutes, and whose top speed is 270km/h. Duration on Kosei Line is calculated with the schedule speed of 131 km/h in proportion as existing express train runs 94.1km in 53minutes with its top speed of 130km/h and schedule speed of 107km/h. If passengers have to change trains, minimum transfer time is set to 7 minutes. Fare of full Shinkansen track is set to the same rate as the Tokaido Shinkansen, and one of existing track like Kosei Line is set to the class A fare system of JR express train. As a result of analysis with the conditions above, cardinal features of the three routes are also shown on Table 1.

8.2 Features of Wakasa Route

Construction cost of this route is more than 900 billion yen, while this route can reduce much time from Tsuruga to Shin-Osaka and stations beyond. Standard size trainset can run on this route. On the other hand, passengers from Kyoto through Tsuruga can reduce only a few minutes, and furthermore they have to pay much money. Existing express train between Nagoya and Hokuriku Area may still remain after opening of the Hokuriku Shinkansen because passengers from Nagoya cannot use Wakasa Route to reduce time and fare. Thus this route plan has great merit to half of passengers for Hokuriku, while it has little merit to another.

8.3 Features of Kosei Route

Construction cost is basically not required because of using existing track. Reinforced train track for running at 160km/h and equipment to change gauge of bogies will be needed, but it may be much cheaper than new train track. However, passengers from Osaka or Kyoto can reduce only 10 minutes. In addition, passengers from Nagoya cannot reduce any. Existing express train between Nagoya and Hokuriku Area will still remain after opening of the Hokuriku Shinkansen, too. It is necessary to make a train schedule of Kosei Line, where higher-speed express and slower trains for freight or commuter runs on the same track. Trains must be designed for Kosei Route; bodies with smaller section, equipments for dual voltage of 25kV AC and 1.5 kV DC.

8.4 Features of Maibara Route

The length of this route is short and the construction cost is one third of Wakasa Route. Reduction amount of traveling time for the passengers from Osaka is almost the mid of Wakasa Route and Kosei Route. This route can reduce more time than Kosei Route, and only this plan can reduce the traveling time from Nagoya. It is not necessary to adjust train schedule with slower trains on Kosei Line. Full size train can run on the track of this route. As above, Maibara Route can reduce traveling time of all passengers through Tsuruga, and furthermore, construction cost is relatively small. But there is a troublesome problem of train schedule for the Tokaido Shinkansen where too much trains are running because trains of the Hokuriku Shinkansen have to connect to or slip into the Tokaido Shinkansen at Maibara.

Table 1. Features of the 3 Routes from Tsuruga to Osaka

Route		Existing Rail	Wakasa Route	Kosei Route	Maibara Route
Track standard		Narrow gauge	The full Shinkansen standard	Raised track with narrow gauge	The full Shinkansen standard
Train Top speed		130 km/h	260 km/h	160 km/h	260 km/h
Length of New Track		---	128 km	(94 km)	46 km
Construction Cost		---	922.9 billion yen	---	330.9 billion yen
Influences on the Other Rails		---	---	Commuter / Freight trains on existing lines	Tokaido Shinkansen
Trainset		---	Standard	Fewer capacity	Standard
Other Problem		---	Track layout of Shin-Osaka terminal	Gauge changeable bogie is under development	Track layout of Maibara junction
Tsuruga to Shin-Osaka	**Via**	(Kyoto)	---	(Kyoto)	Maibara
	Distance	133 km	128 km	133 km	153 km
	Time	75 min.	38min. (-37min.)	65min. (-10min.)	52min. (-23min.)
	Fare	4,500yen	5,130yen (+630yen)	4,500yen (+0yen)	5,440yen (+940yen)
Tsuruga to Kyoto	**Via**	---	Kameoka	---	Maibara
	Distance	94 km	108 km	94 km	114 km
	Time	53min.	50min. (-3 min.)	43min. (-10min.)	34min. (-19min.)
	Fare	3,280yen	4,700yen (+1,420yen)	3,280yen (+0yen)	4,810yen (+1,530yen)
Tsuruga to Nagoya	**Via**	(Maibara)	Kameoka, Kyoto	Kyoto	Maibara
	Distance	228 km	243 km	228 km	112 km
	Time	70min.	93min. (+23min.)	86min. (+16min.)	39min. (-31min.)
	Fare	5,020yen	8,900yen (+3,880yen)	7,640yen (+2,620yen)	5,130yen (+110yen)

8.5 Comparison among the three routes

If existing express train between Nagoya and Hokuriku Area continue running after opening of the Hokuriku Shinkansen at the case of Wakasa Route or Kosei Route, the estimated total amounts of traveling time are plotted as triangle dots in Figure 12. These dots are plotted using data of Figure 10, Table 1 and some additional research about present situations about passengers using connecting trains at Maibara, whose data are not shown in Table 1. In addition, using fare data of Table 1 and value data of 69yen/min.(1995) shown in a research of Nomura, Aoyama, Nakagawa, Matsunaka and Shirayanagi (2001), we also estimated the total passenger benefits as white round dots in Figure 12.

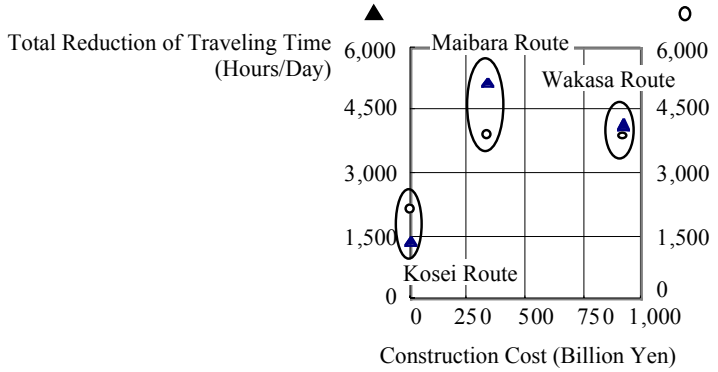
According to the Figure 12, Wakasa Route is the most expensive plan of the three. The amount of total reduction of traveling time is smaller than the cheaper plan of Maibara Route. Total passenger benefit is as large as Maibara Route, and passengers from only Osaka can receive it.

Kosei Route is the cheapest plan of the three. The construction cost except trainsets and strengthening of tracks is almost zero, but the results are also the smallest among these three. Total reduction of traveling time is one fourth of Maibara Route, and total passenger benefit is almost half of the other plans.

Maibara Route may be the best choice among these ideas as a result of analysis in this chapter. The cost is not so expensive, and the total reduction of passengers traveling time is the

maximum of these three, and the total passengers benefit is a little bit larger than Wakasa Route.

As above, Wakasa Route is an expensive investment with almost the same return as Maibara Route. Kosei Route is a cheap investment with low return. And Maibara Route is a moderate investment with enough high return.



Total Passenger Benefit at 1 min.=69yen
(Million Yen/Year)

(data)	Total Reduction of Traveling Time	Total Passenger Benefit (69 yen/min.)
Wakasa Route	4158.3 hours/day	3878.7 million yen/year
Kosei Route	1398.3 hours/day	2157.6 million yen/year
Maibara Route	5155.0 hours/day	3898.1 million yen/year

Figure 12. Construction Cost and User Benefits (1995)

9. PRESENT STATE OF TRAFFIC ON TOKAIDO SHINKANSEN

9.1 Important Issue of Maibara Route

If Maibara Route is selected as the Hokuriku Shinkansen extension route to the westward of Tsuruga, an important issue will be raised. Bullet trains from Hokuriku Area via the new track between Tsuruga and Maibara will run through Maibara and have to slip into the Tokaido Shinkansen. But it is often said that the earliest Shinkansen is too busy to make room for additional trains. In this and the following chapters, we analyze about the Tokaido Shinkansen and make clear whether it has truly no room.

9.2 Traffic on the Tokaido Shinkansen (1995)

We analyzed the census data of passenger flow on national trunk lines in 1995 and wrote a table about traffic on Tokaido Shinkansen as Table 2. Provided amount of seats and passenger load factor of each section on the Tokaido Shinkansen are also indicated in this table. The maximum load factor is observed at the west section (westbound) of Shin-Yokohama Station, and its number reaches up to 75.6%. We also estimated the load factor as 66.1% at the west section (westbound) of Nagoya Station, and 63.8% at the west section (westbound) of Maibara Station. When Maibara Route is open, additional passengers from Hokuriku Area pass these two sections.

Table 2. Traffic on the Tokaido Shinkansen

Section	Direction	Passengers	Seats	Passenger Load Factor
At the West of	**Westbound**	123,900	163,800	75.6 %
Shin-Yokohama Station	**Eastbound**	116,600	165,100	70.6 %
At the East of	**Westbound**	115,700	159,900	72.4 %
Nagoya Station	**Eastbound**	109,800	154,700	71.0 %
At the West of	**Westbound**	102,000	154,700	66.1 %
Nagoya Station	**Eastbound**	93,100	149,500	62.8 %
At the West of	**Westbound**	98,700	154,700	63.8 %
Maibara Station	**Eastbound**	91,400	149,500	61.1 %

9.3 Track Capacity of the Tokaido Shinkansen

Track capacity of the Tokaido Shinkansen is fifteen trains/way/hour, because of track layout in Tokyo terminal. Four deadhead trains are operated between Tokyo terminal and train shed located between Tokyo and Yokohama. So eleven trains per hour can run between Tokyo and Shin-Osaka terminals. In 1992, track circuit was revised and seventeen trains can depart from Tokyo terminal every 3 minutes 30 seconds in one hour. And 18 trains can depart from Shin-Osaka terminal every 3 minutes 15 seconds in one hour. After departure, if each stopping stations has more than two tracks with platforms per way and if the following train doesn't pass the former train, every two trains can keep this interval of 3 minutes 30 seconds on the high-speed track.

10. EFFECTS OF MAIBARA ROUTE TO THE TOKAIDO SHINKANSEN

10.1 Potential Ability of Present Tokaido Shinkansen

Present diagram of the Tokaido Shinkansen is drawn on the assumption of the capacity of fifteen train/way/hour, but powered up capacity is eighteen trains/way/hour near Shin-Osaka. So three additional trains may be able to run between Hokuriku and Osaka or Nagoya. So, we made a trial train diagram of the Tokaido Shinkansen (eastbound) between Shin-Osaka and Nagoya based on present train schedule as Figure 13. The vertical axis indicates distance from Tokyo terminal and the horizontal axis indicates the hour and minute (every hour). In Figure 13, trains on business are displayed as thin line. In the early morning or late evening, diagram pattern is a little bit different from this figure, and in daytime, some thin lines get out of service in proportion to passenger amount.

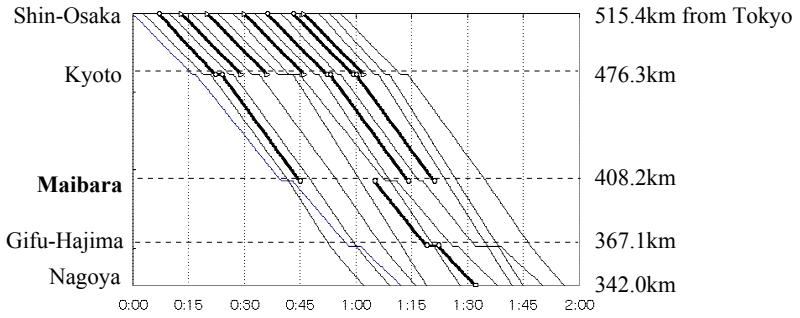


Figure 13. Potential Ability of the Tokaido Shinkansen Between Shin-Osaka and Nagoya
Trial Diagram for Additional Trains Based on Present Diagram (revised in Oct. 2001)

According to this figure, we can find out seven long intervals near Shin-Osaka. Considering trains can start every 3 minutes 15 seconds, we can draw seven additional schedules as thick lines. Some of these lines have been already used for deadhead trains from Shin-Osaka to the train shed located between Shin-Osaka and Kyoto. Three trains of the seven can be extended to Maibara without any influences to the existing trains. In addition, we can also draw one more line from Maibara to Nagoya, which departs at every hour on the five. These three trains between Shin-Osaka and Maibara and one train between Maibara and Nagoya can be operated as through train to/from the Hokuriku Shinkansen.

10.2 Cooperative Ideas for the Tokaido Shinkansen with the Hokuriku Shinkansen

If additional drawing to the present diagram is prohibited because the room we found is to be used for recovery of unusual train schedule, we can discuss about another three cooperative ideas as followings.

The first idea is Separation Plan. In this plan, operations of the Hokuriku Shinkansen and the Tokaido Shinkansen are separated each other, and passengers between Hokuriku Area and stations on the Tokaido Shinkansen have to change trains at Maibara. There may be few

problems on the diagrams of the both. This plan can be success when the Tokaido Shinkansen has enough capacity for additional passengers.

The second idea is Through Train Plan. In this plan, bullet trains from the Hokuriku Shinkansen slip into the Tokaido Shinkansen and get to Osaka or Nagoya without changing trains. But when additional drawing to the present diagram of the Tokaido Shinkansen is prohibited, train schedules for the Tokaido Shinkansen have to be changed over to trains for the Hokuriku Shinkansen. Thus if passenger load factor of the Tokaido Shinkansen raise up to so much higher than now, this plan cannot be adopted.

10.3 Separation Plan

If all the passengers who departs from Hokuriku transfer to the Tokaido Shinkansen, passengers on existing express train "Raicho" or "Thunderbird" are added to the traffic of the Tokaido Shinkansen between Maibara and Osaka, and also passengers on "Shirasagi" express are added to between Maibara and Nagoya. We estimated the traffic and the passenger load factor on the Tokaido Shinkansen of each section as shown in Table 3 when this Separation Plan is selected.

According to Table 3, the traffic on the west section of Nagoya Station (both eastbound and westbound) will increase by 2,400 or 2,700, while the load factor will raise only 1.3 or 1.4 points because the Tokaido Shinkansen has large carrying capacity. The traffic on the west of Maibara will also increase by 6,900 or 8,300, and the load factor will raise almost 5 points. But the absolute load factor is smaller than the present load factor on the east of Nagoya. Thus we can conclude about this idea as that the influences of the Hokuriku Shinkansen is not so significant under the situation of present Tokaido Shinkansen. This plan is not so convenient for passengers, but this can be carried to execution.

Table 3. Estimated Traffic on the Tokaido Shinkansen (Case of Changing Trains at Maibara)

Section	Direction	Passengers	Seats	Passenger Load Factor
At the West of Shin-Yokohama Station	**Westbound**	123,900 (+0)	163,800	**75.6 % (+0.0pt)**
	Eastbound	116,600 (+0)	165,100	70.6 % (+0.0pt)
At the East of Nagoya Station	**Westbound**	115,700 (+0)	159,900	72.4 % (+0.0pt)
	Eastbound	109,800 (+0)	154,700	71.0 % (+0.0pt)
At the West of Nagoya Station	**Westbound**	104,400 (+2,400)	154,700	67.5 % (+1.4pt)
	Eastbound	95,800 (+2,700)	149,500	64.1 % (+1.3pt)
At the West of Maibara Station	**Westbound**	105,600 (+6,900)	154,700	68.3 % (+4.5pt)
	Eastbound	99,700 (+8,300)	149,500	66.7 % (+5.6pt)

10.4 Through Train Plan

After opening of the Hokuriku Shinkansen, twenty-three bullet trains from Shin-Osaka via Maibara and fifteen bullet trains from Tokyo via Nagoya and Maibara will be operated on each way to Hokuriku in a day not to reduce frequency. When these thirty-eight trains are operated instead of existing trains on the Tokaido Shinkansen, the one bullet train with 885 seats on the Hokuriku Shinkansen reduces 415 seats on the Tokaido Shinkansen because each trainset of existing Tokaido Shinkansen has almost 1,300 seats.

We estimated the passenger load factor at each section under the conditions as above, and show them on the Table 4. In this case, the load factors raise up on whole the Tokaido Shinkansen, but only one section goes over the present maximum number of 75.6% on the west of Shin-Yokohama. If there is no increasing of track capacity on the Tokaido Shinkansen, the Hokuriku Shinkansen with this plan impose some burden on the Tokaido Shinkansen, but it isn't so severe on a broad survey..

Table 4. Estimated Traffic on the Tokaido Shinkansen

(Case of Hokusiku Shinkansen Trains Slipping into the Tokaido Shinkansen)

Section	Direction	Passengers	Seats	Passenger Load Factor
At the West of Shin-Yokohama Station	**Westbound**	123,900 (+0)	157,600 (-6,200)	**78.6 % (+3.0pt)**
	Eastbound	116,600 (+0)	158,900 (-6,200)	73.4 % (+2.8pt)
At the East of Nagoya Station	**Westbound**	115,700 (+0)	153,700 (-6,200)	75.3 % (+2.9pt)
	Eastbound	109,800 (+0)	148,500 (-6,200)	73.9 % (+2.9pt)
At the West of Nagoya Station	**Westbound**	104,400 (+2,400)	148,500 (-6,200)	70.3 % (+4.2pt)
	Eastbound	95,800 (+2,700)	143,300 (-6,200)	66.9 % (+4.1pt)
At the West of Maibara Station	**Westbound**	105,600 (+6,900)	145,200 (-9,500)	72.7 % (+8.9pt)
	Eastbound	99,700 (+8,300)	140,000 (-9,500)	71.2 % (+10.1pt)

10.5 Checking Train Capacity of the Hokuriku Shinkansen

If an idea as Figure 13 is selected as a completion method of Project Hokuriku Shinkansen, three trains from Osaka and one train from Nagoya can be operated to Hokuriku every hour, and 60 trains can be operated on each way of the Hokuriku Shinkansen in fifteen hours. The provided seats number of one day reaches more than 53,100, using 12-car-train with 885 seats. It's enough capacity.

If another idea as section 10.2 is selected, any amount of trains can be operated on the Hokuriku Shinkansen.

If the final idea as section 10.3 is selected, thity-eight trains from Osaka or Nagoya will be operated to Hokuriku everyday. The provided seats number of one day reaches more than 36,300, using 12-car-train with 885 seats. It's 170% of exisiting capacity of express trains through Tsuruga.

11. SOME TASKS FOR COMPLETION OF PROJECT HOKURIKU SHINKANSEN

The final section of the Hokuriku Shinkansen is reevaluated as above, while some tasks may still remains as followings.

11.1 Tasks on Wakasa Route

The most important and severe problem is funding. Constructing cost of second-phase Shinkansen is provided by the Japanese Government (2/3 of total) and local governments along the line (1/3 of total). In case of Wakasa Route, Fukui Prefecture, Kyoto Prefecture and Osaka Prefecture are the bearers. Fukui Prefecture may have to pay almost 130 billion yen, Kyoto Prefecture 88 billion yen, and Osaka Prefecture 90 billion yen. But Kyoto Prefectures and Osaka Prefectures are in grave financial trouble. Thus, if this route is selected, the project may be frozen again.

Another task is about access from Kyoto or Nagoya. This Route cannot reduce traveling time nor fare, therefore express train from these areas to Hokuriku cannot be abolished. It may be difficult to put passengers together, frequency of express train for Hokuriku may be small and inconvenient. In addition, one of the aims of this route is a development of Wakasa Area, but it isn't so convenient to access from Kyoto or Nagoya to Wakasa.

11.2 Tasks on Kosei Route

The most important problem is low return. If curves and slopes on Kosei Line are improved to gentler and bullet trains can run at almost 200km/h, this plan may be a good choice. But train schedule with commuter trains or freight trains will still be a difficult problem after track strengthening.

The second task is trainset. If Gauge Changeable Train got ready to run, this plan may become a convenient plan for users. Not only bullet train from Kyoto or Osaka to Hokuriku, but also express trains from Nagoya to Hokuriku via Gifu can be operated with Guage Changeable Train. That is, the usefulness of this plan depends on the new designed trainset. In addition, a Gauge Changeable train is designed for running on existing slow rails with narrow clearance, and it can carry fewer passengers than a full size train.

One more task is about development of Wakasa Area. Unfortunately, Kosei Route improves nothing on Wakasa; therefore other transportation project is required to develop Wakasa Area.

11.3 Tasks on Maibara Route

The most important problem is connecting method to the Tokaido Shinkansen. This problem is considered in this paper. Some upgrading projects are prepared on the Tokaido Shinkansen in near future. After taking them, the capacity of the Tokaid Shinkansen will raise up and it may make bullet trains from Hokuriku be easier to run through Maibara. In addition, if Project Chuo Shinkansen completes, the Tokaido Shinkansen have enough room for additional trains. So another solution is promoting of the Chuo Shinkansen.

Second task is funding. Constructing cost of Maibara Route is estimated as 330.9 billion yen; Fukui Prefecture may have to pay almost 21 billion yen and Shiga Prefecture 89 billion yen. But Shiga Prefecture may not to ready to pay for it.

Final task is about development of Wakasa again. Maibara Route also improves nothing on Wakasa.

12. CONCLUSION

We conclude that there is some possibility for Maibara Route as a completion method to be a good choice at the point of users' benefit or convenience, while there may be another problem of the capacity of the Tokaido Shinkansen. We examined some connecting ideas of the Hokuriku Shinkansen and the Tokaido Shinkansen. We found, at least, the simple connection idea without any through train is one of the practicable solutions. And we also found a potential of present Tokaido Shinkansen for bullet trains slipping into.

We will continue researching on influences of upgrading projects on the Tokaido Shinkansen and other tasks explained in the chapter eleven.

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