

## A Study to evaluate Social Benefit from Alternative Routes in the Shinkansen Network for each region

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### Abstract:

Tokaido Shinkansen is not only a High Speed Train, but also a High Density Transportation means. A large number of passengers depend on Tokaido Shinkansen. But there is no alternative to Tokaido Shinkansen in fact.

If Tokaido Shinkansen would stop their service, Japanese society would face serious problems. And there are some probabilities of a long term stop, for example because of disasters like an earthquake, renewal of the infrastructure, etc.

In this study, the social losses from a long term stop of Tokaido Shinkansen are evaluated by a quantitative method. The results indicate that there is high necessary to develop alternative routes for the Tokaido Shinkansen. The social benefits from alternative routes are evaluated, and these are sufficient. And these social losses/benefits are shown for each region.

Based on these evaluations, the effect of alternative routes for the Tokaido Shinkansen is shown.

### Key Words:

Tokaido Shinkansen, Alternative Routes, Evaluation of Social Loss/Benefit

## 1. INTRODUCTION

### 1.1 Current Situation of Shinkansen Network

Tokaido Shinkansen, as the first Shinkansen in Japan, and the first Super High Speed Train in the world too, was opened between Tokyo and Shin-Osaka in 1964.

Today the scheduled time between Tokyo and Shin-Osaka has been reduced to 150 minutes by "Nozomi" train operated at 270km/h (300km/h on San-yo Shinkansen).

San-yo Shinkansen was opened from Shin-Osaka to Okayama in 1972, and was expanded to Hakata in 1975. Tohoku, Jo-etsu, and Hokuriku Shinkansen were developed after San-yo. Trend of passenger volumes of each Shinkansen is shown in Fig.2.

We can define Tokaido Shinkansen as not only a High Speed Train, but also as a means of High Density Transportation. Traffic density of Tokaido Shinkansen has been increased year by year, reached about 200,000 person/(km day). This volume is three times larger than that of San-yo, and similar to commuter lines in metropolitan area.

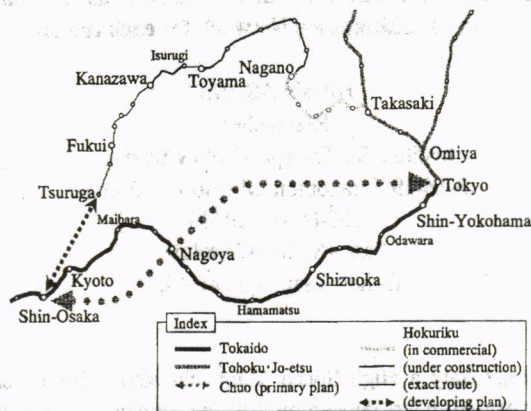


Fig.1. Current Shinkansen network

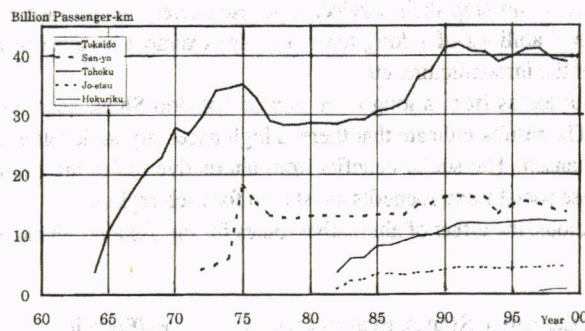


Fig.2. Trend of passenger volumes of each Shinkansen

## 1.2 Problem Consciousness

It is said that the infrastructure of Tokaido Shinkansen must be renewed in future. It can also be assumed that there are some risks of serious disasters like earthquake. In both cases, it is probable that Tokaido Shinkansen must be stopped for long term.

Tokaido Shinkansen has no alternative in fact. The current Shinkansen network is shown at Fig.1, this figure shows central area of Japan.

Hokuriku Shinkansen was opened in 1997 from Takasaki to Nagano. But this development is not completed. Today, Hokuriku Shinkansen is quarter developed. An extension between Nagano and Kanazawa is under construction. The exact route from Kanazawa to Tsuruga is already specified. But the exact route between Tsuruga and Shin-Osaka has not been determined so far.

The route of a new Chuo Shinkansen would stretch from Tokyo, via near Kofu, near Nagoya, near Nara, to Osaka. It is said that Chuo Shinkansen may be the strongest alternative route for Tokaido Shinkansen. But there is not only no concrete scheme, but also no exact route planned for Chuo Shinkansen.

In addition, traffic density of Tokaido Shinkansen is very large, so another transportation means cannot take charge of the full demand (Fig.3).

In fact, many inter-regional passengers depend on Tokaido Shinkansen. Shinkansen's modal share between Kanto and Kansai is over 80%.

If Tokaido Shinkansen would stop its service, many passengers would be left with no alternative, and Japanese society would suffer serious damage. Alternative routes of Tokaido Shinkansen will provide sufficient social benefit, include reduction of social loss from a long term stop of Tokaido Shinkansen. Therefore, it is necessary to develop alternative routes.

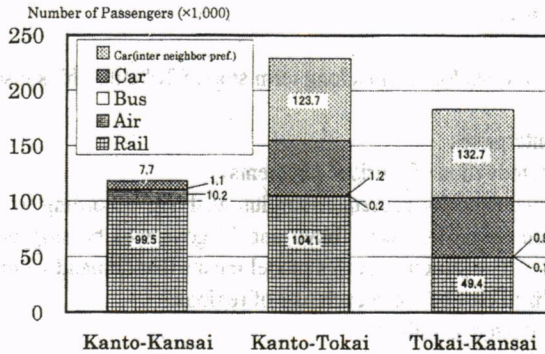


Fig.3 Modal split of inter-regional passengers

## 2. OBJECTIVES

### 2.1 Past Studies

There are many studies to evaluate benefit from Shinkansen developments or its operations. And there are many studies to evaluate an index value of transport network redundancy. But there is no study to point that there is no alternative to Tokaido Shinkansen, to evaluate the social loss if Shinkansen would be stopped, and the effect of alternative Shinkansen routes.

This is the first study to evaluate the social loss if Tokaido Shinkansen would be stopped for long term, the benefit of alternative Shinkansen routes, and to consider better alternative routes by a quantitative method.

### 2.2 Objectives

The objectives of this study are the following:

- To evaluate the social loss from a long term stop of Tokaido Shinkansen
- To evaluate the social benefit from the development of alternative routes for the Tokaido Shinkansen
- To compare social benefit/loss for each region

Each evaluation is performed by a quantitative method.

## 3. SOCIAL LOSS FROM A LONG TERM STOP OF TOKAIDO SHINKANSEN

### 3.1 Assumption

In this study, some assumptions are set as follows:

- Tokaido Shinkansen (between Tokyo to Nagoya) will be stopped for 90 days.



b) That situation could be caused by renewal of infrastructure, disasters, or some accidents.

c) All other social conditions will be constant.

This evaluation is an impact study, to measure the social impact if a long term stop of Tokaido Shinkansen occurred.

### 3.2 Definition of social loss

In this study, I will define social loss from a long term stop of Tokaido Shinkansen as follows:

- a) Loss to passengers
- b) Loss to transport enterprises
- c) Loss to regions (ex. reduction of tourists' payments)

Loss to passengers is evaluated by passenger surplus analysis, according to forecasting on the situation if Tokaido Shinkansen between Tokyo and Nagoya will be stopped. This forecast is made on basis of a model. The structure of this model means that demand volumes are influenced by changing the generalized cost between each pair of regions.

Loss to passengers is evaluated as follows:

$$L_P = \sum_i (C_{0i} - C_{1i})(Q_{0i} + Q_{1i})/2 \quad (1.1)$$

$L_P$  : Loss to passengers

$C_{0i}$  : Generalized cost between each pair of regions in ordinary situation

$C_{1i}$  : Generalized cost between each pair of regions

in a long term stop of Tokaido Shinkansen

$Q_{0i}$  : Passengers volumes between each pair of regions in ordinary situation

$Q_{1i}$  : Passenger volumes between each pair of regions

in a long term stop of Tokaido Shinkansen

$i$  : Index code of each region

This loss can be separated as follows:

$$L_{PB} = \sum_i (C_{0i} - C_{1i})Q_{1i} \quad (1.2)$$

$$L_{PS} = \sum_i (C_{0i} - C_{1i})(Q_{0i} - Q_{1i})/2 \quad (1.3)$$

$L_{PB}$  : Loss from generalized cost increasing (for example travel time expansion)

$L_{PS}$  : Loss from travel stop

Loss to transport enterprises is evaluated as follows:

$$L_T = \sum_{ij} (Q_{0ij} - Q_{1ij})F_{ij} \quad (2)$$

$L_T$  : Loss to transport enterprises

$Q_{0ij}$  : Passengers volumes between each pair of regions in ordinary situation

$Q_{1ij}$  : Passenger volumes between each pair of regions

in a long term stop of Tokaido Shinkansen

$F_{ij}$  : Ticket fare of each transport mode between each pair of regions

$j$  : Index code of each transport mode

Reduction of tourists' payments is evaluated as follows:

$$L_S = \sum_k (N_{0k} - N_{1k})Y \quad (3)$$

$L_S$  : Reduction of tourists' payments

$N_{ok}$  : Number of tourists in ordinary situation  
 $N_{ik}$  : Number of tourists in a long term stop of Tokaido Shinkansen  
 $Y$  : Tourists' payments per person per day  
 $k$  : Index code of each region

The values of the social loss from a long term stop of Tokaido Shinkansen are shown in Fig.6-8.

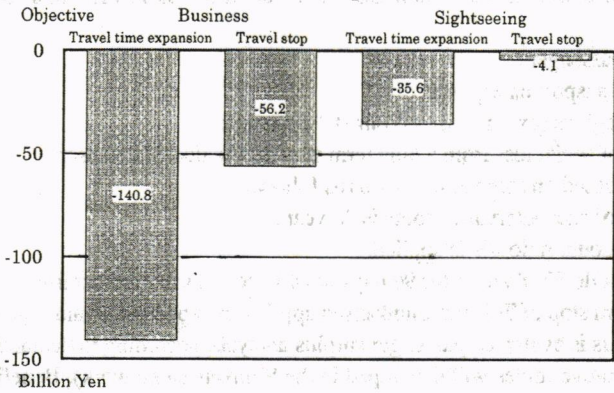


Fig.6 Loss to passengers

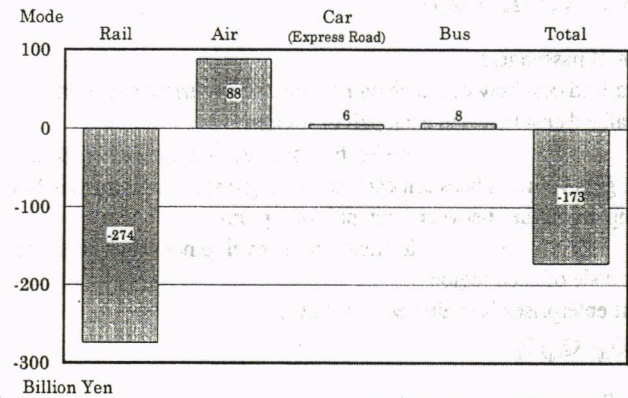


Fig.7 Loss to transport enterprises

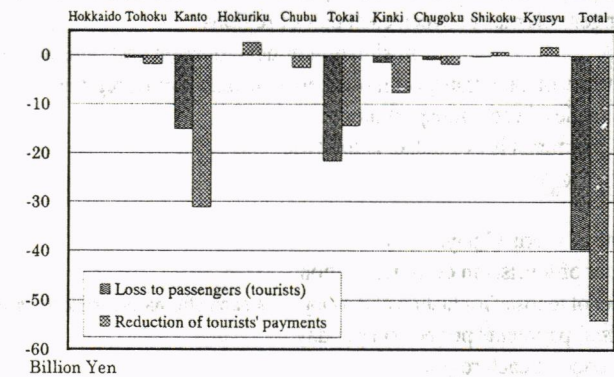


Fig.8 Reduction of tourists' payments (Comparison with loss to passengers)

#### 4. THE SOCIAL BENEFIT OF ALTERNATIVE ROUTES FOR THE TOKAIDO SHINKANSEN

##### 4.1 Definition of social benefit

In this study, I will define social benefit from alternative routes in the Shinkansen network as follows:

- a) Benefit of passengers
- b) Benefit of transport enterprises
- c) Benefit of regions (ex. increase of tourists' payment)
- d) Reduction of social loss from a long term stop of Tokaido Shinkansen

This definition are based on some assumptions as follows:

- a) Project life of each alternative route is 30 years.
- b) A social discount ratio 4% is applied.
- c) Stop of Tokaido Shinkansen for 90 days would occur during project life.

The loss from stop of Tokaido Shinkansen applies an expectation value for 30 years.

Benefit of passengers is evaluated passenger surplus analysis, according to demand forecasting on that situation (alternative routes will developed in the Shinkansen network). Benefit of passengers is evaluated as follows:

$$B_p = \sum_i (C_{0i} - C_{xi})(Q_{0i} + Q_{xi}) / 2$$

$L_p$  : Benefit of passengers

$C_{0i}$  : Generalized cost between each pair of regions in current situation

$C_{xi}$  : Generalized cost between each pair of regions

in situation of development each alternative route at case x

$Q_{0i}$  : Passengers volumes between each pair of regions in ordinary situation

$Q_{xi}$  : Passenger volumes between each pair of regions

in situation of development each alternative route at case x

i : Index code of each region

Benefit of transport enterprises is evaluated as follows:

$$L_T = \sum_{ij} (Q_{0ij} - Q_{xij}) F_{ij}$$

$L_T$  : Benefit of transport enterprises

$Q_{0ij}$  : Passengers volumes between each pair of regions in current situation

$Q_{xij}$  : Passenger volumes between each pair of regions

in situation of development each alternative route at case x

$F_{ij}$  : Ticket fare of each transport mode between each pair of regions

j : Index code of each transport mode

Increase of tourists' payments is evaluated as follows:

$$L_S = \sum_k (N_{0k} - N_{1k}) Y$$

$L_S$  : Increase of tourists' payments

$N_{0k}$  : Number of tourists in current situation

$N_{1k}$  : Number of tourists in situation of development each alternative route at case x

Y : Tourists' payments per person per day

k : Index code of each region

Reduction of social loss from stop of Tokaido Shinkansen are evaluated as follows:

Benefit (Reduction of social loss from stop of Tokaido Shinkansen)



= Loss from stop of Tokaido Shinkansen with alternative routes - without alternative routes

#### 4.2 Cases of alternative routes

In this study, I try to evaluate alternative routes as follows:

Case 0 : No alternative route

Case 1 : Hokuriku Shinkansen (Wakasa route)

Case 2 : Hokuriku Shinkansen (Maibara route)

+ New alternative route between Nagoya to Shin-Osaka

Case 3 : New alternative route between Tokyo and Nagoya (via near Kofu)

+ New alternative route between Nagoya and Shin-Osaka

Case 4 : New alternative route between Tokyo and Nagoya (via near Shizuoka)

+ New alternative route between Nagoya and Shin-Osaka

The value of the social benefit from each alternative routes shown in Fig 11-13.

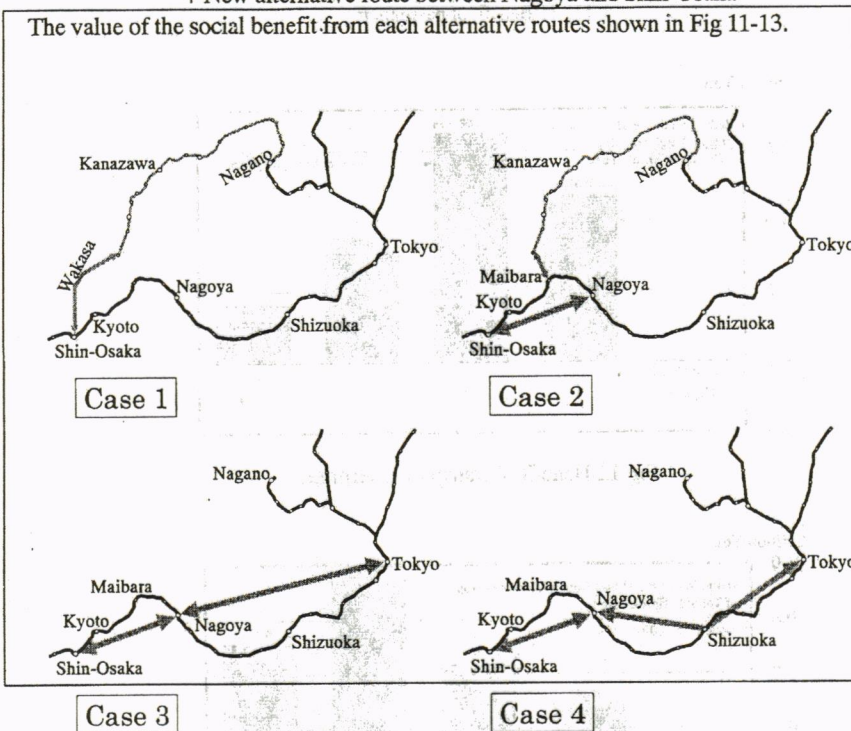


Fig.10 Alternative route at each case

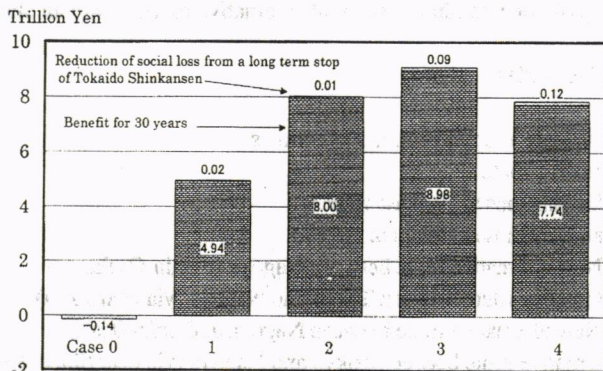


Fig.11 Benefit of passengers

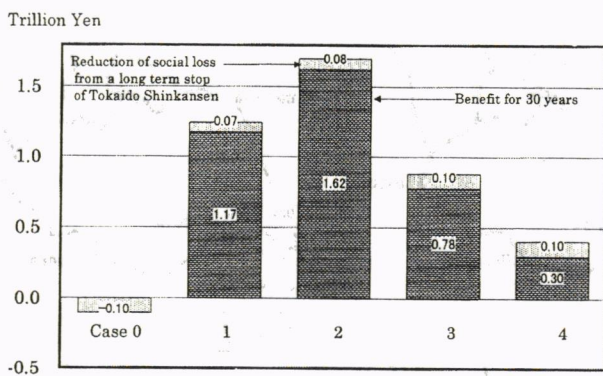


Fig.12 Benefit of transport enterprises

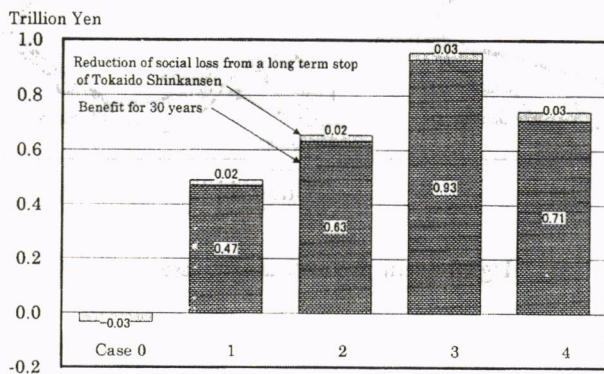


Fig. 13 Increase of tourists' payments



Table 1 Social benefit for each region (Trillion Yen)

Type of social benefit	Case 1	Case 2	Case 3	Case 4
Benefit of passengers	4.95	8.02	9.08	7.86
Hokkaido	0.00	0.00	0.00	0.00
Tohoku	0.17	0.19	0.04	0.00
Kanto	1.66	2.02	3.18	3.27
Hokuriku	2.45	2.63	0.05	0.04
Chubu	0.41	0.43	0.20	0.00
Tokai	-0.01	1.15	3.11	2.73
Kinki	0.23	1.43	2.70	2.13
Chugoku	0.03	0.08	-0.13	-0.19
Shikoku	0.01	0.03	-0.03	-0.04
Kyusyu	0.01	0.06	-0.04	-0.07
Benefit of transport enterprises	1.24	1.70	0.88	0.41
Increase of tourists' payments	0.49	0.65	0.96	0.74
Hokkaido	-0.01	-0.01	-0.02	-0.01
Tohoku	-0.06	-0.09	-0.18	-0.13
Kanto	0.12	0.06	0.35	0.62
Hokuriku	0.70	0.72	-0.24	-0.15
Chubu	0.18	0.19	-0.16	-0.11
Tokai	-0.16	-0.04	1.22	0.54
Kinki	-0.08	0.09	0.40	0.27
Chugoku	-0.06	-0.08	-0.10	-0.09
Shikoku	-0.04	-0.05	-0.08	-0.05
Kyusyu	-0.10	-0.14	-0.23	-0.15

Table 2 Reduction ratio of social loss for each region (%)

Type of social loss	Case 1	Case 2	Case 3	Case 4
Loss to passengers	14.8	12.8	66.6	81.5
Hokkaido	9.6	6.8	94.4	97.8
Tohoku	24.8	21.9	75.4	90.1
Kanto	14.1	10.2	75.2	85.4
Hokuriku	60.8	62.7	68.7	80.1
Chubu	99.8	99.8	99.9	99.8
Tokai	9.8	8.6	41.9	69.4
Kinki	30.0	35.1	93.5	96.8
Chugoku	21.6	13.9	92.0	92.6
Shikoku	-	-	85.4	85.8
Kyusyu	-	-	85.7	88.1
Loss to transport enterprises	66.2	76.1	98.5	99.8
Reduction of tourists' payments	59.2	64.9	79.1	100.1
Hokkaido	-	-	-	-
Tohoku	131.2	156.0	140.3	116.3
Kanto	55.6	56.2	80.3	101.1
Hokuriku	-	-	-	-
Chubu	96.4	100.9	87.3	100.5
Tokai	9.1	14.7	35.4	99.9
Kinki	66.2	82.7	99.4	96.4
Chugoku	103.3	92.8	126.0	79.7
Shikoku	-	-	27.0	97.3
Kyusyu	-	-	-	99.5

## 5 EVALUATION

### 5.1 The social loss from a long term stop of Tokaido Shinkansen

Total loss of passengers for 90 days reached about 240 billion yen (2.2 billion US\$).

Railway enterprises would lose a large ticket revenues, over 270 billion yen (2.5 US\$). This is very serious damage for each enterprise.

There is a great gap between the reduced income of railways and increased incomes for other modes. Total loss to transport enterprises for 90 days would reach about 170 billion yen (1.5 billion US\$).

Reduction of tourists' payments would reach an amount of about 50 billion yen (0.4 billion US\$).

The Kanto area would suffer the largest damage. And that loss is generally larger than loss to passengers (tourists) for each region.

These difference values are caused by characteristic of each evaluation method. The loss of passengers is based on changing of generalized cost between each pair of regions. The reduction of tourists' payments is just real money payments.

It is probable that reduction of money payments concerning business passengers' activity would be far larger value. It would be more important matter for social economy. But the evaluation method of this social loss/benefit has not been authorized. This is the next challenging.

### 5.2 The social benefit of alternative routes

Benefit of passengers of each case is large surpassing 5 trillion yen (43 billion US\$). Therefore, we can regard that each alternative route is social-economically feasible.

Each alternative route would provide benefit with great value to its neighbor area. Especially, Kanto area would be provided larger benefit in any cases (Table 1). And Kinki area is in same situation.

But on some area, social benefits mean minor value. This condition is caused by concentration of passengers' activity around each alternative route, because of forecasting model structure.

### 5.3 Reduction ratio of each loss

Reduction of social loss is 1/10-1/100 smaller than total benefits. We can regard that reduction social loss is too small. But each reduction ratio is sufficient (Table 2).

Loss to transport enterprises and reduction of tourists' payments are social losses with money payments. This is very important. If there are some alternative Shinkansen routes, passenger can travel, even when Tokaido Shinkansen would be stopped. Therefore, social-economical loss of each region is reduced to a minimum.

This is just the effect of alternative routes. The benefit of alternative routes, equal to reduction of social loss from long term stop of Tokaido Shinkansen, would be smaller. But the reduction ratio would be good enough for social economy.

## 6. CONCLUSION

Tokaido Shinkansen is not only a High Speed Train, but also a means of High Density Transportation. We can regard that Tokaido Shinkansen has been the most successful High Speed



### Train.

A large number of passengers depend on Tokaido Shinkansen. But Tokaido Shinkansen has no alternative in fact. If Tokaido Shinkansen would stop their service, Japanese society would suffer serious damage. In this study, the social losses are evaluated by a quantitative method.

Alternative routes are needed in the Shinkansen network. In this study, four alternative Shinkansen routes are evaluated. These alternative routes can provide sufficient benefits for each region. Therefore, each alternative route is feasible.

Social benefit with real money payments would be larger than generalized cost. Especially, money payments concerning business passengers' activity would be very important for social economy. But the evaluation method has not been authorized. This is the next challenging.

Reduction of social loss for each region from a long term stop of Tokaido Shinkansen is smaller. But these reduction ratios are satisfactory, especially concerning social loss with money payments. Therefore, social economical losses are reduced to a minimum, even when Tokaido Shinkansen would be stopped. These benefits will reinforce the necessity of alternative routes, and for each alternative routes will improve benefit-cost ratio.

### ACKNOWLEDGEMENTS

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