COMPREHENSIVE EVALUATION METHOD OF THE LEVEL OF SERVICE FOR SHINKANSEN STATION

Kazuhiko Tochigi[1], Japan Railway Construction, Transport and Technology Agency, kzh.tochigi@jrtt.go.jp

Yasuo Hanyuda[2], Japan Railway Construction, Transport and Technology Agency,yas.hanyuda@jrtt.go.jp

ABSTRACT

For the Shinkansen lines, the enhancement of the function of the network and the strengthening of the connection with other public transportation modes such as conventional railways are required. This is because the Shinkansen lines have been being developed as the mass rapid transport system which forms the basic framework for the transportation in Japan, and it is required to bring the effect of the Shinkansen development to a wider area.
In this study, the followings were conducted. First, an extensive database of the LOS (level of service) of the Shinkansen stations was built based on the result of field researches of the Shinkansen stations. Second, AHP (Analytic Hierarchy Process) questionnaire was conducted to analyze factors for the LOS for Shinkansen. Third, comprehensive evaluation models of the LOS for Shinkansen focusing on the transfer at the Shinkansen stations and the connection with other transportation modes were established, and the quantitative analysis of measures for the improvement of the convenience for the Shinkansen users was conducted.

Keywords: Shinkansen, comprehensive evaluation, AHP

1. INTRODUCTION

For the Shinkansen, the Japanese high speed rail, improvement of the access to the Shinkansen station and the connection with conventional railways, buses and air traffic is required. This is because the Shinkansen is an important part of the high speed transportation in the country, and it is required to bring the effect of its development to a wider area.
The purpose of this study is the objective and quantitative evaluation of the convenience, the comfort and the reliability of the transfer (hereinafter referred as the LOS; the level of service) for Shinkansen by systematically analyzing the utilization forms of Shinkansen stations. For this purpose, a comprehensive evaluation method of the LOS for the Shinkansen was

established based on the results of the field researches on the use of the Shinkansen stations and AHP questionnaire for experts. Furthermore, the case studies on measures for the improvement of the convenience for the Shinkansen station users were conducted and the effects of the measures were analyzed quantitatively with this evaluation method.

2. THE UTILIZATION FORMS AND THE EVALUATION MODELS OF SHINKANSEN

2.1 The outline of Shinkansen

Since the opening of Tokaido Shinkansen in 1964, the total length in operation of the Shinkansen network has reached 2,388 km and 330 million passengers are carried per year. Currently, Japan Railway Construction, Transportation and Technology Agency (JRTT) are constructing the Shin-Aomori – Spporo section of Hokkaido Shinkansen (about 360 km), the Nagano – Tsuruga section of Hokuriku Shinkansen (about 353 km) and the Takeo-onsen – Nagasaki section of Kyushu Shinkansen (about 66 km). The total length of these sections under construction is about 779 km. The Shinkansen lines have the gauge of 1,435 mm and are basically newly constructed separately from the conventional railways. As the gauge of the conventional lines in Japan is 1,067 mm, the improvement of the connection between the conventional and the Shinkansen lines is highly important as well as the access to the Shinkansen lines for the development of more convenient wide-area trunk railway network.

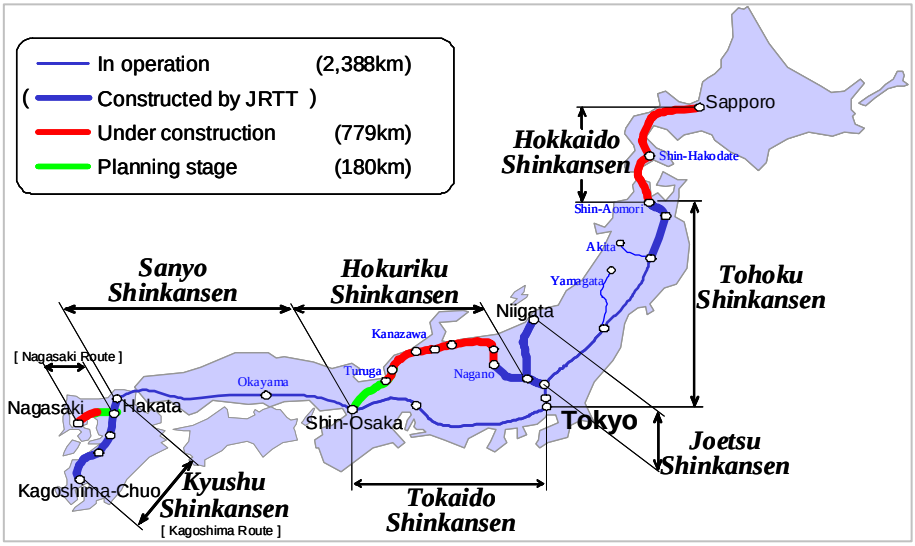

Figure 1 –The Shinkansen network

2.2 The utilization forms of Shinkansen

Figure 2 shows the image of the utilization forms of Shinkansen, taking the purposes of business and leisure as an example. The users take the access transit such as a bus, a tram or a conventional railway from the departure place (their houses) to a Shinkansen station. After the Shinkansen train arrives at the nearest station to their destination, the transportation modes same as when the passengers used to go to the Shinkansen station nearest to their

houses are can be chosen when the destination is near. On the other hand, when the destination is a long way from the Shinkansen station, a conventional railway, an expressway bus or a rental car are generally used.

2.3 The evaluation models

Based on the utilization forms of Shinkansen, the following three evaluation models were set;

1) The evaluation model of access to a Shinkansen station: to evaluate the access conditions from the departure place to the nearest Shinkansen station
2) The evaluation model of transfer; to evaluate the conditions of transfer between a Shinkansen station and another transportation mode to move to the final destination.
3) The evaluation model of connection; to evaluate the conditions of total connection of the route from a departure place to a destination

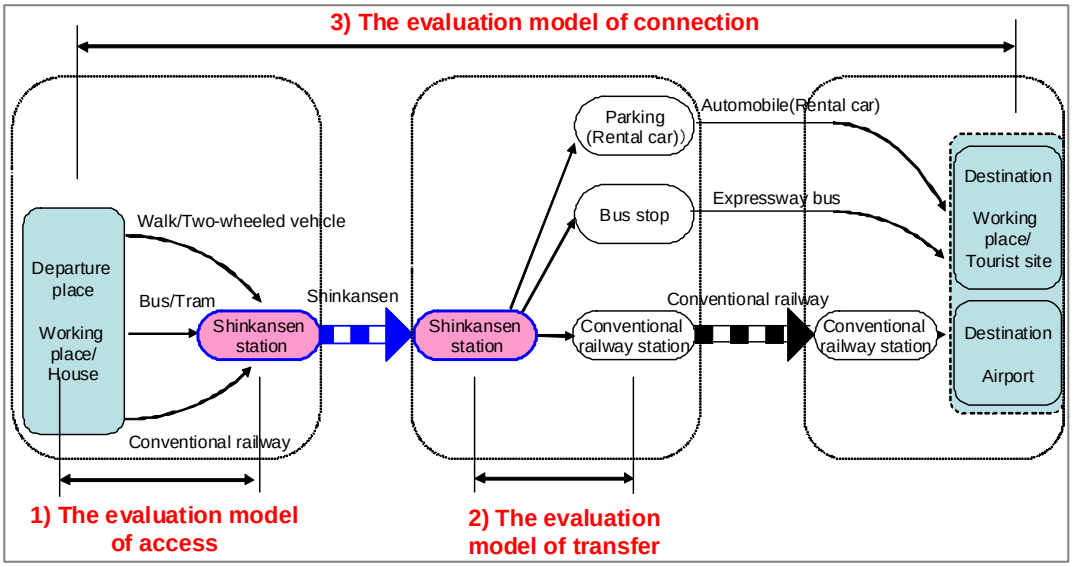

Figure 2 – The image of the utilization forms of Shinkansen

2.4 The field researches on the use of the Shinkansen stations

In order to evaluate the LOS and convenience improvement measures for the Shinkansen stations, the research of the existing data and the field researches of all the 89 existing Shinkansen stations were conducted about the conditions of access, transfer facilities and movements and the actual LOS for the Shinkansen stations was clarified. The research results were collected up for each station and an extensive database was built.

2.4.1 Information for each station

The research results, including the movement distance, the movement time, the number of train services, the presence or absence of signs and the facilities along the moving route, were collected up for each station as the basic data, the access condition and the transfer condition of the stations. As for the facilities along the moving route, pictures are included to

be visually checked. This station information is linked with the location information using GIS. In this way, the extensive database was built.

Table I – The outline of the information for Shinkansen stations

Items	Research items	Research contents
outline of Shinkansen station	basic data	opening date, number of users, number of train services, station structure, station facilities, station square
	data on area	populations of major cities, number of visitors to major tourist sites, location of international airport, international aviation service
information on access transit	transfer route	moving distance, moving time, signs, facilities, service
	facilities	loading zone and facilities of access transit
information on transfer	transfer route	moving distance, moving time, number of train (or other modes) services, presence of service matching the first train
	station facilities	number of escalators and elevators, sign, number of benches, waiting room, types of station stand, presence or absence of restroom

2.4.2 The Shinkansen station database

The database was compiled by storing each data in “nodes” or “links “for easier analysis of the data obtained by the field re-searches. Figure 3 shows the outline. The data on the main facilities at the starting, ending and diverging points on the route was input into the nodes, and the data on the sections linking them was input into the links. This makes it possible to obtain and analyze the date of the facilities along any routes which you set.

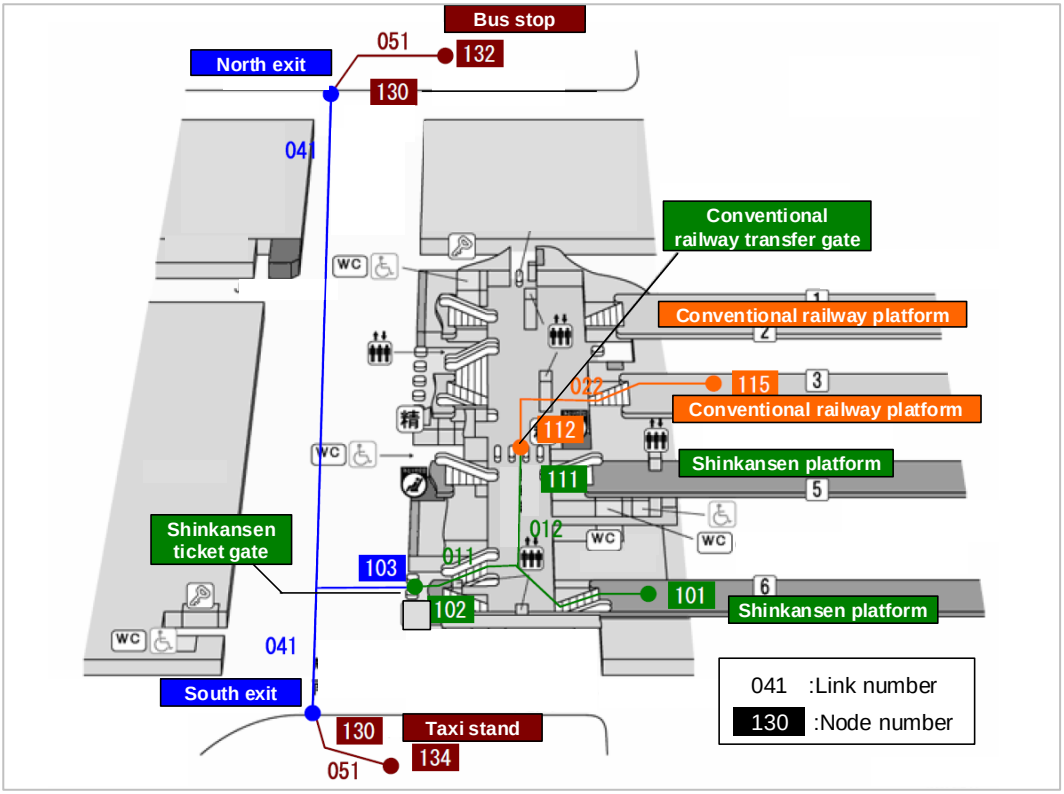

Figure 3 – The outline of the Shinkansen station nodes and links

Table Ⅱ – The outline of the information for Shinkansen stations

		Input items
Node	A) information on node	node number, basic data on node such as type of node
	B) information on facilities of node	number of benches, number of station stands, number of restrooms, presence or absence of roof, presence or absence of signs, number of guidance languages, number of train services, number of bus services, capacity of parking, parking fee
Link	C) information on link	link number, source node number, destination node number, traveling direction
	D) Information on movement of link	traveling distance, journey time, escalators and elevators (type, number, required time)
	E) information on facilities of link	Number of ticket gates, number of ticket vending machines, number of ticket counters, number of benches, number of station stands, number of restrooms, presence or absence of roof

2.5 Establishment of the comprehensive evaluation method

Evaluated points by Shinkansen users are not only on-board comfort and convenient transfer, but also others such as comfort at transfer lounge, transfer guidance, service level of connecting transportations, etc. AHP is considered to be suitable to quantitatively evaluate users' subjective perceptions of those complicate situations. According to the process of AHP, the comprehensive evaluation method of the LOS for Shinkansen was established by systematizing and stratifying evaluation items for the LOS, weighting the items according to their importance for each of the purpose (business or leisure) and grading the evaluation results based on the evaluation score of the items. Figure 4 shows the flowchart of the establishment of this evaluation method.

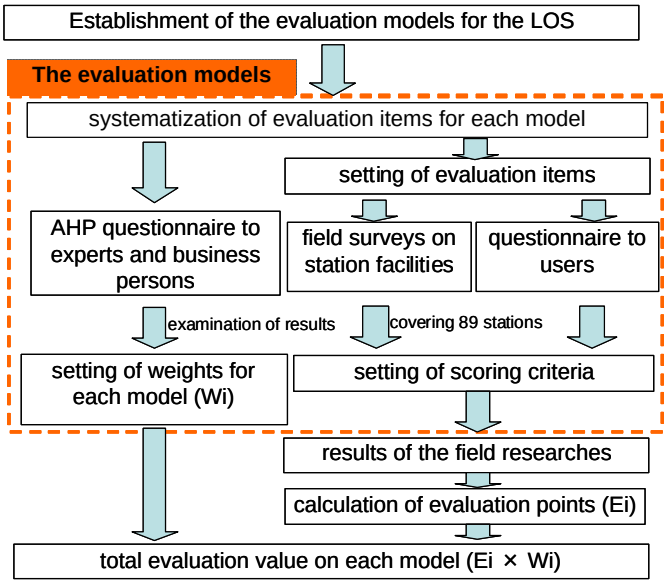

Figure 4 – The flowchart of the establishment of the evaluation method

2.5.1 The systematization of evaluation items and the setting of evaluation indexes

To set the evaluation items for the LOS for Shinkansen we reviewed the existing reports[1) 2)]. As a result, the large, middle and small categories were set with the consideration of the

characteristics of the LOS for Shinkansen, various effects of different improvement measures and the independence between the evaluation items.

The evaluation items are considered for each of the evaluation models enough to properly reflect the utilization forms such as the access and the transfer. Table 3 shows the evaluation system for the access to a station as an example.

Table Ⅲ – The evaluation system for the access to a station

Large category	Middle category	Small category	indexes
transfer convenience	movement for transfer	up-down movement	number of stairs, presence or absence of escalators and elevators
		horizontal movement	moving distance, presence or absence of obstacles along route
		passage and ticket gate	presence or absence of transfer gate, presence or absence of integrated ticket for connected service
	waiting space for transfer	comfort in waiting space	presence or absence of benches
	a sense of ease on transfer	information on transfer	understandability of route signs
		connection for transfer	frequency of access transit service
		seat availability of a transportation mode to be transferred	frequency of first train of access transit
condition around Shinkansen station	comfort around station	presence or absence of passage connecting the both sides of a station	presence or absence of passage
		cultural value of station	historical or cultural value of station
	convenience of commercial facility around station	variety of shops	presence or absence of department store, presence or absence of restaurant and book store
		opening hour of shops	presence or absence of stores opening from the first train to last train
service level of access transit	diversity of access transit		types of connected transportation modes
	operating hour of access transit		presence or absence of service from first train to last train

2.5.2 The setting of the weight of the evaluation items by AHP

Dividing the trip purpose into business and leisure, AHP questionnaire was conducted by the pair comparison method on the importance of each of the evaluation item and the weights of each of the item were set based on the result. AHP questionnaire contains huge amount of questions and answerers need to understand the method. Therefore this study targets those who seem to understand users' consciousness adequately with the references of existing reports[3)]. In the questionnaire, the purposes for travel were divided into business and leisure. While the questionnaire for the business purpose targeted 3 academic experts and 14 business persons, that for the leisure purpose targeted 3 academic experts, 4 travel agency workers, 4 officials of tourism-related municipal bureaus and 5 persons who have no opportunities to use Shinkansen for the business purpose.

In order to ensure the consistency, the answers with the consistency index (CI) of 0.15 or less were regarded as valid for the analysis.

The questionnaire result shows that there are some answers with the CI of more than 0.15 for the models which have many evaluation item options. Hence the evaluation system was modified to have the 4 options or less in order to limit the CI to no more than 0.15 by analyzing the similarities of evaluation items and the tendency of the respondent with the multifactor aggregation method. The consistency was improved as the result of the questionnaire conducted again based on the modified evaluation system, and the weights of the evaluation models were revised.

Each of the evaluation items was weighted according to the average value of the importance based on the answers from all the respondents. The calculated results of the weights for each of the evaluation models and their characteristics are described below.

2.5.2.1 The weights for the evaluation model of access to a Shinkansen station

The evaluation model of access to a Shinkansen station is to evaluate the LOS of the transportation from a departure place to a Shinkansen station or a Shinkansen station to a destination. That is, this evaluates the LOS from the ticket gate of a Shinkansen station to another transportation mode. (Table 4)
One of the characteristics of the weights for this model is that the importance is gave to the diversity of the access modes to or from a Shinkansen station and their operating hours for the both purposes of business and leisure. For the purpose of business, the convenience of up-and-down movement is also weighed. On the other hand, the items related to a sense of ease such as the in-formation on transfer and the connection with other transportation are weighted for the leisure purpose. It seems that this reflects the feeling of anxiety in an unfamiliar tourist site.

Table Ⅳ – The weights for the evaluation model of access

Large category	Middle category	Small category	wight (%)	
			business	leisure
1.convenience of transit	1.movement for transfer	up-down movement	9	6
		horizontal movement	6	5
		passage and ticket gate	2	1
	2.waiting space for transfer	comfort in waiting space for transfer	5	6
	3.a sense of ease on transfer	information on transfer	5	11
		connection with transportation mode to be transferred	6	9
		seat availability of transportation mode to be transferred	4	4
2.condition around Shinkansen station	1.comfort around station	passage connecting the both sides of a station	4	3
		cultural value of station	2	2
	2.convenience of commercial facility around station	variety of shops	5	6
		operating hour of shops	6	4
3.service level of access transit	1.diversity of access transit		13	21
	2.operation hour of access transit		33	22

2.5.2.2 The weights for the evaluation model of transfer

The evaluation model of transfer is to evaluate the LOS of the transfer between a Shinkansen train and a conventional intercity train. That is, this evaluates the LOS within the ticket gate of a Shinkansen station. (Table 5)
The characteristics of the weights for this model is that the importance is gave to the installation of the escalators or the elevators and the connection with another transportation mode for the business purpose, and to a sense of ease in the transfer such as the seat availability and the information on the mode to be transferred for the leisure purpose.

Table Ⅴ – The weights for the evaluation model of transfer

Large category	Middle category	Small category	wight (%)	
			business	leisure
1.movement for transfer	1.up-down movement	up-down movement with stairs	4	3
		installation of escalators	21	10
		installation of elevators	6	4
	2.horizontal movement	movement distance	7	6
		continuity	4	7
	3.passage and ticket gate	width of passage	3	4
		convenience of ticket gate for transfer	4	4
2.waiting place for transfer	1.cmfort in waiting place for transfer	number of restrooms and benches	6	3
		number of station stands	3	3
		waiting room equipped with air-conditioner	5	4
		waiting room equipped with television	1	1
3.a sense of ease on transfer	1.information on transfer	root sign	4	13
		information on transportation modes to be transferred	4	12
	2.connectivity with transportation modes to be transferred		17	9
	3.seat availability of transportation modes to be transferred		11	17

2.5.2.3 The weights for the evaluation model of connection

The evaluation model of connection is to evaluate the LOS of the convenience of transfer, the comfort on a train and the convenience of access to or from a Shinkansen station. That is, this evaluates the connection along the entire route. (Table 6)
The characteristics of the weights for this model are that the importance is given to the comfort on a train and the convenience of transfer. For the business purpose, the layout of the seats and the facilities around a seat are weighed. On the other hand, the facilities in a train such as the restrooms and the separation of the smoking areas as well as the comfort of the seat are weighted for the leisure purpose.

Table Ⅵ – The weights for the evaluation model of connection

Large category	Middle category	Small category	wight (%)	
			business	leisure
1.transfer convenience of station where get off	1.convemience of transfer station	movement for transfer	11	12
		waiting place for transfer	2	2
		a sense of ease on transfer	9	8
	2.diversity on access transit		9	8
2.comfort on train for passengers	1.comfort of Shinkansen train	comfort of seat	18	18
		service on train	4	4
		equipment on train	7	17
	2.comfort of conventional train	comfort of seat	12	8
		service on train	2	2
		equipment on train	7	7
3.LOS for other than train	1.access transit to/from Shinkansen station	access transit to large cities	6	5
		access transit from provincial cities	10	6
	2.condition around station	comfort around station where to get on	1	1
		comfort around station where to get off	2	2

2.5.3 The setting of the scoring criteria

In order to quantitatively evaluate the LOS for Shinkansen, the results of the field researches on the Shinkansen stations were statistically analyzed and the scoring criteria were set.
The scoring criteria of the results of the evaluation index analysis were set by the percentile method. And the items were evaluated on a 5-point scale. The top 20 percentile is scored 5 points (good), the bottom 20 percentile is scored 1 point (bad), and the middle is scored the 2 to 4 points according to the actual research results. Table 7 shows an example of the scoring criteria for the evaluation model of transfer.
* For the index whose evaluation results are discrete, “presence” is scored 5 points and “absence” is scored 1 point. (Scoring criteria for the middle were not set.)

Table Ⅶ – The scoring criteria for the evaluation model of transfer

Items		Indexes (x)	scoring criteria		
			top 20% (5 points)	middle	bottom 20% (1 point)
movement for transfer	up-down movement	number of stairs	0≦x≦68	68<x<93	93≦x
		presence or absence of escalator	x=1.00	1.00>x>0.00	X=0.00
		presence or absence of elevator	x=1.00	1.00>x>0.46	X=0.46
	horizontal movement	horizontal movement distance (m)	0≦x≦98	98<x<2.48	2.48≦x
		presence or absence of difference in level on a floor which a wheelchair can't pass through	x=1.00	1.00>x>0.46	0.46≧x
	passage and ticket gate	minimum width of passage (m)	x≧6.00	6.00>x>3.00	3.00≧x≧0
		presence or absence of transfer gate	x=1.00	–	1.00>x≧0.00
		number of transfer gates	x≧8	8>x>3	3≧x≧0
waiting for transfer	presence or absence of restroom and bench	presence or absence of restroom	x=1.00	–	1.00>x≧0.00
		presence or absence of bench	x=1.00	–	1.00>x≧0.00
	station stand	number of station stands in concourse and platform	x≧3.5	3.5>x>1	1≧x≧0
a sense of ease	route sign	route sign	x=1.00	–	1.00>x≧0.00
		sign with foreign language	x=1.00	–	1.00>x≧0.00
	information on transportation made to be transferred	presence or absence of departure board	x=1.00	1.00>x>0.00	x=0.00
		sign with foreign language	x=1.00	1.00>x>0.00	x=0.00
	connectivity	frequency of service	x≧23	23>x>5	5≧x≧0
	seat availability	frequency of first train (%)	x=1.00	100>0	x=0

2.5.4 The calculation of the total evaluation values

The total evaluation value (converted to the figures on a 100-point scale) was calculated by adding up the scores for all the evaluation items. The scores for the evaluation items were calculated by multiplying the weights (Wi) of each of the evaluation items set based on the result of the AHP questionnaire by the evaluation points (Ei) scored based on the results of the field researches on the stations.

Total evaluation value = Σ （Wi×Ei） ×20

3. THE CASE STUDIES

In order to specifically evaluate the effects of convenience improvement measures by using the comprehensive evaluation method, case studies were conducted and the effects were examined. The evaluation results of the transfer improvement measures on the Okayama and Niigata stations are described below.

3.1 Okayama station

3.1.1 The outline of the measures

The Okayama station is a major station where all the Sanyo Shinkansen trains stop and has the function as the interchange with the lines to the San-in and Shikoku regions. Two measures have been carried out to improve the convenience. Measure 1 is the elevation of the station and the construction of a new east-west passage. Measure 2 is the expansion of the traffic square in front of the west exit. Table 8 shows the outlines of these measures.

Table Ⅷ – The outlines of the improvement measures on the Okayama station

Measure		evaluation indexes		before	after	difference
1	elevation of the station (the Shinkansen line – the JR conventional line)	horizontal movement distance	m	200	155	−45
		number of stairs	number	87	87	−
		installation of escalator	%	0	100	100
		installation of elevator	%	0	100	100
		width of passage	m	2	10	8
		route sign	%	0	100	100
	construction of a new east-west passage (the Shinkansen line – the other transportation modes)	horizontal movement distance	m	440	426	−14
		number of stairs	number	90	90	−
		installation of escalator	%	50	100	50
		installation of elevator	%	50	100	50
2	expansion of the traffic square in front of the west exit (the Shinkansen line – the other transportation modes)	horizontal movement distance	m	426	329	−97
		number of stairs	number	90	92	2
		route without pedestrian crossing	%	50	63	13
		continuity of roof	%	0	38	38
		route sign	%	50	100	50

3.1.2 The evaluation result

The improvement measures on the Okayama station were evaluated by the evaluation model of access for the business purpose.

Although the access to the Okayama station was relatively convenient even before the measures were carried out, the evaluation score has increased by the new east-west passage on Measure 1 which has brought the shortened horizontal movement distance and the easier up-down movement with the addition of the elevators and the escalators.

Furthermore, the evaluation score has further increased by the expansion of the traffic square on Measure 2, which has brought the shortened horizontal movement distance, the comfort of the transfer route and the enough signs.

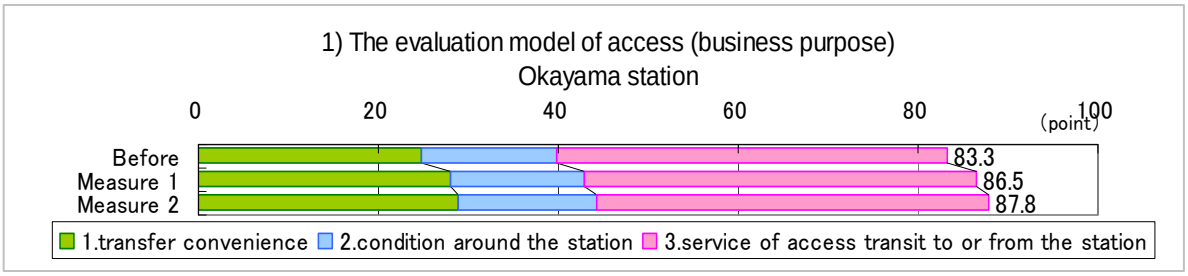

Figure 5 – The evaluation result by the evaluation model of access (business purpose)

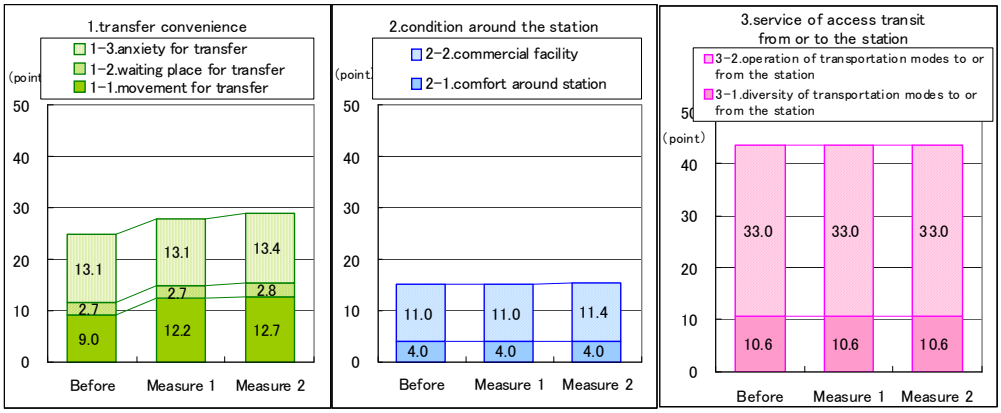

Figure 6 – The breakdown of the evaluation score by item

Similarly, great effects can be seen on the evaluation of transfer. (Figure 7) The evaluation score has increased by 32.7 from 63.2 (before the measures were applied) to 95.9. Most of the effects are the improvement of the movement for transfer. The elimination of the anxiety for transfer has contributed as well. (Figure 8) The elevation of the station means the drastic improvements of the facilities inside the ticket gates and the passenger flow for the transfer, and hence it can be said that the effects of the improvement measures for the transfer inside the ticket gates such as the creation of the barrier-free space and the addition of the route signs have been seen.

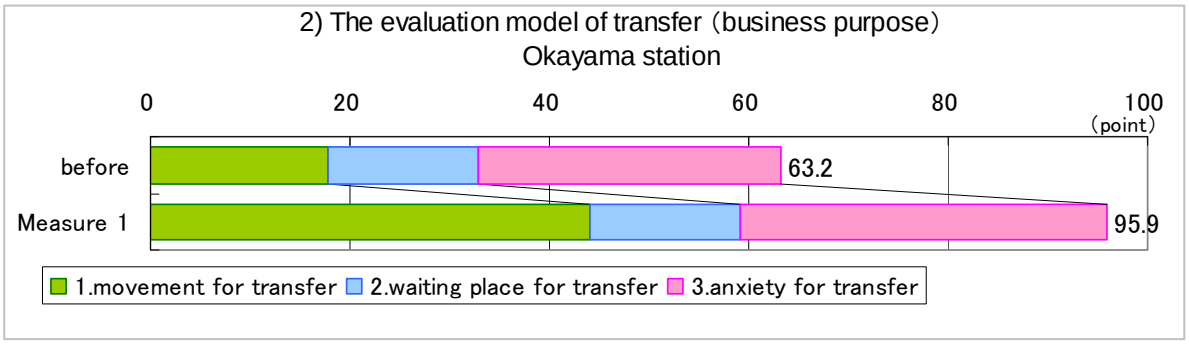

Figure 7 – The evaluation result by the evaluation model of transfer (business purpose)

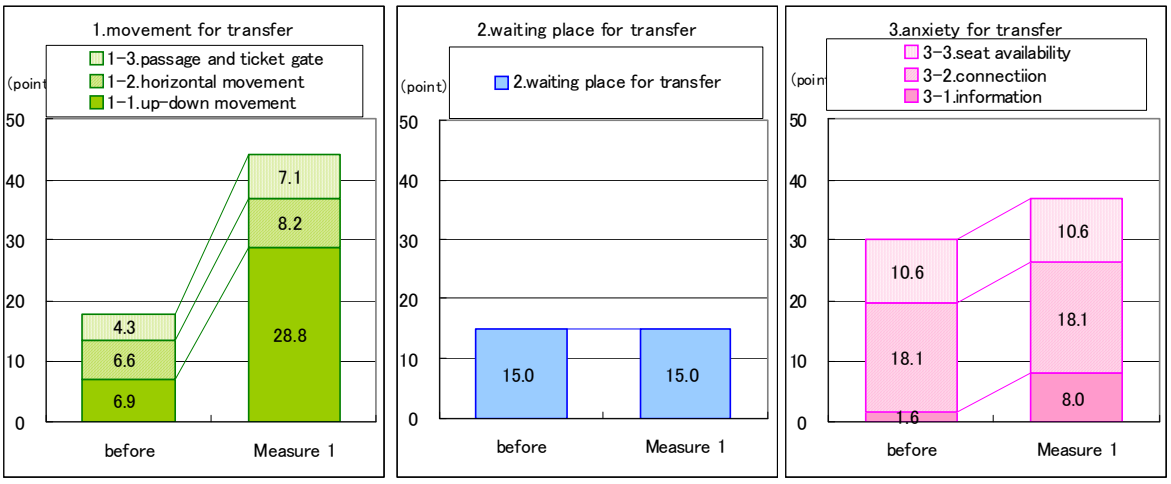

Figure 8 – The breakdown of the evaluation score by item

3.2 Niigata station

3.2.1 The outline of the measures

The Niigata station is the terminal of the Joetsu Shinkansen and a major station in the areas along the Japan Sea, connected with the Shinetsu Main Line and the Echigo Line to Kashiwazaki and Naoetsu and the Hakushin Line and the Uetsu Main Line to Akita and Sakata. Currently, the continuous multi-level crossing is being constructed on the conventional lines as Measure 1. Measure 2, is the plan for the transfer between the Shinkansen line and the conventional lines on the single platform, are being carried out in conjunction with Measure 1. The outlines of these measures are shown in Table 9.

TableⅨ – The outlines of the improvement measures on the Niigata station

Measures		Evaluation indexes		before	after	difference
1	elevation of conventional railways (continuous multi-level crossing) [the Shinkansen line – the JR conventional lines]	horizontal movement	m	268	175	−93
		number of stairs	number	87	106	19
		installation of escalator	%	0	100	100
		installation of elevator	%	0	100	100
		width of passage	m	1.8	6.0	4.2
		route sign	%	0	100	100
2	transfer on a single platform [the Shinkansen lines – the JR conventional lines]	horizontal movement	m	175	80	−95
		number of stairs	number	106	0	−106
		route without difference in level on a floor	%	46	100	54

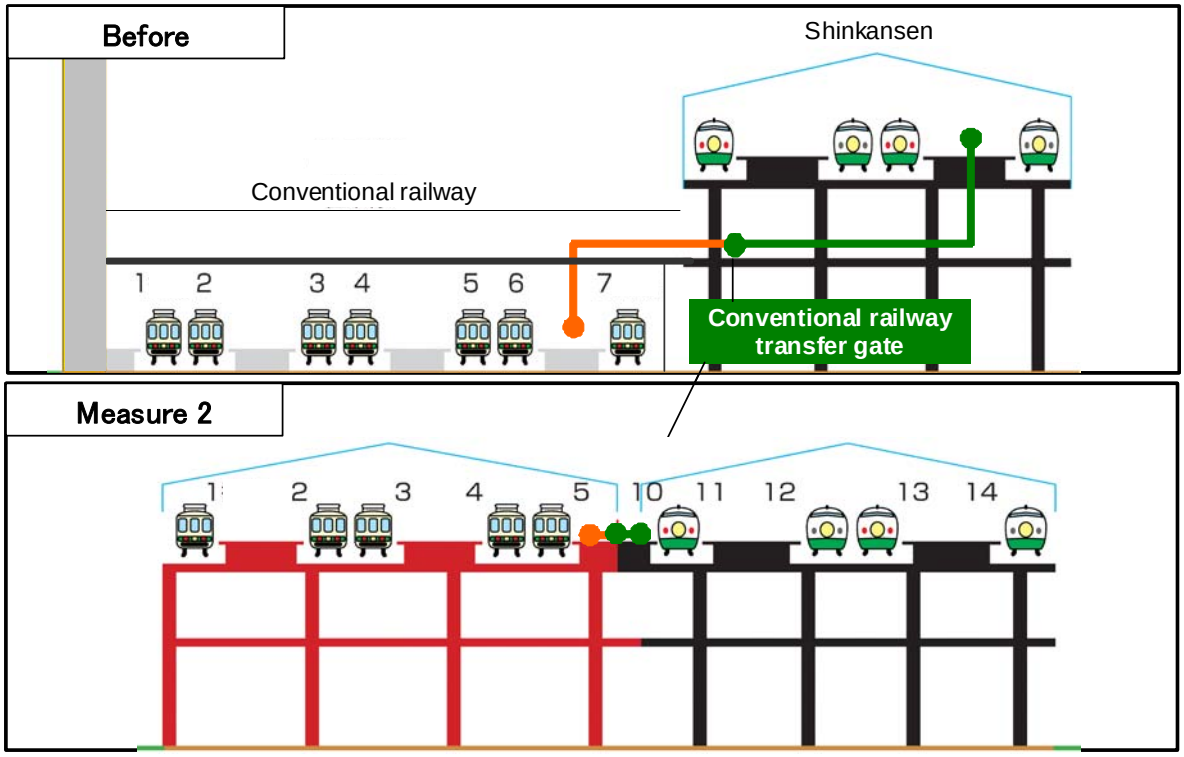

Figure 9 – The image of the improvement measure on Niigata station

3.2.2 The evaluation result

The improvement measures on the Niigata station were evaluated by the evaluation model of transfer for the business purpose. The evaluation score of the Niigata station was ranked relatively low among the existing Shinkansen stations before the improvement measures were carried out. However, the elevation of the conventional lines by Measure 1 has brought the great effects of the shortened horizontal movement distance and the easier up-down movement with the addition of the elevators and the escalators. Hence the evaluation score for “movement for transfer” has increased by nearly 30 points. Furthermore, the transfer at the single platform by Measure 2 has brought the shortened transfer distance and the convenience has been improved. These effects were quantitatively evaluated. As a result, the station has been ranked relatively high among the existing Shinkansen stations.

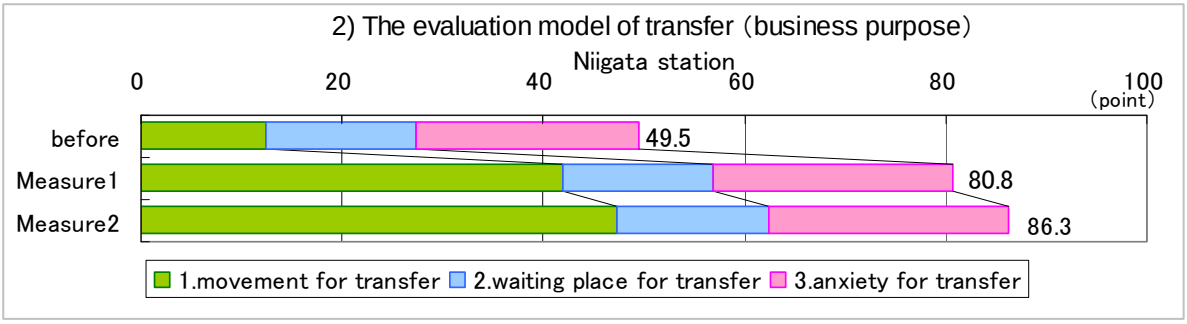

Figure 10 – The evaluation result by the evaluation model of transfer (business purpose)

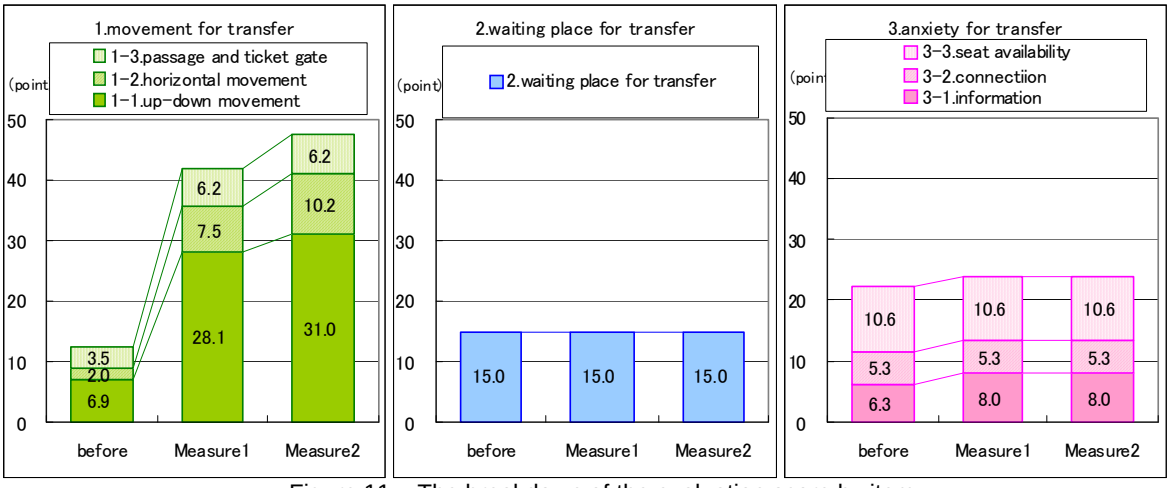

Figure 11 – The breakdown of the evaluation score by item

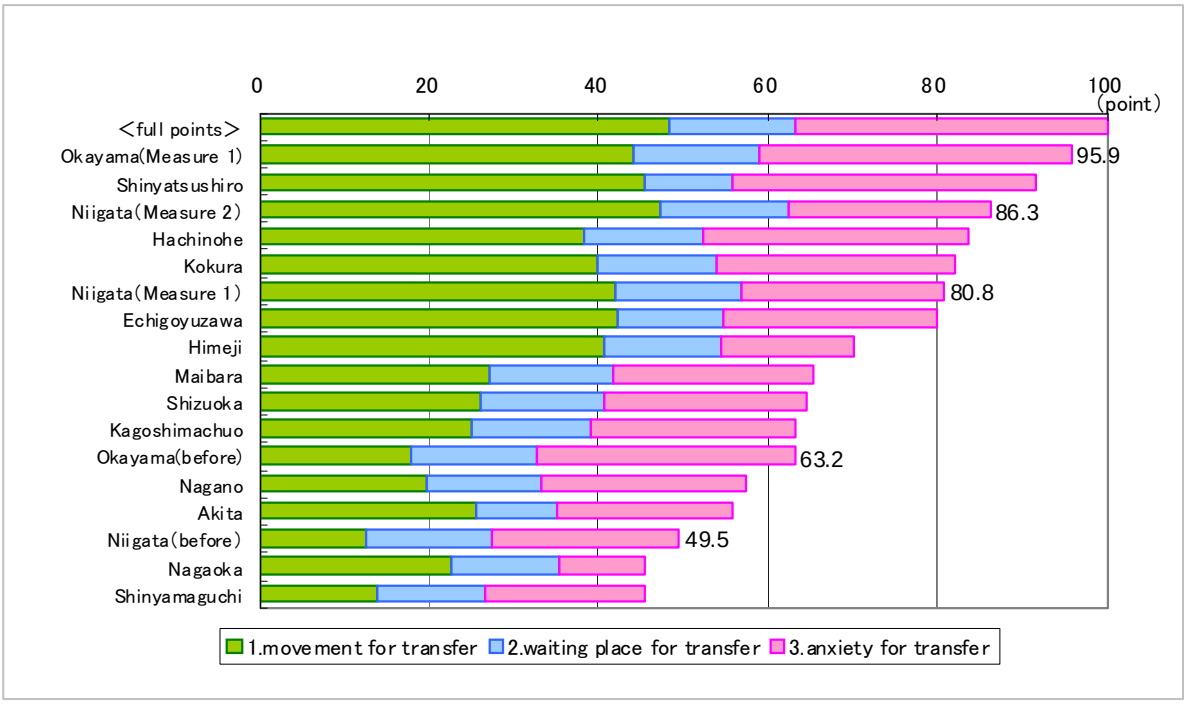

Figure 12 – The comparison between the existing Shinkansen stations

In this way, the evaluation models have been confirmed to be able to quantitatively evaluate the access to a Shinkansen station from another transportation mode and the transfer between a Shinkansen station and a conventional railway for each of the purpose. As seen in the case studies, the effects of the improvement measures for the user convenience can be quantitatively evaluated by selecting the evaluation model for each of the purpose.

4. CONCLUSION

In this study, the comprehensive evaluation method was established for the LOS of Shinkansen such as the access, the transfer and the connection with other transportation modes. This method has been confirmed to be able to objectively and quantitatively evaluate the LOS for Shinkansen.

In order to the establishment of the evaluation models, the various factors for the LOS for the Shinkansen were systematized, and the field researches on all the 89 Shinkansen stations and the AHP questionnaire for the experts were conducted. The database on the results of the field researches on all the Shinkansen stations was built and the evaluation criteria were set based on its analysis result.

The result of the AHP questionnaire shows that the important factors are differing between the business purpose and the leisure purpose. While the importance is placed on the convenience of up-down movement for the business purpose, the information on the transfer and connection for the leisure purpose. Moreover, the importance is placed on the service level of the transportation modes to or from a Shinkansen station on the evaluation model of access, the up-down movement to transfer with another mode on the evaluation model of transfer, and the comfort in a train on the evaluation model of connection.

The case studies quantitatively demonstrated that the improvement measures for the easier up-down movement, such as the creation of the barrier-free space and the transfer on a single platform, brought the great effects. In this way, the evaluation method was confirmed to be useful to understand the effects of the concrete measures.

The evaluation method is expected to be used for detailed studies on improvement measures for more convenient Shinkansen stations during the improvements of the existing Shinkansen station and the planning of new station.

ACKNOWLEDGMENT

This study is a part of “The study on the LOS for Shinkansen”, and was directed by Prof. Seiji Iwakura of Shibaura Institute of Technology, the president of the research committee, and associate professor Mr. Daisuke Fukuda of Tokyo Institute of Technology and associate professor Mr. Makoto Tsukai of Hiroshima University, the members of the committee. The authors express deep gratitude for their support.

REFERENCE

1) Japan Railway Construction, Transport and Technology Agency. (2007): The report on the improvement effect on transfer of the development of the Shinkansen
2) Japan Railway Construction, Transport and Technology Agency (2011): The report on the LOS for Shinkansen
3) Yoshiharu TAKAMURA (2001): A study regarding the application of comprehensive evaluation methods to the relocation of central government functions in Japan