ANALYZING THE ENHANCEMENT OF ACCESSIBILITY DUE TO PUBLIC TRANSPORT IMPROVEMENT AND INTENSIVE LOCATION TO URBAN CORRIDORS

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ABSTRACT

This study aims to evaluate the effects of accessibility enhancement in a whole intended area by concentrative improvement of public transport in urban corridor and gathering population and urban facilities intensively along corridor area. A potential-type accessibility index is applied. Three scenarios are developed: A) Increase the service level of public transport routes along the corridor, B) Equal increase of the service level among the whole areas and C) Land-use development in corridor area. The results indicate that increase of service level of major public transport system brings higher accessibility and equality. Additionally, higher accessibility is brought by land-use development in corridor area with higher service level public transport system.

Keywords: accessibility, public transport, urban corridor

INTRODUCTION

Progress of motorization is strongly related with the expansion of urban areas and the suburbanization of the urban facilities especially in the absence of any strict land use regulations. The expanding urban areas and the suburbanization of urban facilities often promote a car dependent lifestyle and as a result of which the sustainability of the cities becomes a critical aspect.

In the late years, as an approach to control the negative influences of the increased auto mobility, the idea of "compact city" form was proposed. However, for the compaction of the city form, it is essential to have the public transport which is highly competitive with the private automobiles. Introduction of Light Rail Transit (LRT) or Bus Rapid Transit (BRT) in a European and American cities are the typical examples. Also with its introduction, the population and urban facilities get concentrated along the public transport corridor like Transit Oriented Development (TOD).

This study aims to evaluate the effects of accessibility enhancement in a whole intended area by concentrative improvement of public transport in urban corridor and gathering population and urban facilities intensively along corridor area.

METHDOLOGY

In this study, potential-type indicator is applied for accessibility indicator[1]. Merits of potential-type indicator are:

- Attractiveness of urban facilities are used as units of accessibility, therefore it is able to evaluate implementations of transport policies and land use policies in same dimension
- Various transport measures are able to be evaluated by using generalized cost as the travel impedance between a place of residence and the object facilities
- Accessibility is able to be evaluate at every spot
- Data collection for accessibility evaluation is comparatively easy

Potential-type accessibility indicator in this study is defined with formulations (1) and (2).

$$AC_i^m = \sum_k^K \left(\beta^k AC_i^{km} \right) \ , \ \sum_k^K \beta^k = 1 \tag{1}$$

$$AC_i^{km} = \sum_j^J \left\{ AT_j^k \exp\left(-\alpha^{km} c_{ij}^m \right) \right\} \tag{2}$$

where, i: evaluated zone j: neighborhood zone J: total number of zones k: category of urban facility (purpose of travel) K: total number of urban facility categories m: transport mode AT_j^k: attractiveness of k at zone j α^{km}, β^k: parameter c_{ij}^m: travel impedance between zone i to zone j by using mode m (generalized cost)

Formulation (1) means that integrated accessibility at zone i is represented by the summation of AC_j^{km} which calculated by formulation (2) and weighted by parameter β^k that reflects the people's sense of values to k.

Formulation (2) means that attractiveness urban facilities are decreased by travel impedance. Its decrease is represented by exponent function. And AT_j^k is standardised by total amount of AT_j^k in whole intended area. Therefore AC_i^m runs from 0 to 1.

Generalised cost is defined by formulation (3).

$$c_{ij}^m = \sum_l^L \left\{ V \left(\frac{d_l^m}{v_l^m} + t_l^m \right) + c_l^m \right\} \tag{3}$$

where, V: value of time l: link L: total number of links between i to j
d_l^m: travel distance on l v_l^m: average speed on link l

t_l^m: summation of wait time, transfer time and delay time on link l

c_l^m: required cost on link l

As an indicator of accessibility in whole intended area, "Weighted average ACcessibility (WAC)" is adopted. WAC is represented by formulation (4). WAC is weighted average accessibility by population of each zone and it is used as indicators which represents the integrated accessibility in whole intended area. If people live in high accessibility zone intensively, WAC becomes high. Therefore, when a value of the WAC is high, it means that transport service or infrastructure is supplied efficiently to residents.

$$WAC^m = \frac{\sum_i^J AC_i^m P_i}{\sum_i^J P_i} \tag{4}$$

AC_i^m: accessibility in zone i by mode m P_i: population of zone i

INTENDED AREA FOR ANALYZING

Intended area for analyzing is Joetsu city, Niigata prefecture, Japan. Figure 1 shows the location of Joetsu city, and Figure 2 shows the population distribution and public transport network.
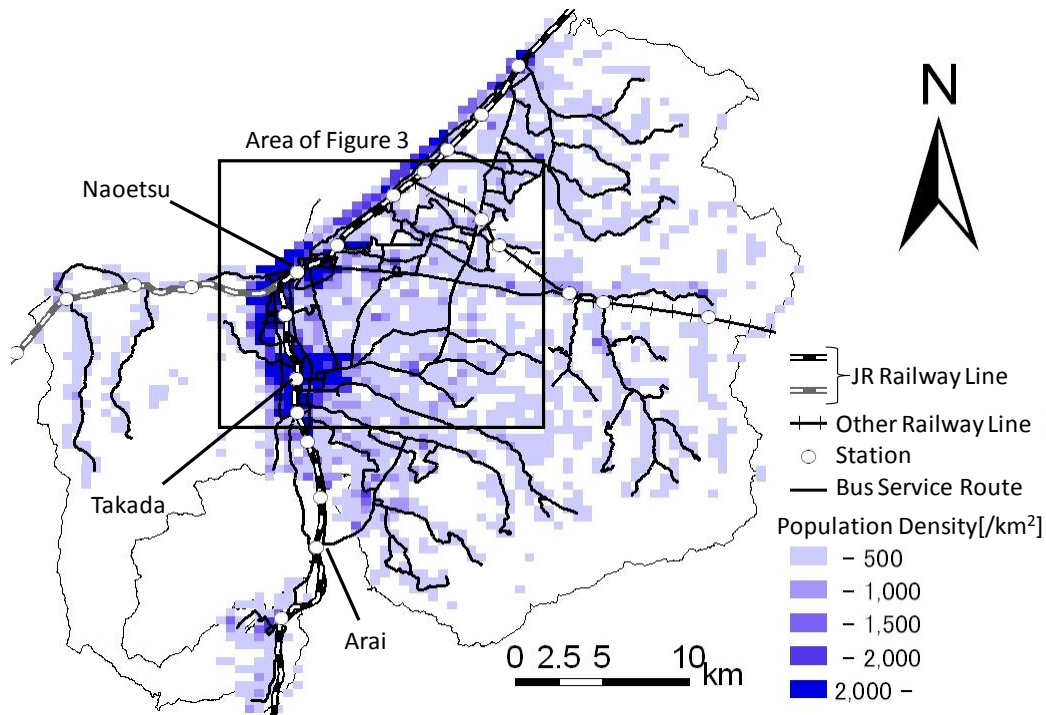
Figure 1 Location of Joetsu City

Figure 2 Population Distribution and Public Transport Network in Joetsu City

The number of population in Joetsu city is approximately 208 thousand peoples. But the area of Joetsu-city is large for population; the width is approximately 973 km^2.

Joetsu city has two central districts, which are named Takada and Naoetsu, and population accumulates these districts and along JR railway line. Then it forms corridor-type urban area. On the other hand, population and some urban facilities have been spreading to suburban area continuously. Figure 3 shows the location distributions of large-scale retail stores and general hospitals. Some of them are located near railway stations, but many of them are now located in suburban area. This means that it is difficult to live without passenger car in Joetsu city.

Public transport in Joetu city is railway (JR and semi-public sector company) and 50 lines bus services. The number of service is little; intra railway service operates approximately every hour in daytime and bus service also operates every hour or less. Consequently, share of passenger car in Joetsu city is very high, 68.6% in weekdays and 79.8% in holidays (2005). And also the rate of car ownership is 1.97 per household, it is as 1.5 times as the average number of Japan (1.33 per household). These facts represent that progress of motorization in Joetsu city is relatively higher than other region in Japan.
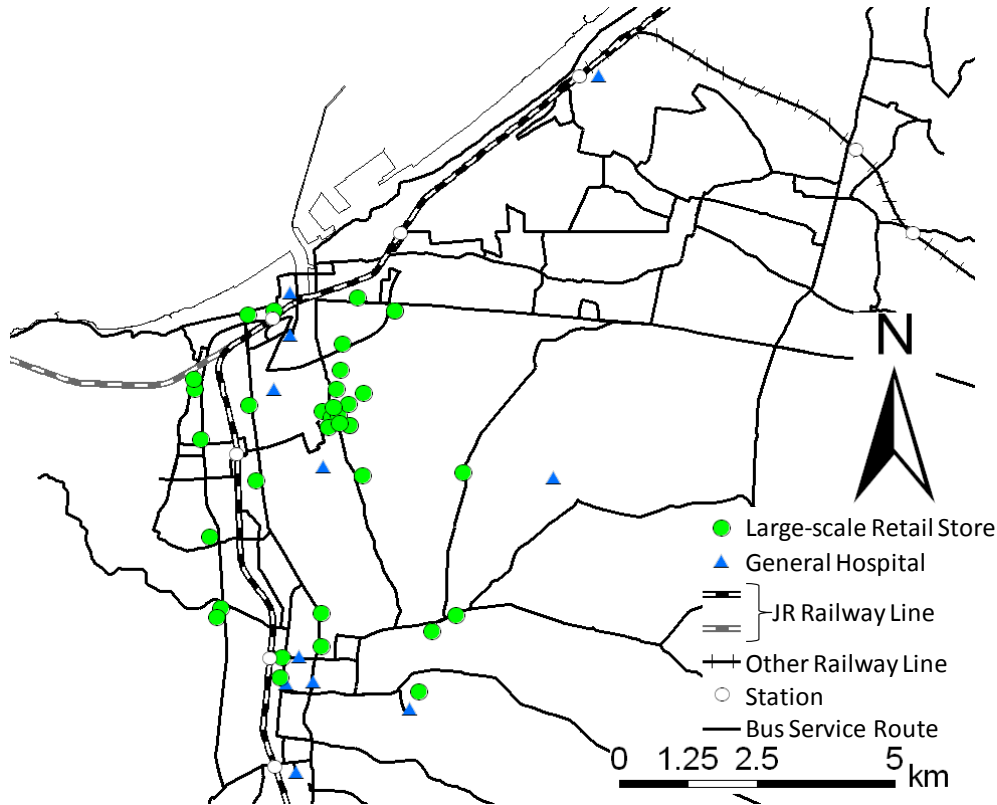

Figure 3 Location distributions of Large-scale Retails Store and General Hospitals

SPECIFICATION OF ACCESSIBILITY CALCULATION MODEL

Parameter Estimation

Parameter α^{km} in formulation (2) is used the result of the estimation of gravity model which shows formulation (5).

$$T_{ij}^{km} = \delta \left(G_i^{km} \right)^\epsilon \left(A_j^{km} \right)^\eta \exp \left(-\alpha^{km} c_{ij}^m \right) \qquad (5)$$

where T_{ij}^{km}: number of trip distribution from zone i to zone j for urban facility k by mode m

G_i^{km}: number of trip generation from zone i to urban facility k by mode m

A_j^{km}: number of trip aggregation to zone j to urban facility k by mode m

c_{ij}: travel impedance from zone i to zone j (generalized cost)

$\delta, \varepsilon, \xi, \alpha^{km}$: parameter

Under ordinary circumstances, gravity model estimated by using the result of person trip survey in Joetsu city. However, significant parameter has not been able to estimate. Therefore, parameter α^{km} is adopted that is estimated by using the result of person trip survey in Nagoya metropolitan area. The value is 0.00128. In addition, this parameter is same value regardless of mode m and category of facility k for precision security.

Parameter β^k is estimated by conjoint measurement by using result of questionnaire investigation intended for residents in Joetsu city about important degree of travel purpose.

Table 1 shows the intended category of urban facility k, attractiveness indicators AT_j^k in this study and results of parameter estimation. Parameters about education, health and shopping are significant; however parameter about employment is not significant.

Table 1 Category of Urban Facility, Attractiveness Indicators and Parameters

category of urban facility	attractiveness indicator	parameter β^k (t-value)
to employment	number of worker	0.0159 (0.8)
to education	capacity of high school	0.320 (13.8)
to health	number of beds in medical facilities	0.341 (14.6)
to shopping and services	floor space of stores	0.323 (14.0)

In generalized cost calculation by formulation (3), value of time is adopted 2,010 yen (approximately 22 dollars).

In case of public transport, travel time is summation of access time, waiting time, boarding time, transfer time and egress time. Access to station or bus stop and egress to destination is assumed on foot (walking speed is 4 km/h). Waiting time at station or bus stop and transfer time is half time of frequency of each line. Boarding time is estimated each lines from timetables. Travel cost is fare.

In the case of passenger car, travel speed is assumed 30km/h in arterial road and 15km/h in other road. Travel route from origin to destination is used shortest one. Travel cost is calculated by fuel consumption (13.8 km/L), price of gasoline (120 yen/L, approximately 1.3 dollars/L) and travel distance.

A zone which is evaluation unit of accessibility is square mesh, approximately 500 meter on a side. The number of zones is 4,063 in Joetsu city.

Present Conditions of Accessibility

Figure 4 shows that present condition of accessibility by public transport. Accessibility contour line is drowning as concentric circle centered in Takada and Naoetsu where urban facilities are gathering in. East zones of Naoetsu along JR line have high accessibility

compared to other zones. This means that railway service is better than other public transport.

Figure 5 shows that the ratio of accessibility by public transport and passenger car transport. Public transport accessibility is very lower than passenger car accessibility, and the WAC ratio is 0.202 (=0.077/0.380). This result means that public transport has little competitiveness to passenger car in Joetsu city. Furthermore, value becomes smaller and smaller from central district to suburban area.
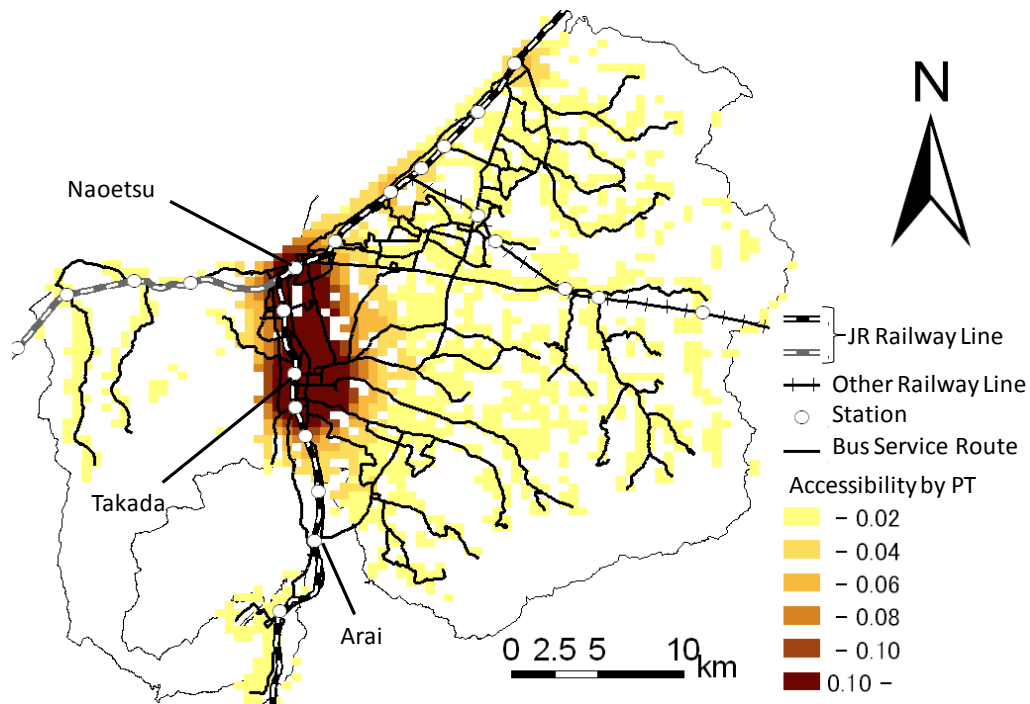

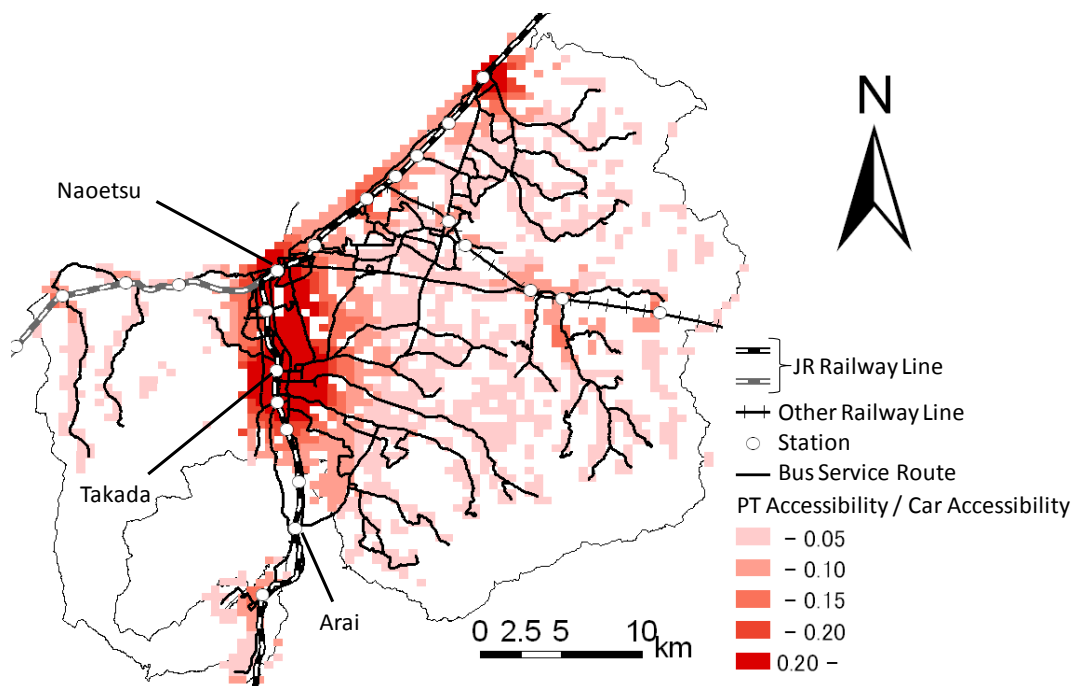Figure 4 Present Condition of Accessibility by Public Transport

Figure 5 Ratio of Accessibility by Public Transport and Passenger Car Transport

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ALTERNATIVE SCENARIOS AND ACCESSIBILITY

EVALUATION

Setting of Alternative Scenarios

Three scenarios are developed and evaluated;
- <A>: concentrative improvement of public transport in urban corridor area
- <B>: average service level improvement of the public transport among the whole intended area
- <C>: urban facilities aggregation to urban corridor area

And present condition called scenario <O>. Table 2 shows the summary of these scenarios.

Scenario <A> is the concentrative improvement of JR line in urban corridor where JR railway line from Naoetsu to Arai (central area of neighbour city) via Takada. Frequency in scenario <A> is every fifteen minutes which is as four times as present frequency.

Scenario <B> is the average service level improvement of bus services in a whole intended area. The improvement cost is the same as the implementation cost and increased running cost by scenario <A>. Increased running cost by scenario <A> is calculated 1.59 million yen per day and depreciation of implementation cost is calculated 17.1 thousand yen per day. If these costs are used to bus service improvement in whole area, bus services are able to increase frequency 1.35 times.

Scenario <C> is urban facilities aggregation to urban corridor area without public transport improvement. To represent this condition, attractiveness of urban facilities in scenario <C> is as twice as present condition.

Scenario <A+C> means that scenario <A> and scenario <C> are implemented at same time.

Table 2 Summary of Alternative Scenarios

scenario	frequency of railway in corridor area	frequency of railway in other area	bus service	urban facility distribution
<O>	1 per hour	1 per hour	same as present condition	same as present condition
<A>	4 per hour	1 per hour	same as present condition	same as present condition
<B>	1 per hour	1 per hour	frequency is as 1.35 times as present condition	same as present condition
<C>	1 per hour	1 per hour	same as present condition	attractiveness of urban facilities in corridor area is as twice as present condition

Evaluation of Alternative Scenarios by "WAC"

Table 3 shows the results of WAC calculation in each scenario. As a matter of course, scenario <A+C> improves WAC value the most, 27.2 % raise in comparison with scenario <O>. Increasing rate of scenario <A+C> is bigger than the summation of increasing rate of scenario <A> and scenario <C>. This result shows that implementation of public transport improvement and agglomeration urban facilities aggregation produces a synergistic effect on accessibility enhancement.

In comparison with WAC of scenario <A> and scenario <B>, scenario <A> is bigger. This result shows that concentrative improvement of public transport along urban corridor area enhances accessibility more than average improvement in terms of WAC.

However, a difference of accessibility in each zone is concerned. Therefore validation of it is performed after the following section.

Table 3 Result of WAC Calculation in each Scenario

		WAC	Increasing Rate from <O>[%]
<O>	present condition	0.077	-
<A>	concentrative improvement of railway service in urban corridor area	0.088	14.8
<B>	average service level improvement of bus service among the whole intended area	0.080	3.9
<C>	urban facilities aggregation to urban corridor area	0.084	8.7
<A+C>	scenario <A> with scenario <C>	0.098	27.2
WAC by passenger car		0.380	-

Accessibility Distribution by Public Transport in each Alternative Scenarios

Scenario <A>: concentrative improvement of public transport in urban corridor

Figure 6 shows that the increasing rate of accessibility in scenario <A> from scenario <O>. Accessibility in urban corridor area, especially Naoetsu and around railway stations, is well improved. Accessibility in other zones near railway station is also well improved. On the other hand, increasing rate in east zones of Takada is lower than zones along railway line.

Scenario <B>: average service level improvement

Figure 7 shows that the increasing rate of accessibility in scenario <B> from scenario <O>. Accessibility in the zones which are far away from railway line is well improved. And increasing rate in such zones, especially end of bus line and east zones of Takada, is higher than scenario <A>. However, increasing rate in other zones is low. In terms of WAC, scenario <A> is better alternative. However, in terms of fairness, scenario <B> has possibilities to be better alternative. Examination about this is performed in next section.

Scenario <C>: urban facility aggregation to urban corridor area

Figure 8 shows that the increasing rate of accessibility in scenario <C> from scenario <O>. Accessibility improvement effect concentrates only corridor area; however, increasing rate is lower than scenario <A>. In other zones, accessibility is not improved. On the contrary, there are zones where accessibility is decreased. This reason is urban facility attractiveness in these zone is relatively decreased by urban facility aggregation to urban corridor. From this, urban facility aggregation without public transport improvement does not have effect to enhance accessibility.
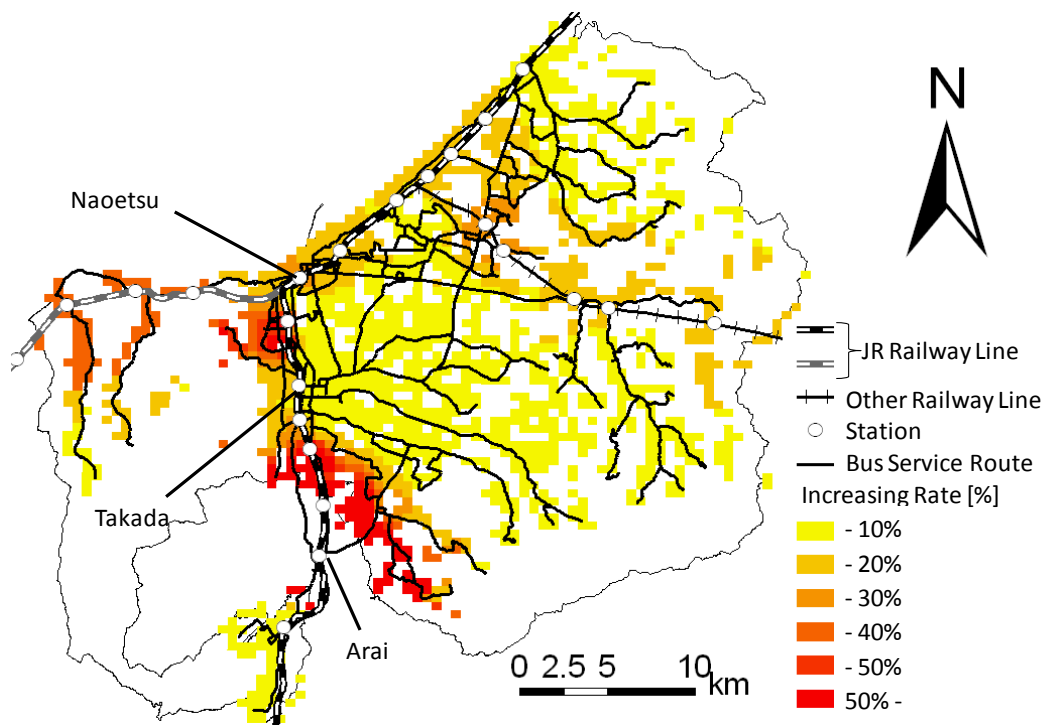
Figure 6 Increasing Rate of Accessibility in Scenario <A>
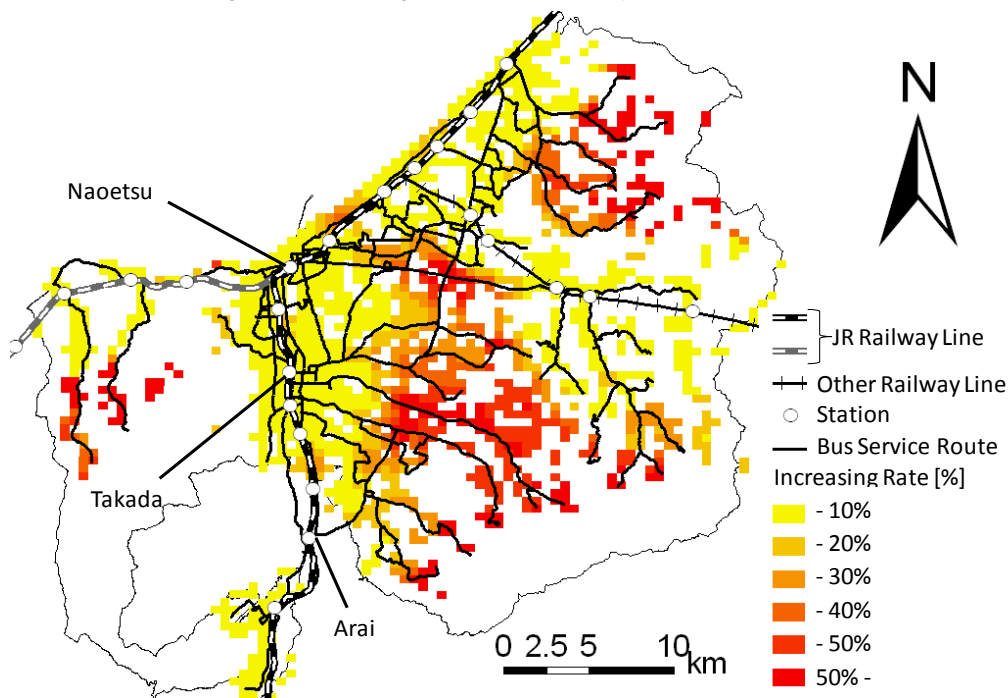
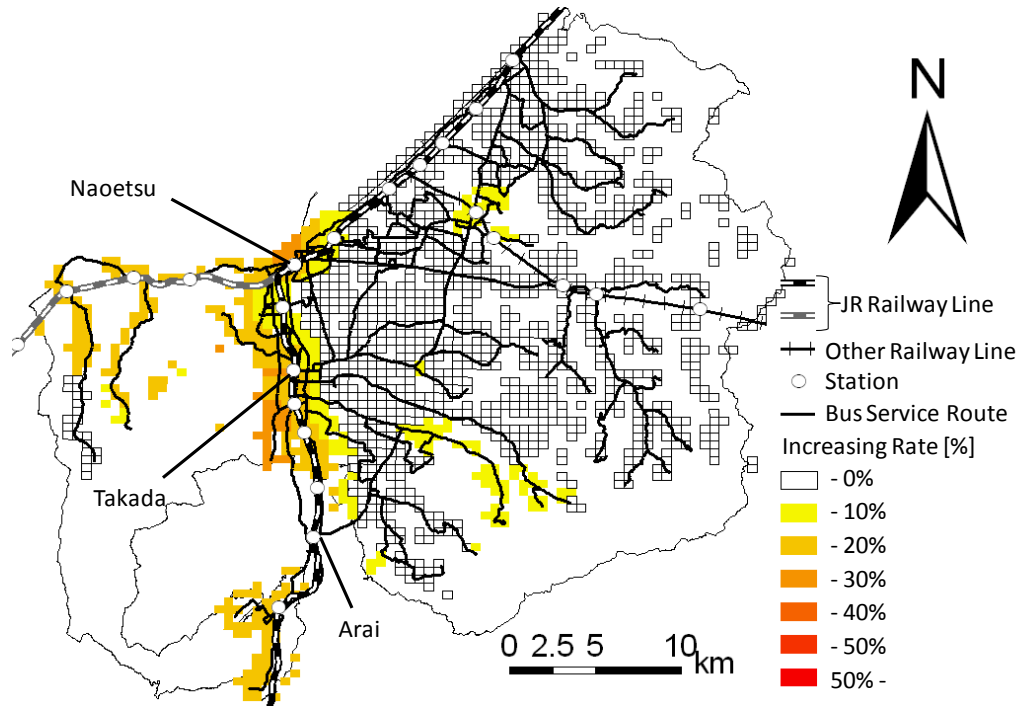Figure 7 Increasing Rate of Accessibility in Scenario <B>

Figure 6 Increasing Rate of Accessibility in Scenario <C>

Evaluation of Fairness by Gini's Coefficient

In former section shows that to enhance accessibility in intend area averagely or effectively, scenario <A> or scenario <A+C> is better alternative. But scenario <B> has possibility to be better alternative in terms of fairness. Therefore, fairness of each scenario is evaluated by Gini's coefficient. Gini's coefficient runs from 0 to 1 and shows that fairness is high so that a value is small.

Table 4 shows that the Gini's coefficient of each scenario. The results suggest that scenario <A> has the highest fairness. Gini's coefficient of scenario <B> is almost as same as scenario <A>. This means that average service level improvement is not always fair alternative than concentrate improvement of public transport.

On the other hand, scenario <C> is more unfair alternative than present condition. This means that urban facility aggregation to urban corridor or center area without public transport improvement expand differential of accessibility. This result suggests that improvement of public transport is essential in terms of fairness. As a result, fairness of Scenario <A+C> is improved.

Table 4 Result of Gini's Coefficient Evaluation in each Scenario

	Gini's coefficient
scenario <O>	0.204
scenario <A>	0.182
scenario <B>	0.184
scenario <C>	0.209
scenario <A+C>	0.190
passenger car	0.291

CONCLUSION

In this paper, accessibility enhancement effect in a whole intended area by concentrative improvement of public transport in urban corridor and gathering population and urban facilities intensively along corridor area are evaluated using potential-type indicator.

In result, to enhance accessibility in intend area averagely or effectively, concentrative improvement of public transport in urban corridor is better alternative. It seems to be unfair alternative; however, it is not always unfair in terms of Gini's coefficient evaluation. In this paper, bus service network is assumed not to be changed; however, implementation of scenario <A> with bus service network revision will enhance accessibility more in whole intended area.

On the other hand, urban facility aggregation to urban corridor area without public transport improvement (scenario <C>) does not enhance accessibility by public transport. Moreover, fairness is get worth. But, urban facility aggregation to urban corridor area with public transport improvement (scenario <A+C>) has synergistic effect on accessibility enhancement. From these results, concentrative public transport improvement in urban corridor enhances public transport network convenience, and high-satisfaction is brought to their user and residents in intended area. And this effect is enforced with land-use development in urban corridor area.

REFERNCE

1) PIVM (Rijksinstituut Voor Volksgezondheid En Mileu): Accessibility measures: Review and Application, RIVM report 408505006, 2001.