A Practical Study on Evaluating the Benefits of Transportation for Building Sustainable Cities

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Abstract: Akashi city is a local city in Japan which has established a comprehensive traffic and transportation plan to create an accessible transport network and improve local public transportation service. This plan builds a review process which follows the plan-do-check-action (PDCA) cycle every 5 years. In 2015, the city verified that plan assuming later review. During the process of verification, it is necessary to make quantitative assessments of the effect of public transportation on making sustainable cities, in the context of building a compact city. Different evaluation indexes from public transportation ridership and mode share are required.

This study confirmed the practical use of new evaluation indexes such as cross-sector benefits and public transportation accessibility in the evaluation process of public transportation in Akashi city.

Keywords: Public Transportation, Cross-sector Benefits, Accessibility, Sustainability

1. INTRODUCTION

In recent years, Japanese public transportation has experienced difficult circumstances, due to depopulation and an aging society. Public transportation ridership has been decreasing, leading to negative effects such as transport network reduction and decreasing quality of public transportation services. On the other hand, the Japanese government has promoted national land policy associating urban development with transport policy for regional vitalization. The policy is named “compact plus network.”

In the movement of public transportation policy development, evaluation has been based on the concept of the plan-do-check-action (PDCA) cycle in Japan. The concept of the PDCA cycle has been adopted for managing public transportation utilization since the concept of PDCA cycle was introduced in local public transportation plans. In recent years, this concept has been integrated into Japanese public policy, and indicated in local public transportation network plans.

However, in the “Check” stage of the cycle, some direct consequences such as changes in ridership and opinion are generally used for measuring the effects of public transportation. For instance, studying the PDCA cycle in a local bus system, Takebayashi and Nitta (2009) pointed out that evaluation by ridership, balance of payments and changes in usage preferences

are generally used in the planning processes of Japanese community bus services. Yajima *et al*. (2011, 2012) focused on the effects of continuing PDCA cycles by performing multiple reviews. They proposed improvements to bus services by assessing satisfaction levels and balance of payments, based on questionnaire results and operating data. Yamazaki *et al*. (2002) also examined the development process of community bus service by evaluating accessibility and frequency of use via questionnaire. Matsunaka (2012) found that many social economic indexes such as proximity to large-scale facilities, consistency with urban planning, potential ridership, conversion from car dependency, transport service level, background population, geography, financial conditions, internal rate and reduction of CO2 have been used to evaluate French urban public transportation projects named in the "Grenelle de l'Environnement" conference.

In recent years, study has focused on the spillover effect of public transportation for cross-sector benefits (Carr *et al*., 1991; Fowkes *et al*., 1994). For instance, Nishimura *et al*. (2014) pointed out that the value and necessity of public transportation have never been clarified in an objective and quantitative analysis. Thus, they focused on the concepts of cross-sector benefits and calculated various costs related to the field of transportation in cities without public transportation. They indicated that a lack of public transportation has measurable disadvantages.

Conventionally, accessibility, which can measure access opportunities to destinations by public transportation is used for policy assessment (Tanimoto, 2007) and implications (Cheng and Chen, 2015). However, a simplified method of calculating accessibility has not been defined well for practical use.

In this study, the authors attempt to construct a process for evaluating Akashi City's public transportation effects based on the methodology of evaluating approaches in practical studies on public transportation.

2. PROCESS OF PLANNING REVIEW IN AKASHI

2.1 Outline of Traffic and Transportation Planning in Akashi

The Traffic and Transportation Plan of Akashi (TTPA) is an individual plan which contains the fifth comprehensive plan of Akashi (formulated in March, 2011). It is designed considering the sustainable city and movement of people. TTPA is positioned as the master plan of overall transportation policy, which includes the direction of road and traffic systems.

The purpose of TTPA is to clarify the essential strategy and scheme for establishing traffic and transportation systems which can change with the time and provide safety and accessible movement for everyone, based on promotion of public transportation utilization.

The basic idea of the TTPA is the realization of applying regional characteristics in city planning through active exchange. The planning period is from 2013 to 2022.

In the TTPA there are five basic strategies: Constructing a traffic and transportation system centering on public transportation, making a safe and highly-accessible traffic environment, approaching the realization of low carbon society, promoting active exchange and fostering a sense of value for public transportation. A wide variety of traffic and transportation measures are carried out on the basis of these five basic strategies. In addition, for the purpose of promoting the development of packaged programs based in basic strategies, Akashi city has set five main programs: A branding strategy for Akashi, revitalization of the city center, development of transportation nodes, restructuring the bus network and improving traffic safety. The city has introduced practical efforts regarding each project.

2.2 Process of Planning Review

In the TTPA, planning review is scheduled every five years after checking project effects and changes in the environment surrounding public transportation such as social changes,

development and financial conditions. Figure 1 shows the concept of PDCA in the TTPA.

Based on the concept of PDCA, in 2015 a committee for mid-term evaluation of the TTPA was established, and traffic and transportation measures were introduced in parallel. The committee plans to review the TTPA in 2017 based on the mid-term verification, which will readjust traffic and transportation strategies.

In this study, the authors consider the progress of developing programs related to public transportation and useful for evaluating public transportation in the mid-term verification of the TTPA.

In the TTPA, three numerical targets (public transportation ridership, rate of public transportation modal split and rate of outgoing trips) are considered as the results of development programs related to public transportation (also part of Check in PDCA). Numerical targets are shown in Table 1.

The following section details measurements for the achievement of these three targets.

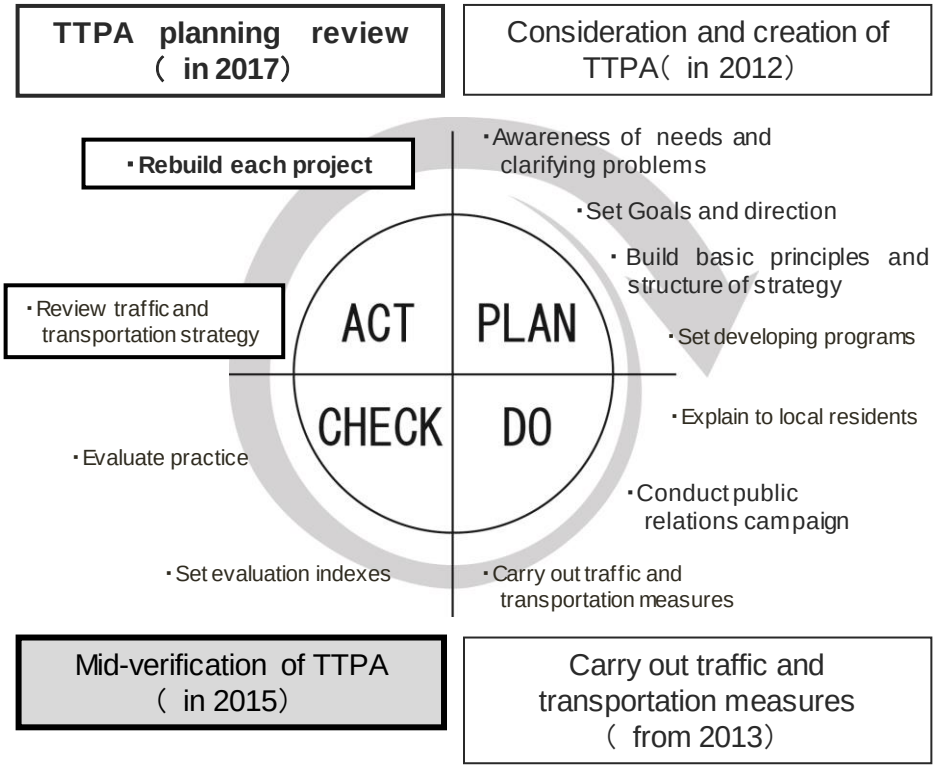


Figure 1. PDCA of TTPA （Akashi city, 2013, edited by authors）

Table 1. Numerical targets

	Index	Target values in 2022	Process for setting target values
(1)	Public transportation ridership	One hundred million riders per year	Based on the peak value in 1995
(2)	Rate of public transportation modal split	Increase to 22% by 2022	Calculated by target value of '(1) Public transportation ridership' and population projections in the fifth comprehensive plan of Akashi
(3)	Rate of outgoing trips	Maintain standards at 77%	Assumed that the rate of outgoing trips in 2010 is maintained

(1) Public transportation ridership

Public transportation ridership is defined as the summation of railway, bus, marine traffic and taxi ridership in each year. The target value is a total ridership increase to one million riders per year in 2022 in order to maintain vital service level.

In Figure 2, annual public transportation ridership is 9,484 million in 2014. Assuming preservation of this trend, ridership in 2022 would reach the target value.

Figure 3 shows ridership for each public transportation mode from 2007. Railway users have increased since 2010, but there is a downward trend between 2013 and 2014. Bus users have also increased from 2010, and in 2014 ridership hit its largest value since 2007. However, marine ridership and taxi use has decreased since 2007.

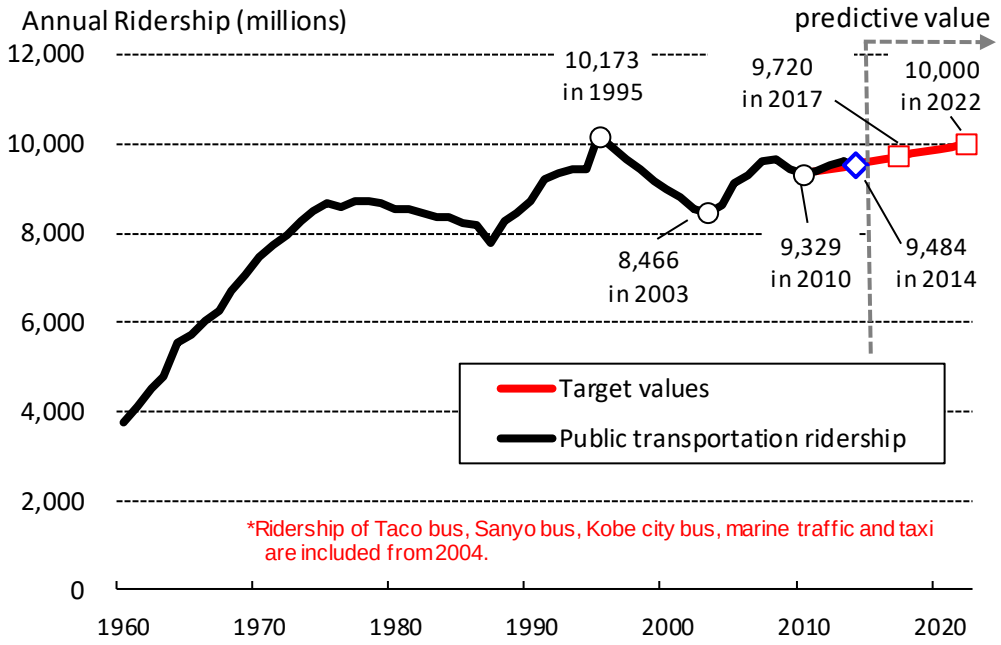


Figure 2. Trend of public transportation ridership (Akashi city, 2013, edited by authors)

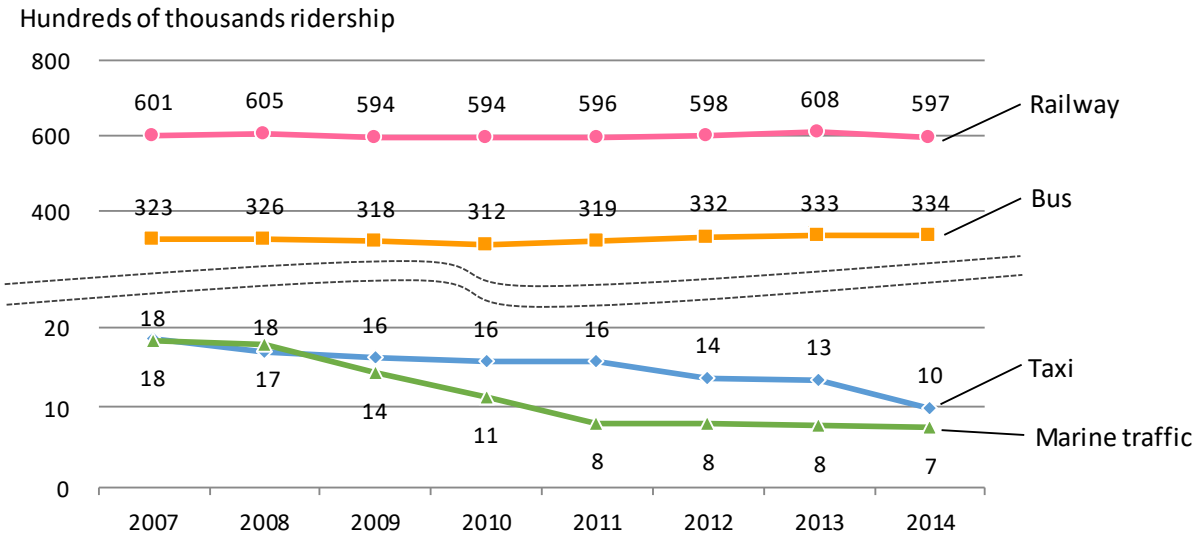
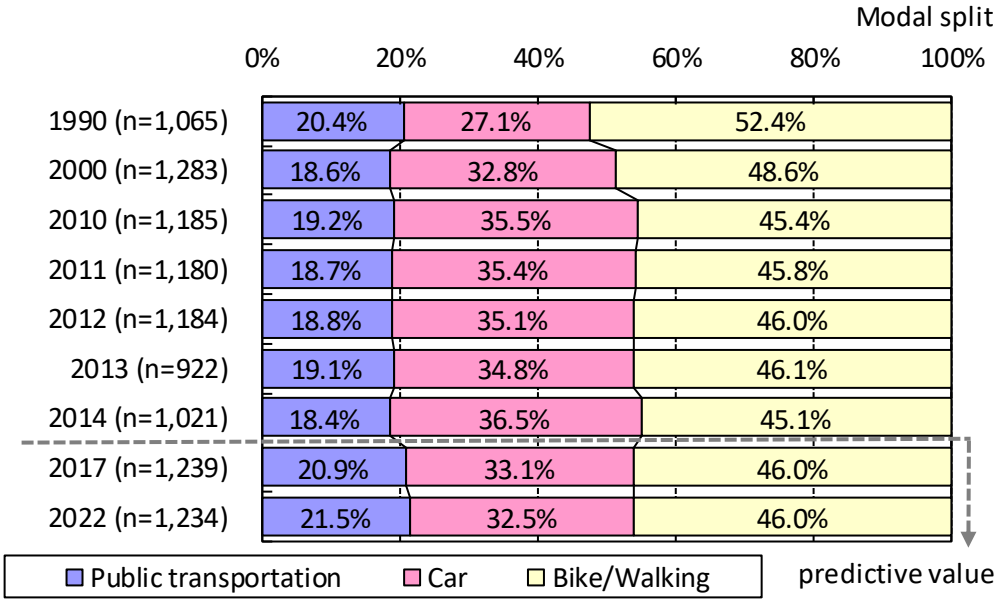


Figure 3. Public transportation passengers, by mode

(2) Public transportation modal split

Target values for public transportation modal split suppose car use decreasing to 32%, and public transportation use increasing to 22% by 2022. The purpose of these targets is to promote a modal shift from private car to public transportation, bicycling and walking.

Figure 4 indicates that the rate of public transportation use has remained unchanged since 2010.



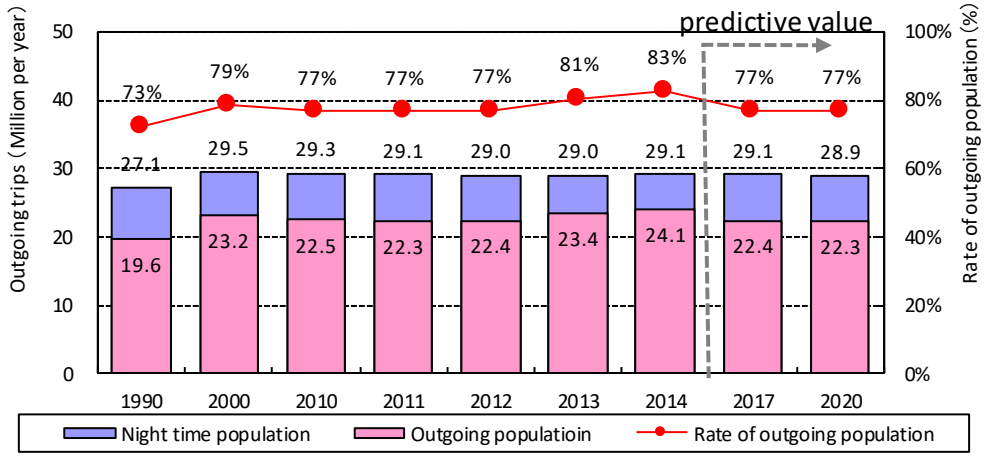
Source: Census (1990 - 2010), Fifth comprehensive plan in Akashi, Third person trip survey in Kinki, Fourth person trip survey in Kinki, Fifth person trip survey in Kinki, Person trip small survey (2011-2013)

Figure 4. Modal split, by year (Akashi city, 2013, edited by authors)

(3) Rate of outgoing trips

The target for outgoing trips* in 2022 is to maintain standards at 77%, as recorded in 2010.

Figure 5 shows that the rate of outgoing trips has increased since 2012, and the value in 2014 was 83%, the highest value since 1990.



Source: Census (1990 - 2010), Fifth comprehensive plan in Akashi, Third person trip survey in Kinki, Fourth person trip survey in Kinki, Fifth person trip survey in Kinki, Person trip small survey (2011-2013)

Figure 5. Change in rate of outgoing trips (Akashi city, 2013, edited by authors)

* Rate of outgoing trips is defined as the number of people making trips outside the home on the given survey date.

2.3 ISSUES OF TTPA REVIEW

As described above, public transportation ridership and the rate of outgoing trips indicated upward trends. However, in recent years, population decline and aging population are becoming apparent in Akashi.

For instance, of the rate of expenditure for each department in Akashi, the rate of expenditure in civil engineering (costs in road construction, parks and municipal housing, maintenance of these facilities, and project costs of public transportation measures) trends downward just as the increasing rate of people's livelihood (such as welfare costs of assistance for elderly, disabled and caregivers) trends upward. These trends are shown in Figure 6.

Figure 7 shows trends of the balance for city bonds and funding balance. The balance for city bonds which is the equivalent of the city's debt has increased in recent years, and the fund balance which is the equivalent of the city's savings have remained unchanged. It shows that Akashi faces an extremely tight fiscal situation.

However, public transportation is an indispensable presence for elderly and young people who cannot drive. Therefore, measuring a sustainable city by its maintenance of public transportation is not only evaluated by output indexes such as ridership and public transportation modal split, but also evaluated in areas other than traffic and transportation from a standpoint of the necessity to continue public transportation such as community bus service.

This study is intended to build a process which can perform multifaceted evaluation of policy effects regarding public transportation in Akashi. In order to achieve this purpose, a public transportation accessibility index and cross-sector benefits are selected as performance indicators.

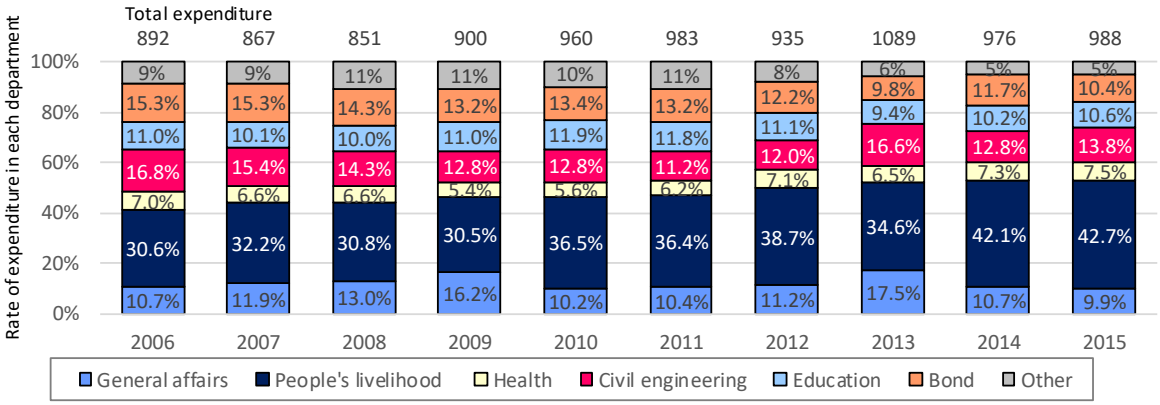


Figure 6. Rate of expenditure in each department (Akashi city, 2016, edited by authors)

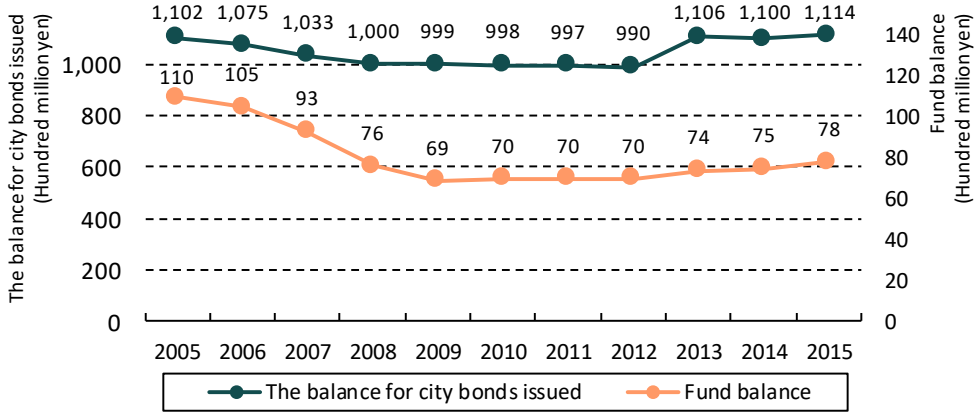


Figure 7. Trends of the balance for city bonds issued and fund balance (Akashi city, 2016, edited by authors)

3. EVALUATING PUBLIC TRANSPORTATION ACCESSIBILITY

3.1 CALCULATING AN ACCESSIBILITY INDEX AND YEARLY COMPARISON

Accessibility can be defined as an indicator of the impact of land-use and public transportation development and policy plans on the general function of society (Geurs and van Wee, 2004). Geurs and van Wee also defined the components of accessibility: the land-use component, the transportation component, the temporal component and the individual component. However, many studies focusing on the relationship between changes in accessibility and urban development have defined accessibility as travel time by using transportation. For instance, Hou and Li (2011) defined accessibility as the inter-city travel time and showed that inter-city railway development has reduced travel time and increased economic and population potentials of cities. Papa and Bertolini (2015) focused on the effects of Transit Oriented Development for accessibility, which in their study was defined as travel time using public transportation.

In this study, the authors selected public transportation accessibility, developed as an intelligible index by the Public Transport Policy Department, Policy Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT) to clarify the changes in accessibility in Akashi city.

The purpose of MLIT in studying public transportation accessibility is to promote compact cities based around public transportation. It expresses the service level of public transportation as evaluated in terms of three general factors: length of public transportation service line, frequency of transportation services and total score of these two values. Public transportation accessibility comprises three types: Spatial accessibility, Temporal Accessibility and Integrated accessibility (see Table 2).

MLIT issued a municipal evaluation survey which measures the three accessibility types for each public transportation; railway, and the comprehensive public transportation mix. The survey is distributed to each city where the population is more than ten-thousand. Each city can learn about its level of accessibility as compared with the national average.

Table 2. Public transportation accessibility

Accessibility		Description
(1)	Spatial accessibility	・ Length of service line. ・ Spatial accessibility increases as density of service lines to regional area increases.
(2)	Temporal accessibility	・ Frequency of service. ・ Temporal accessibility increases as frequency of service increases.
(3)	Integrated accessibility	・ Product of spatial accessibility and temporal accessibility

Figure 8 shows the calculated result of three public transportation accessibility indexes, described in the municipal survey of Akashi.

Each accessibility value is calculated by regression formula based on the data set of 1720 municipalities as of December 1, 2012.

Focusing on the results for Akashi, spatial and temporal accessibility of railway service are smaller than the national average, but total accessibility is higher. This is due to the regression formula for integrated accessibility being different from simply multiplying spatial accessibility by temporal accessibility.

Spatial accessibility of bus service is larger than the national average, but temporal accessibility is smaller.

Comprehensive evaluation of public transportation shows that spatial accessibility is

larger than the national average, but temporal accessibility is smaller. In other words, length of railway and buses indicate high density in the region, but the service level of these remain at a low level compared with the national average.

3.2 RECALCULATING THE ACCESSIBILITY TARGETED IN 2015

(1) Background of recalculation

Public transportation accessibility indexes evaluated in the municipal survey provide easy comparison with other cities due to calculation using the same method. However, the data set was built in 2010, and railway and bus services included not only ordinary services but limited services.

In this study, the authors have calculated public transportation accessibility in Akashi focusing on ordinary railway and bus services in October, 2015. In addition, accessibility in 2010 was recalculated to only consider ordinary services. In this manner changes in accessibility could be captured.

(2) Methodology

Initially, network data for rail and buses services was constructed using Geographical Information System (GIS). We calculated the length of these networks and estimated total travel distance by measuring the frequency of rail and bus service at rail stations and bus stops on ordinary days, then multiplying the length by frequency of transportation service. However, we omit limited bus services such as nonstop service for schools and hospitals, because of restricted user base.

In this regard, for comparison of accessibility between 2010 and 2015, we calculated the accessibility of 2010 in same way as for 2015 by using railway and bus service data which is published on the National Land Numerical Information download service. Figure 9 shows the Akashi railway and bus networks in 2015.

(3) Result of recalculation

Figure 10 shows the results of recalculation for each year. Between recalculation results, there is no major difference in railway service accessibility, but in bus service temporal accessibility decreased because we targeted ordinary public transportation services. As a result, temporal accessibility of public transportation service also decreased.

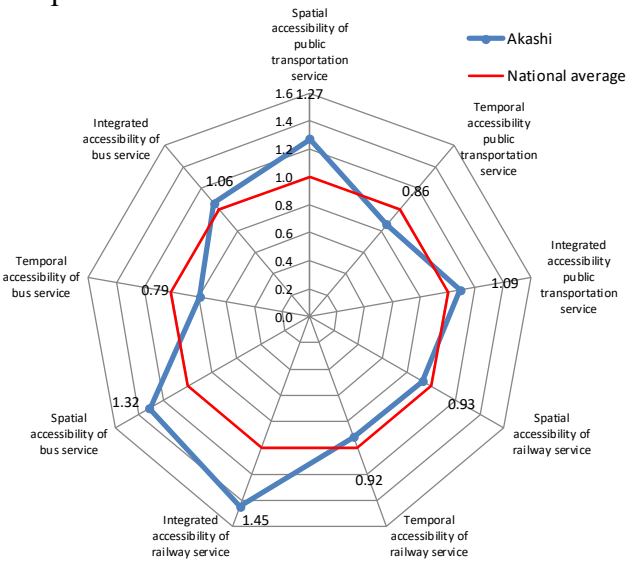


Figure 8. Public transportation accessibility in Akashi (MLIT, 2015)

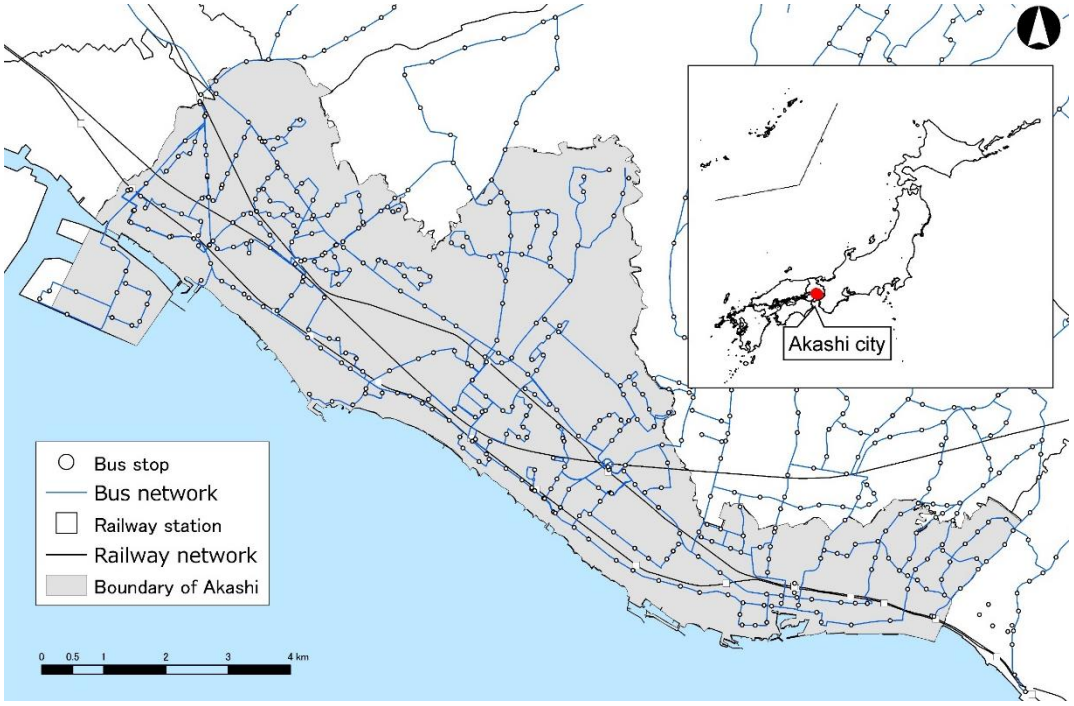


Figure 9. Public transportation network in 2015

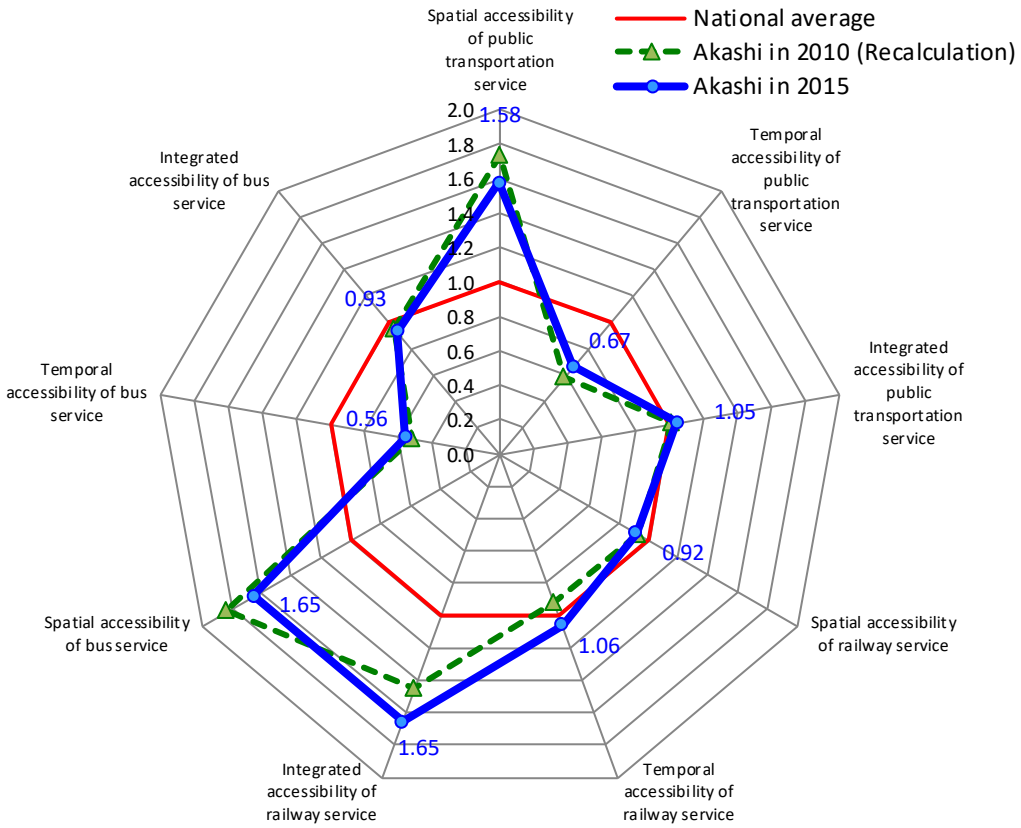


Figure 10. Public transportation accessibility in Akashi (Recalculation)

Focusing on changes in accessibility over time, we find no change in spatial accessibility of railway service because new railway routes were not developed between 2010 and 2015. On the other hand, temporal accessibility increased in same period, because of increasing frequency of railway service. As a result, integrated accessibility has also increased.

Nevertheless, spatial accessibility of bus service decreased, and temporal accessibility increased, therefore integrated accessibility indicated the same value in 2015 as in 2010. The reason for decreasing spatial accessibility of bus service is that Akashi city transitioned a city bus to a private business operator in March, 2012. Therefore, there is no changes in bus service level from the perspective of users, but spatial accessibility has decreased by losing total length from the municipal bus network.

3.3 REGIONAL PUBLIC TRANSPORTATION ACCESSIBILITY

Public transportation accessibility can be calculated easily. Therefore, we can divide some small region and determine regional accessibility as a tool for investigating gaps in public transportation service level.

Figure 11 shows the regions in the TTPA. Figure 12. indicates the result of calculating regional accessibility in 2010 and 2015.

For regional accessibility, Akashi eastside and Nishi-Akashi enjoy high integrated accessibility of railway service. Because of that these areas include the stations which have larger number of the passengers. There is a key traffic area in Akashi eastside, and spatial accessibility of bus service in this area also indicates high standards compared with other regions. On the other hand, accessibility of railway and bus service in Uozumi is low, indicating a regional divide in public transportation accessibility. In the Futami area, spatial accessibility of bus service increased between 2010 and 2015 due to newly introduced bus service on the artificial island is located to the southeast of Akashi.

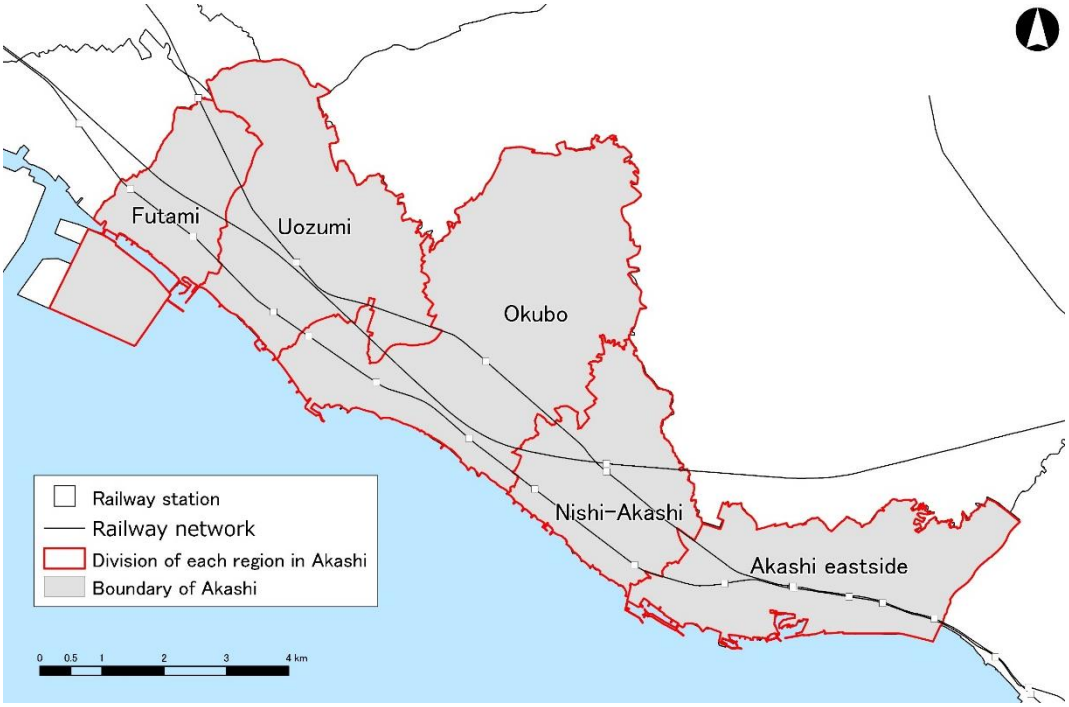
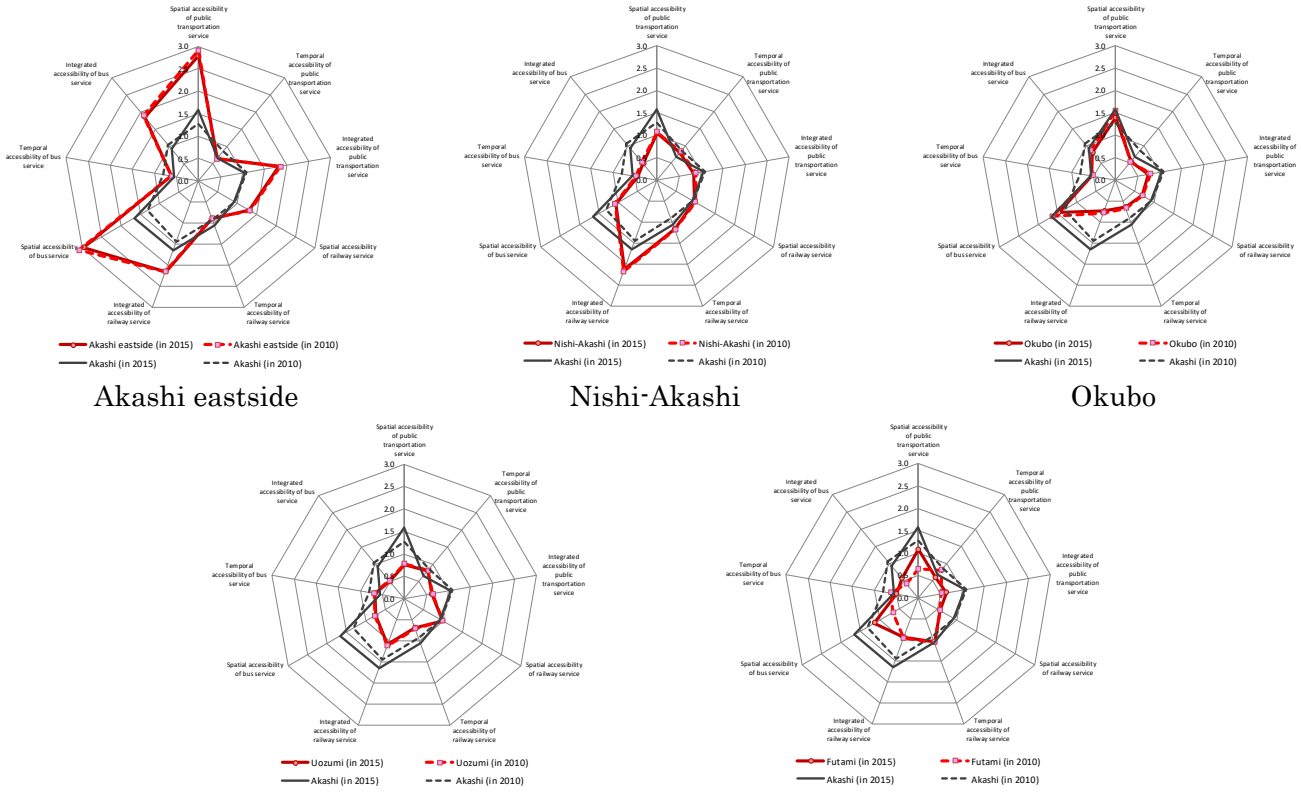


Figure 11. Regions in Akashi



Akashi eastside　　Nishi-Akashi　　Okubo

Uozumi　　Futami

Figure 12. Regional public transportation accessibility

3.4 REMARKS OF PUBLIC TRANSPORTATION ACCESSIBILITY

Many calculation methods for transportation accessibility have already been proposed, mainly in academia. However, there is no method to easily calculate accessibility at the national level. By using MLIT's municipal survey of public transportation accessibility, it is possible for each city to compare itself with other cities, and to evaluate its public transportation service level objectively. In addition, it is also possible to understand changes over time and regional gaps by using the disclosed calculation method. In other words, we can measure the impact of public transportation policy on public transportation accessibility.

However, from the point of view of keeping public transportation established, the benefits of public transportation related development are not made clear by evaluating accessibility alone. As such, the authors tried to use the concept of cross-sector benefits to calculate the social benefits of community bus service, which is one of the public transportation systems in Akashi.

4. CROSS-SECTOR BENEFITS OF RUNNING AKASHI COMMUNITY BUS

4.1 BRIEFING OF CROSS-SECTOR BENEFITS AND TARGET PROGRAM

(1) Outline of cross-sector benefits of public transportation

In the field of public transportation, cross-sector benefits can be described as the effects on related sectors of keeping public transportation established, valuated by the possibility of social cost savings (Fowkes 1994). Nevertheless, there is no established method to calculate the cross-sector benefits of public transportation. In this study, the authors tried to confirm the calculation of the cross-sector benefits targeting community bus* service in Akashi, based on the previous study of Nishimura *et al.* (2014).

* Community bus service in Japan is established by local governments in order to eliminate regional transit deserts.

(2) Community bus service in Akashi

The Akashi community bus service known as “Taco bus” began running in 2004 as a social experiment, with full-fledged fare based service beginning in 2006. Initially, the community bus played the role of connecting the core rail station and west of Nishi-Akashi where there are vulnerable bus networks and high car dependence. The TTPA (in May, 2007) described this role. In 2007, the community bus was extended to reduce inconvenient transport areas and secure the mobility of mobility-constrained residents. As of 2015, total bus routes including the “Taco bus mini” number 15 (Taco bus with 9 routes, Taco bus mini with 6) total. Fare for all lines is 100 yen for adults, 50 yen for children. Figure 13 shows trends in Taco bus and Taco bus mini ridership. Ridership showed upward trends since 2007, and more than one hundred-thousand people have used the Akashi community bus in 2015.

From the results obtained in investigation of the actual state of public transportation users in 2014 (Akashi city, 2014), Figures 14 and 15 indicate that major Akashi community bus users are women and elderly people (over 65 years old).

As seen above, total ridership on the Akashi community bus has increased in recent years, and community bus service plays a part in a mobile lifestyle, especially for elderly people. However, some routes have not been able to surpass the standard 50% ratio of current income to current expenses (Taco bus mini is 20%). As a result, Akashi expenses about one hundred fifty million yen every year for maintaining community bus services, in the form of grants.

Figure 13. Trend of Taco bus and Taco bus mini ridership

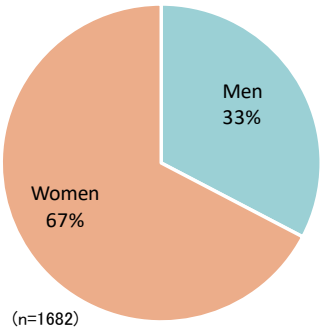


Figure 14. Gender of Akashi community bus users

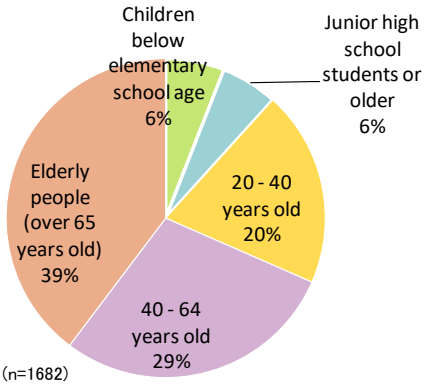


Figure 15. Age of Akashi community bus users

Based on these situations, the public transportation sector will be caught in a financial crunch because of increasing of social welfare costs. Multifaceted policy evaluation of continuing community bus service will be quite necessary for Akashi in the future.

4.2 POLICY EFFECT OF RUNNING AKASHI COMMUNITY BUS

Nishimura *et al.* (2014) described twelve sectors which can be used to evaluate the necessity of public transportation: medical, welfare, commercial, education, sightseeing, construction, disaster-prevention, traffic safety, general affairs, urban and regional planning, environment and regional community.

From the point of view that the Akashi community bus service is intended to reduce transport inconvenience, this study focused on seven sectors in order to calculate cross-sector benefits: medical, welfare, commercial, traffic safety, general affairs, environment and regional community. Table 3 shows the result of these calculations, in terms of cross-sector costs if Akashi community bus were canceled.

This study calculated cross-sector benefits based on calculation methods from previous studies, using assumed values contained in publicly available data. Under normal circumstances, benefits should be calculated based on actual costs as informed by related sections of each sector. Therefore, in the practical operation of cross-sector benefits, establishment of a cooperative framework includes not only public transportation section as a whole, but also related sections for sharing information.

Focusing on the calculated results, the costs of canceling the Akashi community bus total about 5 hundred million yen per year. In contrast, expenses of Akashi community bus service in 2014 were about 1.5 hundred million yen. As a result, social benefits of Akashi community bus are larger than the yearly subsidies the city spends on the unprofitable service.

As for policy evaluation of the role of public transportation in society, results indicate that evaluation from the point of view of cross-sector benefits is more desirable than evaluation considering only the ratio of current income to current expenses, which is generally used on bus service evaluation by Akashi city and many other bus service companies in Japan. Moreover, the social benefit derived from running the Akashi community bus indicates that to maintain the Akashi community bus is desirable.

On the other hand, there are some remaining issues. In this study, total cost saving effects of Akashi community bus are around 3.5 hundred million yen. This amount is about 2.3 times the subsidies for running the Akashi community bus, and many times its operating costs. It is difficult to use the current method of cross-sector benefits evaluation as a basis for reviewing individual bus routes, as is emphasized in Nishimura *et al.* (2014). Nevertheless, this method will be useful for evaluating the social benefits of maintaining an entire community bus system.

5. Conclusion

In recent years, building compact cities has become a focus in Japan for responding to changes in social and financial situations caused by depopulation and aging society. In this study, the authors constructed a process to evaluate public transportation effects based on the methodology of multifaceted evaluation approach in public transportation practical studies.

Firstly, we clarified the trends of basic indexes such as public transportation ridership and public transportation modal split, which are focused as the output index of transportation policy. In Akashi, public transportation ridership has increased in recent years. This can be considered an effect of transportation measures implemented in the traffic and transportation plan of Akashi.

Table 3. Results of calculating of cross-sector benefits for Akashi community bus (assuming cancelation of bus service)

Sector	Measures for each sector	Annual Cost (thousand yen)	Assumptions	Year of data
Medical	Transportation service to hospital	116,096	Expenses for hospital bus service running at same levels as Akashi community bus.	2014
	Increase of medical expenses	19,561	Walking time decreased from more than thirty minutes to less than thirty minutes when the user can no longer use Akashi community bus. Longer walking time is considered a health benefit, meaning that reduced walking time can be evaluated as a loss.	2014
Welfare	Free distribution of taxi tickets and new transportation service	320,286	Distribution of taxi tickets equivalent to 1,360 yen per month (one-way 680 yen) to residents over 70 living more than 300m from Akashi community bus stops.	2015
	Further preventive long-term care service	3,638	Multiply expense per person of existing long-term preventive care by Akashi community bus users over 65.	2013
Commercial	Door-to-Door Sales of daily necessities	8,615	Multiply expense per person of existing meal long-term care delivery services by Akashi community bus users over 65.	2013
Traffic safety	Increases in traffic accident and safety education for elderly drivers	7,027	Appointment of police exclusively assigned to traffic safety measures targeted at elderly driver.	2014
General affairs	Further measures to support population increase settlement policy	7,120	Existing measures doubled	2015
Environment	Further measures to fight global warming	13,656	Existing measures doubled	2013
Regional community	Further measures to support the outgoing trips	8,513	Existing measures doubled	2013
Total Cost		504,512		
Subsidies for Akashi community bus service in 2014		155,361		
Total cost saving benefits of Akashi community bus		349,151		

Considering expenditures in each department in Akashi, the rate of expenditure in civil engineering indicates downward trends while increasing the rate of people's livelihood, and public transportation in Akashi faces an extremely tight fiscal situation. Therefore, it is necessary to consider by numerical evaluation the effects of public transportation for creating a sustainable city.

As for policy evaluation of public transportation by analyzing accessibility, we calculated public transportation accessibility for railway and bus service in 2010 and 2015. We clarified that frequency of railway service serves to increase temporal accessibility. However, the spatial accessibility of bus service has decreased from 2010 to 2015 because of the transfer of city bus service to a private business operator in 2012, though there were no changes in bus service level from the perspective of riders.

Finally, we calculated the cross-sector benefits of the Akashi community bus. Results show that the total cost saving effects of the Akashi community bus service are larger than its running subsidies. In other words, Akashi community bus has a positive social benefit, and the need to maintain community bus service is clear.

To measure policy effects of maintaining public transportation in a society of constant change, we evaluated public transportation in Akashi city by verifying the practical availability of new evaluation indexes (such as cross-sector benefits and public transportation accessibility). Accordingly, the following two main findings were confirmed:

- Public transportation accessibility can be understood by simple calculation of service level, changes over time and regional gaps.
- There is no established method to calculate the cross-sector benefits of public transportation, and it is difficult to use the current method as a basis for reviewing individual bus routes. However, social benefits and necessity of maintaining public transportation can be clarified in a quantitative way.

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