Estimating Riding Frequency Change of Community-bus by LOS Change of Bus Operation
- A Case Study on "Kururin-bus" in Nisshin City, Japan -

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Abstract: Many municipalities in Japan operate bus services in order to support inhabitants' daily lives. This bus is called a "community-bus" in Japan. In general, a level of service of the community-bus is lower than that of a bus operated by a private company. However, it is expected to raise the number of passengers for reducing the municipal expenditure. Therefore, consciousness of a community-bus was investigated at Nisshin City in Japan, so that riding frequency changes of the community-bus by the "fare", the "interval" or the "travel time" change were able to be grasped. The result shows the level of service (LOS) changes in the interval and the travel time affect the riding frequency more. By a model describing a relationship between the LOS and the riding frequency, the riding frequency distribution was identified. Moreover, the fare revenue was also estimated when the LOS of the community-bus would be changed.

Keywords: Community-bus, LOS, Riding frequency, Consciousness, Fare revenue

1. INTRODUCTION

Japan has been becoming a motorized society even now, especially in suburban area. Currently, the car ownership in Japan remains high and, conversely, the number of public transportation passengers has been declining gradually. Moreover, Japan has confronted enormous challenges with aging population now. Generally, it becomes difficult to continue driving a car in proportion to age due to a decline of physical function. Traffic accidents involving an elderly driver who is 65 years old and over have been increasing year by year in Japan. It is expected that the elderly weakened in physical function stops driving as soon as possible. However, there is no way for the elderly to travel in a daily life if public transportation service is not provided around the area where the elderly lives. Furthermore, not only the elderly but also people without a driving license (e.g., the handicapped or students) will experience mobility difficulty more in area where public transportation is not provided.

It is an important duty for a municipality to provide reliable public transportation service especially for the elderly and also the handicapped. Many municipalities in Japan therefore introduce bus services and spend on a part of the bus operating cost in order to support lives of inhabitants who cannot drive a car. This bus is called a "community-bus" in Japan. The fare of a community-bus is set to be cheaper such as free of charge or 100 yen because a community-bus is regarded as a part of public service. Consequently, although expenditure of a municipality to operate a community-bus has become a burden, inhabitants

require to maintain community-bus service and to ensure their daily mobility. The simplest solution for this problem is to reduce operating cost. In order to reduce operating cost, a municipality must cut off some services. However, this may not be able to gratify the requirement of people with mobility difficulty. Another solution for this problem is to increase fare revenue. For this, a possible way is to raise the fare or to increase the number of passengers. However, it is so difficult for a community-bus to increase passengers in a short time, because patronage of a community-bus is mainly those who can't drive a car. Consequently, it must be required to cut off some services and also to keep the number of passengers at least, which can reduce the expenditure of the operating cost and continue the community-bus operation. In order to keep the number of community-bus passengers after cutting off the services, it is necessary to clarify the demand of community-bus passengers when the level of service (LOS) is changed.

Kakimoto *et al*. (2011) show that many problems have appeared because demand and developmental level of public transportation are different between areas by amendment of Road Transport Law in 2002, Japan. In particular, the cost efficiency has been getting worse after the deregulation. Ichikawa *et al*. (2013) reveal that fare revenues of community-bus service cover only about 25 % of the operating expenses on a national average, and suggest that municipalities have to review carefully for introducing a Demand Responsive Transit (DRT) from financial perspective as a sustainable local transportation mode. Welfare economic approach applied by Ljungberg (2010) shows that operating local public transportation requires to increase subsidization but it would give rise to a net social benefit. In research of bus service, Hoang-Tung *et al*. (2013) successfully propose a psychological demand model for bus service industry. They reveal that people judge service quality based on both satisfaction and emotion related to the target service quality. Moreover, several researchers have addressed bus services with demand equilibrium (Kocur *et al*. 1982; Paulley *et al*. 2006), and also community-bus service (Okayama *et al*. 2010; Takebayashi *et al*. 2010; Yoshida. 2014). These researches have addressed to describing the relationship among the user consciousness, the LOS and the demand of bus passengers. However, a distribution change of the riding frequency by the LOS changes has not been clarified yet.

For clarifying the suitable level of bus service to keep the number of community-bus passengers after cutting off the services, this study aims to grasp the changes of the riding frequency and also the distribution by the LOS changes of community- bus service. Important factors of the bus service are generally "fare", "time table" and "route". In this study, "fare", "interval" and "travel time" are selected as the factors of the LOS, in which "interval" can be regarded as an average waiting time calculated by "time table" and "travel time" can be substituted for "route". Consciousness on the community-bus service is therefore investigated by a questionnaire at Nisshin City, Aichi prefecture in Japan so as to grasp the actual riding situation of the passengers and also the relationship between the LOS of the community-bus operation and riding frequency of the passengers. Furthermore, an estimation model of a riding frequency distribution when the "fare", the "interval" and the "travel time" of the community-bus are changed, and the optimal combination of the LOS to maximize the riding frequency is sought by the constructed model.

2. SURVEY ON CONSCIOUSNESS OF COMMUNITY-BUS PASSENGERS

2.1 Outline of Community-bus in Nisshin City, "Kururin-bus"

Nisshin City is located in the central part of Aichi prefecture in Japan. The area of the city is

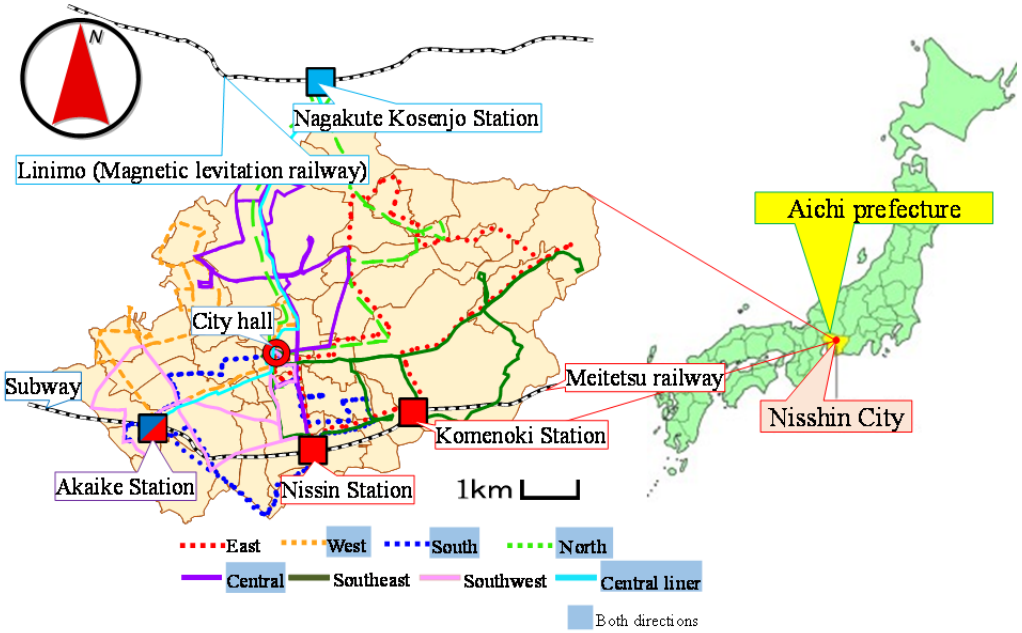

Figure 1. Route map of "Kururin-bus"

34.9 km^2 and the population is about 87,000. This city has a property of a commuter town to Nagoya city which has a population more than 2 million and also Toyota city which has many automotive factories. The ratio of the elderly who is 65 years old and over is about 18.6% in Nisshin City, which is lower than 25.1% in the whole Japan.

"Kururin-bus" is a community-bus operated by Nisshin City from April in 1996 for the purpose of supporting the accesses to the stations, the city hall, hospitals, groceries, welfare facilities and the library from residential areas within the city. The elderly, the handicapped, a person without a driving license and children are assumed to be main patronage.

Figure 1 shows the routes of "Kururin-bus" on the map of Nisshin City. There are 8 routes circulating within the city. Each route connects some of railway stations (Akaike Station, Nisshin Station, Komenoki Station, Nagakute Kosenjo Station). Seven routes of "Kururin-bus" (North, South, East, West, Central, Southwest and Southeast) depart from the city hall simultaneously and arrive at the city hall too. The central liner connects stations located at the north and the south of the city by a shuttle service. Each route has 11 bus services a day between 6:50 and 20:25 of departure time. The fare of one riding is 100 yen for routes except for the central liner of which fare is 200 yen. A season ticket of a month is 1,000 yen and 3 months is 3,000 yen only for the elderly. Inhabitants of 15 years old (a junior high school student) and under, the handicapped and a caregiver are entitled to a free pass. Transferring from a route to another at only bus stop of city hall is gratis. Although the number of "Kururin-bus" passengers has recently been increasing year by year and an annual number of passengers exceeds 500 thousands in 2014, such trend has turned to decline in 2015. The ratio of the fare revenue to the bus operating cost is about 20%. This means that the community-bus service has to be funded by taxpayer's money regardless of riding the bus.

2.2 Consciousness Survey

An Origin-destination (OD) of bus stops and consciousness of "Kururin-bus" passengers were investigated in 2013. The questionnaire was distributed to all passengers of "Kururin-bus" for

Table 1. Pattern of supposed fare, interval and travel time

LOS		A	B	C	D
1 ride fare (Current fare is 100yen)	Up	200 yen	150 yen	200 yen	150 yen
	Down	50 yen	50 yen	10 yen	10 yen
Interval (Current interval is 80 min)	Up	120 min	100 min	120 min	100 min
	Down	60 min	60 min	40 min	40 min
Travel time (Current travel time is each actual travel time)	Up	doubled	one-and-a-half	doubled	one-and-a-half
	Down	half	half	two-thirds	two-thirds

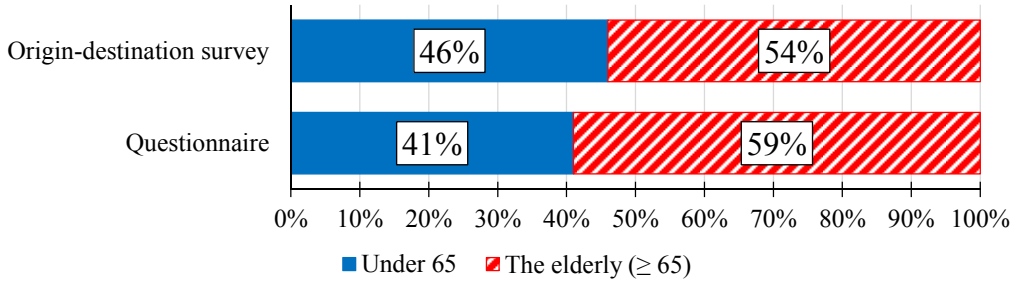

Figure 2. Ratio of the elderly by different survey

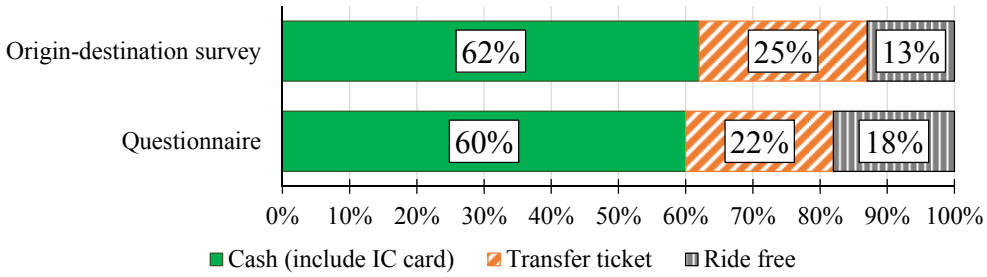

Figure.3. Ratio of payment method of fare

two days. Questions consisted of “personal attributes”, “purpose of riding”, “trip situation”, “consciousness” and so forth. Moreover, stated preference (SP) questions, in which the LOS of the community-bus operation would be improved or worsened, were included. Four patterns of the SP question shown in Table 1 were prepared, in which improving or worsening the LOS was differently combined by each pattern. For example in pattern A, with regard to the fare, the questions are “How many days would you ride “Kururin-bus” for a month if the fare would change to 200 yen a ride?” and “How many days would you ride “Kururin-bus” for a month if the fare would change to 50 yen a ride ?”. Consequently, 4 types of questionnaire sheets were produced, in which a different set of 6 SP questions was included, for alleviation of respondent’s burden to answer. Every respondent therefore answers only one type of questionnaire sheet. These questionnaires were distributed randomly to the passengers. As a result, 999 questionnaires have been distributed and 366 respondents have been collected. The collection rate of the questionnaire is 36.6%.

Figure 2 shows the ratio of the elderly to all respondents by the survey of the questionnaire and the O-D trips. Over 50 % of the passengers are the elderly of 65 years old and over. This means that “Kururin-bus” is important transportation measures for the elderly inhabitants in Nisshin City. Figure 3 shows the ratio of each payment method of the fare.

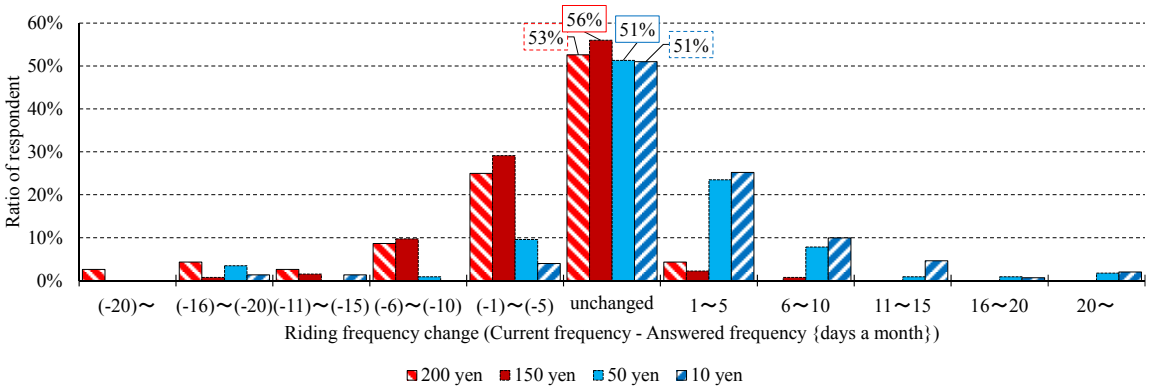

Figure 4. Riding frequency change by supposed fare

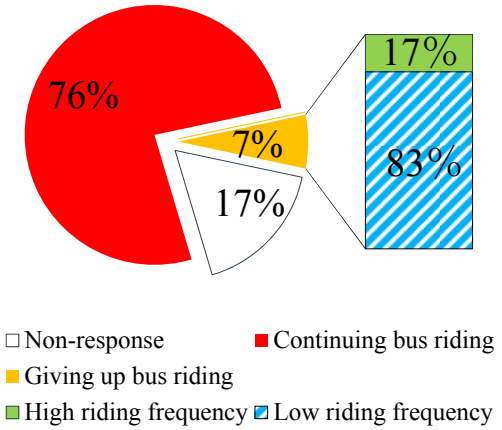

Figure 5. Ratio of respondent giving up bus riding by raising fare

Payment in cash (including an IC card payment) is about 60%, payment by a transfer ticket is over 20% and riding free is under 20%. This figure also shows that more than half of passengers pay in cash to ride “Kururin-bus”.

From these figures, it can be seen that there is no significant deviations between respondents of the questionnaire and actual passengers investigated by the O-D survey, so that the answers of the questionnaire can be regarded as the consciousness of all “Kururin-bus” passengers.

3. ANALYSIS OF RIDING FREQUENCY CHANGE

3.1 Riding Frequency Change by Fare Change

The following sections show the fundamental relationships between the riding frequency and the LOS for construction of a model to estimate the riding frequency.

Figure 4 shows the difference of the riding frequencies from the current frequency to the changed frequency when the fare of 1 riding will be changed. A positive value means increasing of the frequency from the current and a negative value means decreasing of the frequency. The result shows that the riding frequency varies significantly by the change of the fare. Note that about 50% of respondents will not change the riding frequency by the fare change. The riding frequency would decrease as the fare would be raised to 150 yen or 200 yen. Conversely, reduction of the fare to 50 yen or 10 yen from 100 yen leads to increasing of

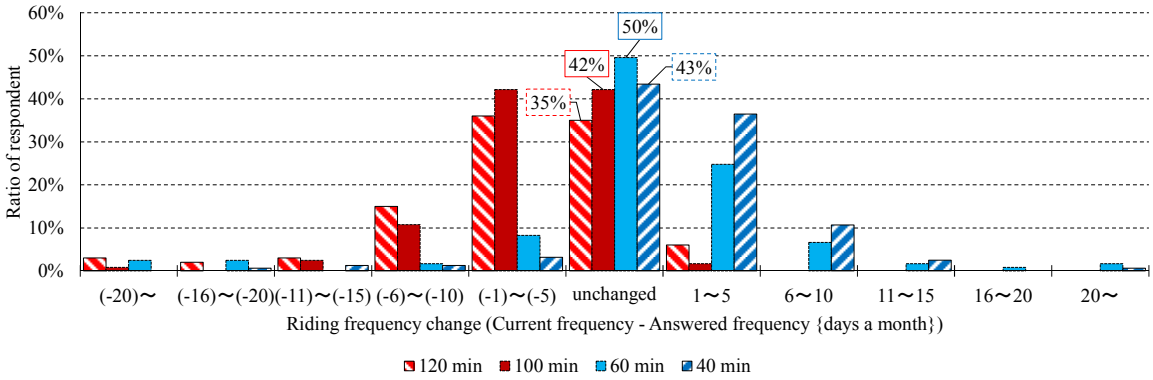

Figure 6. Riding frequency change by supposed interval

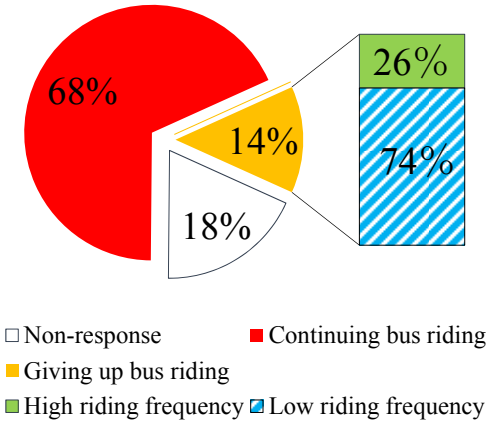

Figure 7. Ratio of respondent giving up bus usage by widening interval

the riding frequency. Moreover, it can be seen that some respondents reduce the riding frequencies more than 10 days.

Figure 5 shows the ratio of the respondents who give up bus riding because of the raised fare. In this figure, the riding frequency of the respondents giving up bus riding is divided into two groups, high frequency and low frequency. The boundary between two groups is 10 days a month, because 10 days a month is average riding frequency of all respondents. The ratio of respondents giving up a bus riding is 7% when the fare will be raised, in which 83% of the respondents have low riding frequency. This shows that most passengers with low frequency do not depend on a community-bus to travel in a daily life.

3.2 Riding Frequency Change by Interval Change

Figure 6 shows the difference of the riding frequencies from the current frequency to the changed frequency when the interval of the bus service will be changed. The result shows that the riding frequency varies significantly by the change of the interval of the bus service. Note that 40% of respondents will not change the riding frequency even if the interval of the bus service would be changed. The riding frequency would decrease as the interval would be widened to 100 minutes or 120 minutes from 80 minutes. Conversely, narrowing the interval to 60 minutes or 40 minutes leads to increasing of the riding frequency.

Figure 7 shows the ratio of the respondents who give up bus riding because of the widened interval of the bus service. The ratio of the respondents giving up bus riding is 14%

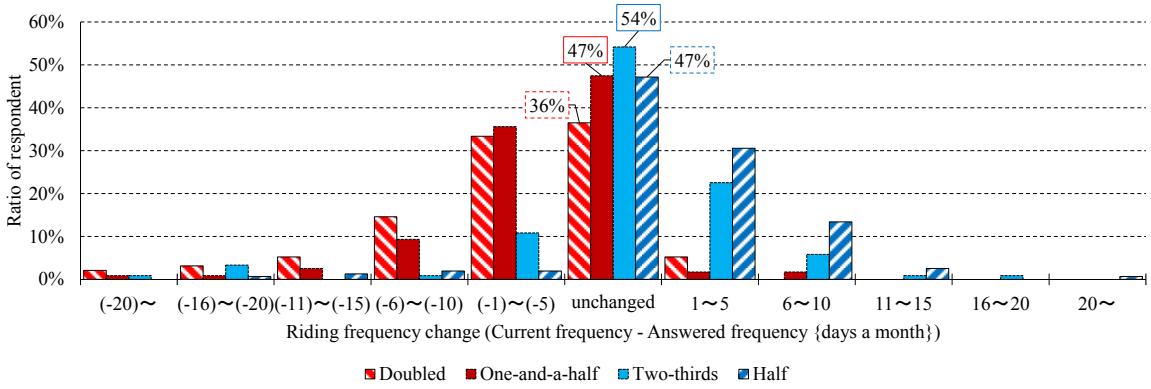

Figure 8. Riding frequency change by supposed travel time

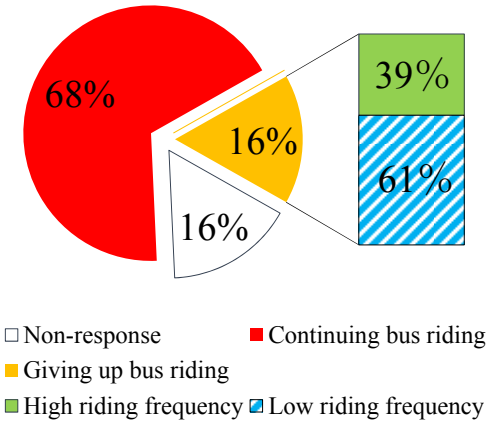

Figure 9. Ratio of respondent giving up bus usage by prolonging travel time

when the interval will be widened, in which 74% of the respondents have low riding frequency. This also shows that most passengers with low frequency do not depend on a community-bus to travel in a daily life as same as the case in the raised fare.

3.3 Riding Frequency Change by Travel Time Change

Figure 8 shows the difference of the riding frequencies from the current frequency to the changed frequency when the travel time between boarding and alighting bus stops will be changed. The current travel time means the actual travel time of each respondent, so that these travel times are different by each. The result shows that the riding frequency varies significantly by the change of the travel time. Note that 40% of the respondents will not change the riding frequency even if the travel time would be changed.

The riding frequency would decrease as the travel time would be prolonged to one-and-a-half or doubled from the current travel time. Conversely, shortening the travel time to a half or two-thirds leads to increase of the riding frequency.

Figure 9 shows the ratio of the respondents who give up bus riding because of the prolonged travel time. The ratio of respondents giving up bus riding is 16% when the travel time will be prolonged, in which 61% of the respondents have low riding frequency.

Table 2. Correlation coefficient with riding frequency

Factor	Correlation coefficient	Factor	Correlation coefficient
Gender	-0.04	Regular riding	0.09
Age	-0.15	Satisfaction about fare	0.06
Occupation	-0.13	Maximum allowable fare	0.10
Student	0.22	Current riding frequency	0.73
Having a license	0.07	Fare	-0.17
Year of riding a community-bus first	0.08	Interval	-0.23
Frequency of going-out	-0.33	Travel time	-0.25
Payment method of fare	-0.11		

3.4 Correlational relationship with riding frequency

Table 2 shows correlation coefficients between the riding frequency after the LOS change and each factor. The "Current riding frequency" has high correlational relationship with the riding frequency after the LOS change. A passenger with current high frequency tends to ride a community-bus higher frequently even if the LOS would change. These passengers seem to be those who depend on a community-bus to travel in a daily life. In terms of the LOS, "Travel time" has the highest negative correlational relationship with the riding frequency. This result coincides with the questionnaire results already described above.

From the comparison of the results obtained from different service changes, it can be seen that the riding frequency of a community-bus is less declining by the fare change than other LOS changes such as the interval of bus service or the travel time between bus stops of boarding and alighting. This means that the fare does not seem to be most important factor whether a passenger rides a community-bus because the fare is set to be cheaper than that of a bus operated by a private bus company. Moreover, the most passengers depend on a community-bus in a daily life, so that they have to ride a community-bus regardless of the fare.

On the other hand, the travel time seems to be the most important factor whether a passenger rides a community-bus. As the travel time of a community-bus becomes longer to cover the area as wide as possible, a small LOS change of the travel time seems to have considerable impact on the riding frequency.

4. ESTIMATION MODEL OF RIDING FREQUENCY

4.1 Analysis of Riding Frequency

Personal attributes were obtained from the questionnaire such as age, gender, occupation, travel purpose, current riding frequency, licensed driver and so forth. Since these attributes may affect the riding frequency of a community-bus, a multiple regression model to estimate the riding frequency is constructed with these personal attributes and the other factors on the LOS of bus operation.

An exponential regression model shown as eqn. (1), by which travel demand is generally estimated (Yoshida. 2014), is adopted for estimating the riding frequency after the LOS change.

Table 3. Model coefficient and accuracy

Variable	Partial regression coefficient	Standardized partial regression coefficient	*t*-value
Student Dummy	1.90	0.08	3.98**
License Dummy	-0.50	-0.03	-1.55
Main transportation mode	-0.77	-0.05	-2.45**
Payment method of fare	-0.76	-0.06	-3.25**
Maximum allowable fare	0.59	0.04	2.35*
Regular riding	-1.12	-0.05	-2.66**
Current riding frequency	0.73	0.69	37.76**
Fare	-2.90	-0.15	-9.07**
Interval	-7.48	-0.21	-12.26**
Travel time	-5.66	-0.24	-14.22**
Multiple correlation coefficient		0.816	

*:5% significant, **:1% significant

$$Y_j = \alpha e^{\sum_k \beta_k x_{jk}}, \quad (1)$$

Where,

Y_j : Riding frequency of sample j,
X_{jk} : k th explanatory variable of sample j,
α, β_k : Parameters.

Table 3 shows the model coefficients estimated by a stepwise regression and the accuracy of the model. In this model, the objective variable is the riding frequency of a sample, and the explanatory variables are “Student dummy” (1 if a sample is a student or 0 otherwise), “License dummy” (1 if a sample has a driving license or 0 otherwise), “Main transportation mode” dummy (0 if a main transportation mode is “Kururin-bus” or 1 otherwise), “Payment method of fare”, “Maximum allowable fare”, “Regular riding” dummy (1 if a sample rides “Kururin-bus” regularly or 0 otherwise), “Current riding frequency” and “LOS change” (ratio of the changed LOS to the current LOS).

The multiple correlation coefficient is 0.82 and the coefficient of determination is 0.67. The constructed model is considered as statistically significant. From the standardized partial regression coefficients shown in Table 3, it can be seen that the influence of “Current riding frequency” on the riding frequency is the most significant. Since this coefficient is positive, the riding frequency after the LOS change tends to vary as proportion to the current riding frequency. A student tends to become a high frequency passenger. A person with a driving license and a person doesn’t ride a community-bus as a main transportation mode tend to become a low frequency passenger. It is thought that students require a community-bus more than other passengers because they cannot drive to school. A person who rarely rides a community-bus seems to afford to travel by other transportation modes, so that a community-bus may not be indispensable to travel in a daily life.

Regarding the LOS, “Interval” has the largest value of the partial regression coefficient among the LOS. “Travel time” has the largest value of the standardized partial regression coefficient. This difference is caused by a standard deviation. The supposed “Interval” in the questionnaire is between 0.5 and 1.5 times of the current value. The supposed “Travel time” is between 0.5 and 2 times of the current value. Consequently, it is shown that “Travel time” has

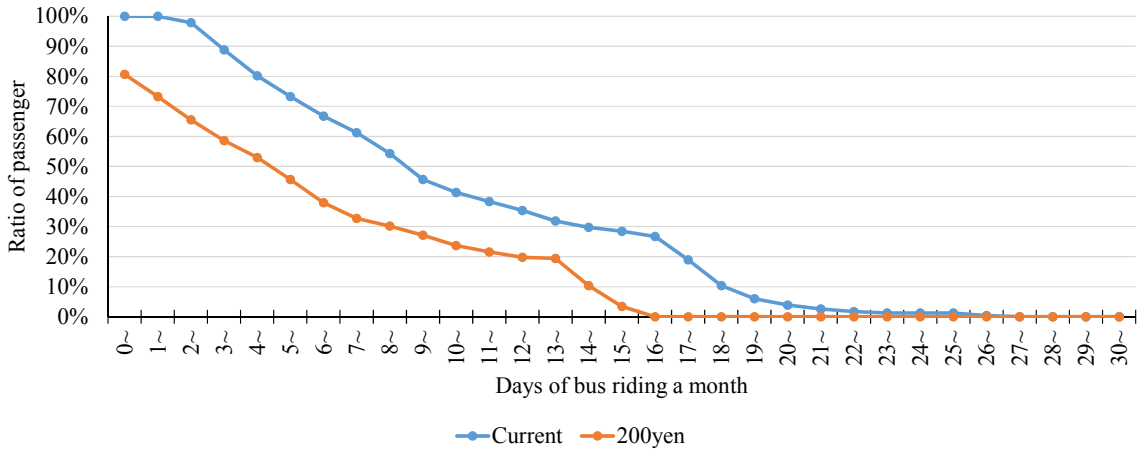

Figure 10. Riding frequency distribution under current and changed fare

the biggest effect among the LOS changes. This implies a passenger giving up bus riding will increase by prolonging a travel time more than other worsened LOS.

4.2 Analysis of Riding Frequency Change by LOS Change

The riding frequency distribution is estimated by using the constructed regression model when the LOS of a community-bus is changed. The answers of the questionnaire are used as the explanatory variables except the fare in this analysis. Moreover, it is supposed that a payment method of the fare is unchanged even when the LOS of a community-bus is changed. Induced demand is not considered even if the LOS will be improved in this analysis.

Figure 10 shows the riding frequency distribution under the current fare of 100 yen and the changed fare of 200 yen. The vertical axis of this figure denotes the ratio of passengers who ride a community-bus more than the days of the horizontal axis to all passengers. In comparison of “Current” with “200 yen”, the distribution of “Current” looks like to move down in parallel to the distribution of “200 yen”. However, actually, the riding frequencies more than 15 or 16 riding per month change to riding frequencies more than 11 or 12 by the raised fare, so that the total of the riding frequency is decreased.

The riding frequency tends to decrease as the fare is raised. The ratio of passengers riding a community-bus more than 0 days a month is about 80% when the fare is raised to 200 yen. It implies that passengers giving up bus riding amount to about 20%. The raised fare reduces the number of passengers and also decreases the riding frequency of a community-bus.

In order to find the optimal combination of the LOS to maximize the riding frequency under the condition where synthetic LOS is constant, the riding frequency is estimated by the constructed model. The synthetic LOS multiplies the ratios of each changed LOS to the current LOS, and is set to be 1 because it is equal to the current level. This is represented as equation (2). For example, if the fare is worsened, another LOS is set to be improved, which assures that the synthetic LOS is constant from the current LOS.

$$X_f \times X_i \times X_t = 1 \ , \tag{2}$$

where,

Table 4. Patterns of LOS combinations

(1 denotes as same as the current level)

Pattern	Fare	Interval	Travel time
a	2	1/2	1
b	2	1	1/2
c	1	2	1/2
d	1	1/2	2
e	12/7	2/3	7/8

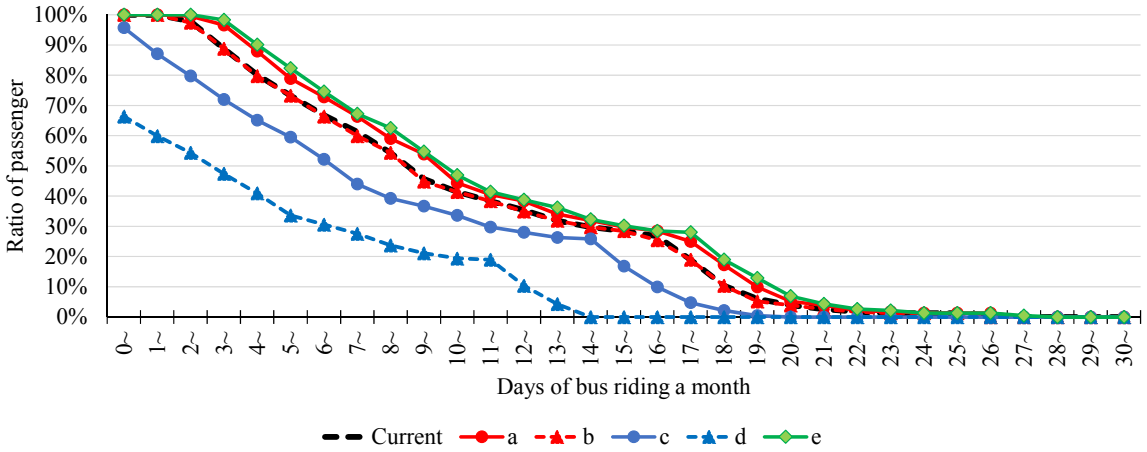

Figure 11. Estimated riding frequency distribution under different combination of changed LOS

X_f : ratio of changed fare to the current fare,

X_i : ratio of changed interval to the current interval, and

X_t : ratio of changed travel time to the current travel time.

Table 4 shows the patterns of the changed LOS combinations. In patterns “a” and “b”, the fare is set to be doubled because the upper limit of allowable fare is about 200 yen from the questionnaire result. The travel time is shortened and the interval is widened in pattern “c” and vice versa in pattern “d”. All these patterns do not contain the situation where the fare is reduced because the fare revenue must be kept at least as same as the current. Pattern “e” is the optimal combination where the total of the riding frequency is maximized.

Figure 11 shows an estimated riding frequency distribution under each combination of the changed LOS. Two red lines denote the distributions when the fare is doubled. Pattern “a” increases the riding frequency more than pattern “b”. Two blue lines denote the distributions when the fare is not changed. Pattern “d” increases the frequency more than pattern “c”. Moreover, red lines are located above blue lines. This means that the LOS change related to the time is more sensitive than one related to the fare.

From the above, it is found that shortening the travel time will increase the riding frequency more than narrowing the interval. Moreover, improving the interval or the travel time will increase the riding frequency even if the fare will be raised. Therefore, the riding frequency will not decrease by the raised fare as long as the interval or the travel time will be improved.

From the estimation results, it is found that the riding frequency becomes the maximum when the fare is set to be about 170 yen, the interval is about 50 minutes and the travel time is 7/8 times of the current. It can be also seen that there is possibility to increase the fare revenue if the LOS will be set as the optimal combination.

5. CONCLUSIONS

Many municipalities in Japan operate a so-called community-bus for assuring mobility in a daily life of residents and spend considerable public funds to maintain the operation of the community-bus. However, it is required to reconsider the community-bus service because the increase of public welfare expense has been leading to tight financial condition due to the unprecedented aging society. Consciousness on the community-bus service was therefore investigated by a questionnaire at Nisshin City, Aichi prefecture in Japan so as to grasp the actual riding situation of the passengers and the relationship between LOS of the community-bus operation and riding frequency of passengers.

From the result of the questionnaire, it is found that over 50 % of the passengers were the elderly who are 65 years old and over. This means that the community-bus of Nisshin City plays an important role to provide a transportation mode for the elderly inhabitants. Moreover, it is found that over 50 % of the passengers paid in cash (including by an IC card) to ride the community-bus.

The difference from the current riding frequency to the changed riding frequency under the changed LOS was analyzed. About 40 ~ 50% of respondents would not change the riding frequency even if the LOS would be changed. The analysis result also shows the respondents would change the riding frequency more by the interval or the travel time change than the fare change. Especially, some respondents would decrease the riding frequency to 0, namely, give up the community-bus riding if the LOS would be worsen. The maximum ratio of respondents giving up community-bus riding was 16% if the travel time would be prolonged. This means that the travel time is the most important for a passenger and the impact by the fare change is less than one by the other LOS change. Moreover, passengers with high riding frequency have lower ratio to give up community-bus riding than those who with low riding frequency when the fare or the interval is worsened. This implies a community-bus is indispensable for those who with high riding frequency to travel in a daily life.

By using the questionnaire result, an estimation model of the riding frequency has been constructed by a multiple regression analysis. Moreover, the optimal combination of the LOS was found by the model under the conditions where synthetic LOS was constant from the current LOS. As a result, the riding frequency will become the maximum when the fare is about 170 yen, the interval is about 50 minutes and the travel time is 7/8 times to the current travel time. Furthermore, it is possible that the fare revenue will be increased if the LOS is set as the optimal combination.

For further research, it is necessary to consider a change of a payment method by the fare change and induced demand by the LOS improvement. Moreover, possibility to apply the constructed model in this study to other community-buses operated in different areas should be explored.

ACKNOWLEDGEMENT

Authors would like to thank Nisshin City for cooperation with this study.

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