Planning of Flexible Transport Services for Rural Area Considering Operation Cost

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This paper focuses on the potential role of Flexible Transport Service (FTS) in low and dispersed demand area. The term demand responsive transit (DRT) has been increasingly applied in the recent 10 years in the public transport system. Flexible transport services can provide passengers with alternative options on route, schedule, which can cope with the problem of the present situation in some rural, low- density areas at a lower operating cost compared to the infrequent fixed route local public bus services.

In Japan, after the deregulation in 2002, some mass transit companies left from bus services in local areas. This causes problems for some older people and disabled people with difficulties on traveling in rural areas. To meet these needs, a measure that subsidizes on the taxi fare is being carried out to support the special groups' transport needs. In this research, we aimed to examine the role of the taxi subsidy system from the relation with on- demand ride-sharing taxi in depopulated area.

Key Words: *flexible transport services, rural areas, taxi fare subsidy, internet survey*

1. Introduction

A flexible public transportation service is a general term which describes a range of arrangements that are typically used in local public transportation. We found FTS as a transport service which has some flexible characteristics on route, vehicle, schedule, and passenger and payment system. In the public transportation service, this competes with the traditional type of service which comes along with a fixed timetable, fixed route, and fare, and scheduled drivers with vehicles on a regular basis[1)].

According to the statement[2)], FTS system usually uses Travel Dispatch Centers (TDCs) to deal with the booking and reservation process. This device has the ability to arrange passengers to vehicles and schedule the time. Automated Vehicle Location (AVL) and GPS systems are used to supply real-time information about the location of the car and situation in order to maintain the service smoothly and successfully.

When we look at the previous time of FTS, there were door-to-door Dial-a-Ride services (sometimes called as Special Transport Services - STS or "paratransit") in the past[3)]. This service was provided for restricted groups (usually the disabled and elderly).customers must do the telephone reservation some days in advance before they plan to travel so that the manager would arrange the service manually the day before the trip.

Recently, Demand Responsive Transit and Flexible Transport Services have been playing a vital rule in several European cities, areas, and regions with advanced interest and benefits as a creative supplementary solution to the traditional, fixed passenger transport service. Especially, these types of flexible transport services become an optimal method for low- density population regions where demand service hour is low, in addition to this, target users are also disassembled among the special groups such as elderly, disabled people and students and tourists[3].

Implementing of FTS in rural areas may be the optimal solution for the current state of rural areas transportation, but there are still some challenges to be conquered. Compared with fixed, conventional services, low demand rate also seems to an obstacle to cause insufficient service provider in dispersed, rural areas. Another factor that challenges the present situation of transportation for these regions, is that local authorities often have funding barriers. And that would be a reason for many services in rural areas or areas of low demand have been stopped from service since the level of subsidy requirement is too high to satisfy within the set of competing requirements [2].

Now, the worldwide nation's population is entering the aging society. The dramatic change in the population will cause new challenges for the provision of transportation services. In low density, rural areas, infrequent fixed route public transportation is not able to meet the need of special groups such as elderly who don't have driving license or fear to drive and disabled people. FTS plays an important role in improving the social inclusion where demand is low and often spread large area.

In Japan, Taxi Subsidy System (TSS), as well as Demand Ride-Sharing Taxi (DRST), are being introduced in some rural areas of Japan as being one of the solutions among FTS.

Taxi Subsidy Scheme (TSS) supports the transport costs for limited groups who have difficulties on utilizing public transport service because of their physical weakness. This types of service affords community members with general social inclusion and participation in social activities, which prevent them from the risk of social isolation[6].

According to the statement of Ishio[8], the taxi subsidy scheme which is currently run in Japan is also classified into the following three types.

1. Elderly type--- this type refers to the condition of people who is at the age of 70 or over.
2. Welfare type---this type refers to the condition of people with disability regardless of age.
3. Integrated type--- this type refers to a type that integrates both elderly and welfare type.

The integrated type of taxi fare subsidy system was developed from taxi subsidy system, which aimed to provide limited number of people who experience profound difficulties using other modes of public passenger transport with fixed number of tickets per year. They can use these tickets as a part of payment when they take a taxi. In depopulated areas, taxi fare subsidy system is mainly used for outpatient visits and shopping etc. The welfare department of the municipality is often in charge. However, there are restrictions on the number of times of use per year, and it cannot deal with the high- frequency movement of demand.

2. EXISTING RESEARCH AND PURPOSE OF THIS STUDY

According to statement [3], Finland and Belgium adopted DRT into their mainstream public transport system for its citizens who are over 65. From these experiences, both countries found that it is very important for a government to consider about the quality of life of its elderly citizens and the ability to live independently. Also, it is not difficult to find that, with the help of latest technologies like Travel Dispatch Centers(TDCs), Automated Vehicle Location (ALV), FTS service is able to satisfy a large number of requests of people and cars.

In Japan, although there are many existing studies on demand-coupled taxis and community buses, there are few studies on taxi tickets and taxi assistance.

A research by Hayakawa[9] in 2004 compared FTS systems and showed that demand type taxi is the mainstream for region with a population of over 6,000. But For population under 6000, and additional situation if there is no taxi operator, a kind of private service, called 自家用有償(jikayo _yusho)in Japanese provided by local residents is welcomed . However, if taxi operators exist, they consider the implementation of taxi service. For example, Bicchu town of Okayama prefecture (population approximately 2000) introduces paid transportation by private cars as "welfare transfer service". Then In Nega village of Nagano prefecture (population approximately 900) adopts the demand ride sharing taxi service.

According to other Hayakawa's[10] research, Tatebayashi city of Gunma prefecture (population approximately 78.000) and Omachi city of Nagano prefecture (population 29.000) also introduced taxi assistance to the elderly with the elimination of the bus service. In these two cities, elderly people were supported by distributing taxi tickets, but the pressure on municipality and users increased. This revealed a fact that bus service is more efficient than taxi subsidy system, which caused the restart of bus service in these regions. However, Hayakawa said that taxi subsidy system makes a certain sense because some elderly people has the difficulty to access to the bus stop.

Meanwhile, according to another research done by Moriyama [11], demand ride-sharing taxi seems not to be economical because it does need operating cost even there is no reservation. In fact, sometimes it is necessary for driver to wait for customers; in that case, this service is also very costly. In addition to this, reservation problems also form big barriers for older people. In this way, proper introduction considering the local condition is vital, especially the consideration of policies including taxi utilization in depopulated areas.

The aim of this study is to examine the role of taxi subsidy system from the relation with on demand ride- sharing taxi from satisfying the demand of special groups in rural, dispersed population areas.

3. THE COST ANALYZES ON IMPLEMENTING OF TAXI SUBSIDY SYSTEM AND DEMAND SERVICE

(1) Outline of operating cost for simulation model

In this study, a simulation model is developed to estimate the operating cost of taxi subsidy system and on demand ride sharing taxi service, which consider the sharing ratio according to population density. In general, for the evaluation of mobility services, the satisfaction level and payment of users, and management by supplier and operation cost by local government are to be considered. In this research, we mainly focus on the operation cost by government.

(2) Creating the targeted model area

We choose Sana-gouchi village in Tokushima Prefecture as a targeted model area, spreading virtually from center to suburbs. The image is shown in **Fig.1**. The village is consist of 16 areas of two grids of 1 km square, the population density decreases as going from the center to the outside. According to the actual situation of Sana-gouchi village in Tokushima Prefecture, we assumed the population of each areas as model A, and in order to evaluate the effect of demand size, we assumed population model B which is created by multiplied A by 5. The population of each model by area is shown in **Table 1**. In this study, mobility support service is provided for the trips of residents moving from each area to the center.

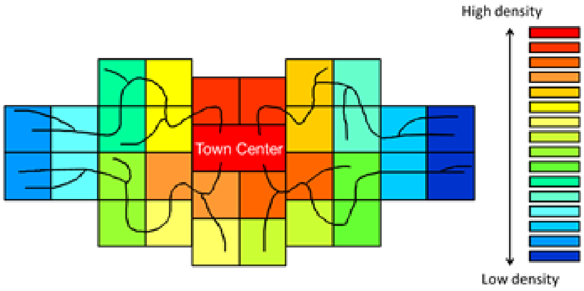

Fig.1 Model Region for Simulation Analysis

Table 1 Assumed Population of Model village

Aera	Ratio of population	Population	
		Model A	Model B
1	0.11%	3	15
2	0.32%	9	45
3	0.54%	15	75
4	0.87%	24	120
5	1.16%	32	160
6	1.62%	45	225
7	1.84%	51	255
8	2.38%	66	330
9	2.74%	76	380
10	4.15%	115	575
11	6.21%	172	860
12	8.84%	245	1225
13	11.66%	323	1615
14	16.17%	448	2240
15	18.41%	510	2550
16	22.96%	636	3180
Total	100.00%	2770	13850

Table 2 Estimated Ratio of Target group of FTS

case	target group	estimated population ratio	source
T1	Disable	4%	MHLW 2012
T2	75 years old and older non driver licence holder	9%	MIAC Statiscs Bureau 2012
T3	65 years old and older non driver licence holder	14%	
T4	20 years old and older non driver licence holder	21%	NPA 2012

(3) Assumption for targeted people

The population ratios of four target groups for the mobility service are estimated, shown in **Table 2**.

The target people of demand ride- sharing taxi was a person who is over 20 years old and without driving license. As marked T4 in **Table 2**. The population ratio of this group is estimated to be about 21%.

The subjects of taxi subsidy system were such persons like disabled people, “old” elderly (over 75 years), and “young” elderly (aged 65-75 years). They are marked T1, T2, T3 in the **Table 2**, and the population ratios of these subjects are estimated to be 4%, 9% and 14% respectively.

(4) Case setting for service sharing by area

The distribution of mobility services by area was set as shown in **Fig.2**.

Case 1 supports all areas with demand ride- sharing taxi service except the central area. Case 2 supports area 1 with a taxi subsidy system and the rest of the area is supported by a demand-coupled taxi. In Case 3, the scope of the taxi subsidy system is expanding. In Case 15, demand ride- sharing taxi only runs in the central area, the remaining areas are supported by taxi subsidy system. And Case 16, supporting all areas with taxi subsidy system except the central area.

In order to support the mobility of local residents in the area by demand ride-sharing taxi, the distance of necessary traveling route was estimated. Here, over 70% of the households in the area were provided access to the taxi service within 200m operation route.

For the estimation, 20 districts with different density of buildings in Tokushima prefecture were chosen randomly, an operating route satisfying the above conditions was created, and the distance was measured. As a result, if the density of the building is decreasing, the necessary route length becomes short, but when the buildings are dispersed, the length is close to the theoretical maximum route length. The average length of necessary route extension with 1 km square mesh became 1.84 km.

Area	Responsibility Case															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	−	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
2	−	−	○	○	○	○	○	○	○	○	○	○	○	○	○	○
3	−	−	−	○	○	○	○	○	○	○	○	○	○	○	○	○
4	−	−	−	−	○	○	○	○	○	○	○	○	○	○	○	○
5	−	−	−	−	−	○	○	○	○	○	○	○	○	○	○	○
6	−	−	−	−	−	−	○	○	○	○	○	○	○	○	○	○
7	−	−	−	−	−	−	−	○	○	○	○	○	○	○	○	○
8	−	−	−	−	−	−	−	−	○	○	○	○	○	○	○	○
9	−	−	−	−	−	−	−	−	−	○	○	○	○	○	○	○
10	−	−	−	−	−	−	−	−	−	−	○	○	○	○	○	○
11	−	−	−	−	−	−	−	−	−	−	−	○	○	○	○	○
12	−	−	−	−	−	−	−	−	−	−	−	−	○	○	○	○
13	−	−	−	−	−	−	−	−	−	−	−	−	−	○	○	○
14	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○	○
15	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○

○ : Responsible by TSS − :by DSRT

Fig. 2 The distribution of mobility services by area

(5) Taxi auxiliary ticket utilization rate

Based on the Ishio's previous survey[8] of the existing taxi subsidy system, the mean value of the usage rate of the number of tickets (the ratio of the number of used sheets to the number of delivery sheets) is 48%, the amount of subsidy at the maximum use of time and the mean value of usage rate subsidized by municipal government was 9%. From these results, in the taxi subsidy system, the utilization rate out of 48 annual subsidiary times was assumed in two cases of 48% and 9%.

(6) The utilization rate of demand ride-sharing taxi

In Hyogo Prefecture's survey[7] about the community bus service, the relationship between the utilization rate by route and the daily service frequency is shown. Among these, the utilization rate was calculated on the route with fewer frequency, the utilization rate was 0.625%, and the daily frequency was 3.75. However, this usage rate indicates the number of users for the population along the service route. The utilization ratio is assumed 3% considering the population ratio of target users (21%) who are over 20 and don't have driving license.

(7) Estimation for operation cost for taxi subsidy system

The amount of grant for taxi subsidy system was set to 3 patterns of 60 yen, 100 yen, and 140 yen per km. This means that the unit price per km of taxi is 200 yen, supporting 30%, 50%, 70% of the amount, and the remaining amount is supposed to be paid by user. As for the demand ride-sharing taxi, it is assumed that the taxi's traveling distance travels 1.84 km to pass through the 1 km mesh.

The number of subsidies is, once a week, 48 times a year.

The estimation formula of the operation cost is as follows (1).

$$\sum_i X_i = dt_i \times sp \times nt \times ur \times pt_i \qquad (1)$$

Here

X_i : annual operating cost of TSS for area i (Japanese yen)

dt_i: Service distance from area i (distance to the center × 2)

sp : Subsidy per km (yen / km) -- 60, 100, 140 yen

nt : Annual distribution number of taxi tickets -- 48

ur : Utilization rate (%) -- 9%, 48%

pt_i : Number of targeted people in area i (people)

(8) Estimated operating costs for demand ride-sharing taxi

The cost of operating a demand ride-sharing taxi was estimated at 220 yen / km from previous study [12]. It was supposed that the operation is 4 times a day, twice a week, 384 times a year as a minimum service level that users can see.

The fare paid by the user was set to three patterns, one ride 100 yen, 300 yen, 500 yen, which are seen commonly.

The estimation model of the operation cost is as follows (2)

$$\sum_i y_i = ds_i \times cs \times ns - fs \times us \times ps_i \qquad (2)$$

Here

y_i : Demand ride sharing taxi operation cost to area i (yen)
ds_i : Service distance from area i (distance to the center×2)
cs : Travel expenses per km – 220 yen / km
ns : Annual number of operations -- 384 times / year
fs : Demand ride taxi fare --100, 200, 300 yen / times
us : Utilization rate of demand ride sharing taxi – 3%
ps_i : Targeted population for demand ride sharing taxi for area i

(9) An example of estimation

As an example, we show the simulation results of model case when the supplementary amount of the taxi subsidy system is 60 yen and the usage rate is 9% and the fare of the demand-coupled taxi is 500 yen in the population model. The results are shown in the **Fig.3.**

From **Fig.3**, among these three subjects of taxi subsidy systems, in case 1, when target people of demand ride-sharing taxi is 0%, and the target area ratio of demand ride-sharing taxi is 0%, the total operating expenses of demand ride- sharing taxi will be the lowest value.

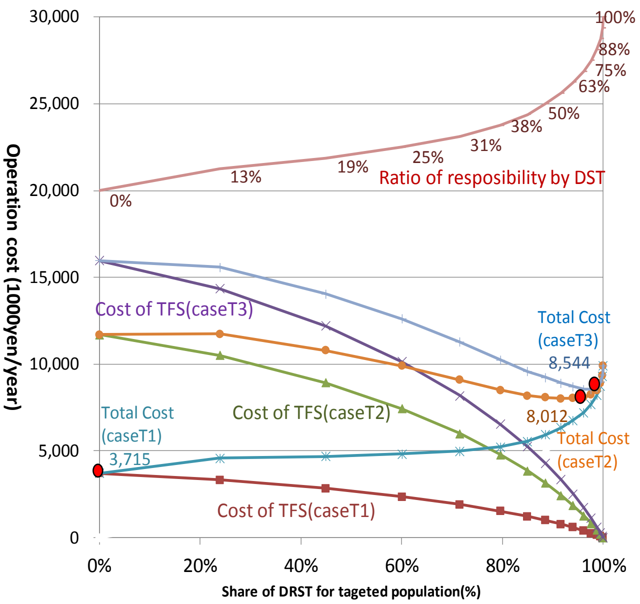

Fig. 3 Total annual operating cost for the proportion of target users in DRST

However, in case 2, lowest result occurs when the target people of the demand ride-sharing taxi are about 91.61%, the target area of ratio is 56.25%. In case 3, that is when the target people of demand ride-sharing taxi are about 96.11%, and the target area ratio is 68.75%.

(10) Simulation results

In the simulation performed for each patterns, the lowest case would be the optimal ratio among the total amount of each case for both taxi subsidy system and demand ride-sharing taxi.

(11) Consideration of the simulation results

Table 3 summarizes the simulation results of each pattern performed this time. From **Table 3**, the factors which influence the demand operation service ratio are the usage rate of taxi subsidy system, the population of targeted people, and the amount of grant and the ratio of targeted subjects of taxi subsidy system.

Table 3 Simulation results

Optimal Resposibility patern by DST and TFS								
Utilization ratio of TFS	TFS target group case	Fare for DST	Model A			Model B		
			Taxi fare subsidy					
			60 yen/km	100 yen/km	140 yen/km	60 yen/km	100 yen/km	140 yen/km
9%	T1	200～500 yen/ride		DST=0% TFS=100%				DST= 80～96%
	T2						DST=	
	T3				DST=80～96%		96～98%	
48%	T1	200～500 yen/ride						
	T2		DST=			DST=98～100%		
	T3		96～98%					

Among them, it was found that the utilization rate of the taxi subsidy system and the population of the targeted people have a particularly great influence on the demand operation service sharing ratio. On the contrary, there is no change finding with the situation in which the fare is at 200 yen / times, 300 yen / times, 500 yen / times. Therefore, as a factor that did not affect the demand operation service sharing rate, a fare for a demand ride-sharing taxi can be cited.

Also, in this simulation, the scope of the targeted people of the demand ride-sharing taxi was 80% or more when 0% was excluded. From this result, under the condition of low density areas, there would be two options from the viewpoint of annual operating cost efficiency. One case is that a demand ride-sharing taxi is provided for more than 80% of the targeted people. And the remaining part will be supported by taxi subsidy system. The other case is that taxi subsidy system is provided for all of targeted people.

4. CONCLUSION

From the operation cost simulation, demand ride-sharing taxi will be effective if the system can provide service to more than 80% of targeted people. But if not, taxi subsidy system will make the operating cost in the cheapest level.

On the other hand, it has been noticed that people tend to have more different travel expectations and unpredictable travel behaviors which is different from the previous time. They expect more flexible and personalized service from the providers[3].

There remain several problems for calculation of operation cost, we need refinement of the simulation models. The evaluation from the viewpoints of users and operators is also need to be discussed in the future study.

REFERENCES

1) Steve Wright, C. David Emele, 1, Masayuki Fukumoto c, Nagendra R. Velaga d, John D. Nelson , , The design, management and operation of flexible transport systems: Comparison of experience between UK, Japan and India, (2014) 330-338
2) Corinne Mulley, John D. Nelson, Flexible transport services: A new market opportunity for public transport, Research in Transportation Economics 25, 39–45, 2009
3) John D. Nelson, Steve Wright a, Brian Masson a, Giorgio Ambrosino b, Aristotelis Naniopoulos , Recent developments in Flexible Transport Services, 2010.
4) Velaga, Nagendra R., et al. The Potential Role of Flexible Transport Services in Enhancing Rural Public Transport Provision. Journal of Public Transportation, Vol.15,No 1, pp.111-131. 2012
5) Kunihiro Kishi and Keiichi Satoh, Attitudinal Study on a Reciprocal Community Transport System in Japan, International Journal of Sustainable Transportation, 1:161-171, 2007,
6) Taxi subsidy scheme by ACT government , Updated July 2018, Available at https://www.assistance.act.gov.au/adult/transport_and_registration/taxi_subsidy_scheme
7) Community bus assessment guidelines, Hyogo ken,2008, (in Japanese) Available at https://web.pref.hyogo.lg.jp/ks05/documents/000178787.pdf
8) Megumi Ishio, Hideo Yamanaka and Junko Sanada: A Study on Characteristics of Tax Fare Subsidy Scheme in Rural Areas and Its Future，Proc. of Infrastructure Planning in Japan Society of Civil Engineers, Vol.69,No.5 pp.I_771-I_780, 2013.(in Japanese)
9) Shiji Hayakawa: Research on Future of Non Conventional Mobility Service in Loacl Transpotaion，pp1-184，The Japan research Center for Transport Policy， 2005 (in Japanese)
10) Shiji Hayakawa: Taxi subsidy system for elderly can secure the mobility of residents? -Case study of Tatebayashi City Gunma Prefecture and Oomachi city Nagano Prefecture -, pp. 105-118，Society of Public Utility Economics，2005 (in Japanese)
11) Masayuki Moriyama : Life and public transportation at hilly and mountainous area under depopulation and aging， pp25-29，Japan Housing Association，2010 (in Japanese)
12) Hiroto Inoi and Ryosuke Fukumoto: Research on the operation cost of "Fukushi-Yusho service" (special bus service for the disabled), Proceedings of Conference of Japan Society for Traffic Engineers, Vol.30, pp.417-420, 2010