Availability of Volunteer-based Dynamic Ridesharing with Bipartite Group in a Low-density Small Community in Japan

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Abstract: In regions of Japan, in small, low-density communities that have inadequate public transport services, the lack of support systems for persons of limited mobility is emerging as a social issue. To complement this, this study focuses on volunteer-based dynamic ridesharing. In this paper, the feasibility of ridesharing is analyzed by pre-survey data and the availability is examined through a field experiment. The pre-survey showed that the field suited the ridesharing experiment, due to some results of a proper proportion between demanders and suppliers for rideshare, and a synchronicity of trip destinations and travel times, etc.. The experiment, however, revealed issues such as worry and hesitation of volunteer-based suppliers who have no opportunity to match other demanders except stable-matching pairs, incentives for their participation and their reservation, and sudden cancellation of the suppliers at the matching locations after their reservations. This paper describes improvements of the proposed ridesharing system.

Keywords: Low-density Small Community, Volunteer-based Dynamic Ridesharing, Charge-free, Demanders and Suppliers, Field-experimental Study, Stable Matching

1. INTRODUCTION

In regions of Japan, many of small low-density communities in hilly and mountainous locations have areas with inadequate public bus services. Such areas have a problem of how mobility should be ensured as a guarantee for persons who cannot use private cars. In such areas, local municipalities try to cater to the demands for persons of limited mobility by means of community bus service, and demand-responsive bus service, etc., due to unprofitability of normal fixed-route bus service. However, even though demand-responsive buses are run in such areas, if there is little time on which people use the buses, or if it is difficult to increase the bus-use rate without adjacent destinations, then per-capita operation costs become equivalent to those of personal transport. Even though community buses are alternatively run in such areas, if many passengers complain of low service-frequency, excessive travel time, or circuitous routes, etc., then the number of passengers decreases to a small amount. When such situations bring on fading of bus services in the areas, alternative ways to the limited mobility of not only people who cannot drive private cars but also people who cannot even use public transport are required. In the areas with the fading of bus services, in practice, people of limited mobility usually ask their family for pick up and drop off, or sometimes ask the nearest neighbors to share a ride when the neighbors go out. This study

focuses on the systemization to support such rideshare behaviors.

By the way, regions of Japan are facing rapidly aging and depopulating societies, and thus need to be activated. One of the regional activation measures by the Japanese Ministry of Land, Infrastructure, and Transportation (MLIT) is to promote “habitation-in-two-regions” or “multi-habitation”. The “habitation-in-two-regions” or “multi-habitation” is defined as a lifestyle in which people stay in a city for a certain period of the year and spend for the reminder of the year in two or more numbers of countryside enjoying the benefits of both locations. In countryside promoting the “habitation-in-two-regions”, in general, people moving from cities to the countryside and living in cottages or villas are mostly half-settled after their mandatory retirements. Such persons often form a low-density small community together with persons who have lived there for many years, so that the cottages and villas for “new-comers” and the dwellings for “natives” are sprinkled in the same area. Regardless of “new-comer” and “natives”, due to aging community in such area, there are some households that are composed of the elderly who currently have difficulty driving private cars by themselves, even though they could drive easily in the years before. Support of mobility for the sake of such elderly people is important to the enhancement of amenities for “habitation-in-two-regions”. When efficient operations of bus services are difficult in such area, the way that persons who regularly use private cars share rides with the elderly of limited mobility is conceivable as an alternative.

This study focuses on a volunteer-based dynamic ridesharing among such bipartite group that persons who regularly use private cars are referred to as volunteer-based suppliers of ridesharing and the elderly of reduced mobility who cannot use cars are referred to as demanders of ridesharing. Firstly, ridesharing mentioned in this study is defined based on literature review. Secondly, operational conditions of the ridesharing system is proposed through case study concerning rideshare services in North America, Europe, and Japan. Thirdly, from among small low-density communities including “habitation-in-two-regions” with no public bus services, this study chooses an experimental site, where there is no ridesharing service. Subsequently, pre-survey is conducted to check whether the operating conditions are satisfied. Fourthly, when the site is judged feasible for the ridesharing as the results of pre-survey, the availability of proposed ridesharing system is examined through the field experiment. Finally, in order to deal with issues found soon after the experiment, system improvement is considered.

2. DEFINITION

As for the definition of ridesharing in this study, ridesharing is to share a ride with one or more than one person during a trip when someone who makes the trip by driving a private car between an origin and a destination, i.e. “OD”. Then, this study terms a driver who can offer a ride during the pick-up and drop-off as a “supplier” of ridesharing, and terms a passenger who would like to share the ride during the time the driver picks up and drops off as a “demander” of ridesharing. Thus, ridesharing can be said to be when a demander partially shares a supplier’s car-trip, under pre-agreement between the demander and supplier regarding the time and location of where the demander is picked up and dropped off by the supplier. In ridesharing, ODs of both demander’s trip and supplier’s trip do not always need to be matched. A trip distance of supplier’s trip is as long or longer than a trip distance of demander’s trip.

Additionally, as for the definition of dynamic ridesharing system in this study, dynamic ridesharing system is a ridesharing system incorporating reservation mechanism in order to spatially and temporally match a part of OD for a trip between the demander and supplier. In

this system, several options for the time and location of where the demander is picked up and dropped off by the supplier are provided, while several options for the time and location of where the supplier picks up and drops off the demander are provided. Accordingly, matching of rideshare through the reservation occurs separately from the time and location of where the demander is picked up by the supplier.

By the way, in addition to ridesharing of car-trip, although sharing bike-trip can be configured, this study focuses on car-trip alone. The case of trading transportation service for money, of course, fits the definition of fare-paying and for-profit services such as taxies. The case of sharing vehicles, such as car-sharing or car-clubs, and of not sharing trips, does not fit the definition of ridesharing.

As for secondary effects of ridesharing, ridesharing is expected to enhance communications through travels with others and increase “acquaintances in community”, in a society with thin human relations. In ongoing “habitation-in-two-regions” areas, in general, communications are shallow not only between “new-comers” and “natives” but also between mutual “new-comers”. In a hyper-aged and depopulating society, a mechanism of mutual help is very important to support the community. Ridesharing attracts attention as one of the mechanisms for supporting the construction of human relations for mutual help.

Chan and Shaheen (2012) define ridesharing as a non-profitable system in which both driver and passenger are similar in a way to their OD or each one of the OD. Chan and Shaheen consider ridesharing as ranging from the acquaintance-based one such as Fampool, to the organization-based one such as Carpool/Vanpool, to the casual and ad-hoc one such as Slugging. Reviewing the history of North America with ridesharing, they exhaustively divide the history into five phases, from the car-sharing clubs that arose under the controlled economy during WWII, to real-time ridesharing that uses cutting-edge ICT.

Amey *et al.* (2011) categorize shared vehicle transportation services, positioning the initiatives of driver/passenger for trip determination as the horizontal axis, and their profit motive as the vertical axis. In the shared vehicle transportation services including taxies, Jitney or private shuttles, transit service, commuter vanpools, family shared trips, and non-family shared trips, Amey *et al.* consider ridesharing as ranging from the commuter vanpool to the non-family shared trips, as well as certain types of family shared trips. Then, ridesharing widely covers a position where the trip-determination initiative of the passenger is large and the profit motive is small.

Deakin *et al.* (2011) demonstratively assess the potential for dynamic ridesharing for travel between downtown Berkeley, California, and UC Berkeley Campus. Deakin *et al.* consider dynamic ridesharing as a way to share rides, with matches made ad lib or up to several days in advance, using mobile phones or websites to make appointments. In the dynamic ridesharing system, a traveler submits either a ride-offer or a ride-request, and a ride-matching service center automatically scans a database to identify other ride-requests or ride-offers placed for trips with similar origins, destinations, and arrival times. As with casual and ad-hoc carpooling such as Slugging, travelers who always carpool together for one trip may not particularly need this system. However, Deakin *et al.* point out that, if parking charges are high and parking supply is regulated, financial incentives and parking subsidies for carpooling greatly increase interest in dynamic ridesharing.

In general, dynamic ridesharing is considered to be that, in the case that the spatial-temporal match is founded with a part of OD for a trip, both driver and passenger for the trip move together while sharing a vehicle, so that a system of information sharing and mutual recognition is needed to match the space and time. As the practical use of ICT and the sharing of geographical information are developed, various services with respect to dynamic ridesharing are proposed. In the next section, as examples of these ongoing services are

reviewed, operating conditions of ridesharing are investigated.

3. CASE STUDY

This section shows a few examples of services which can successfully match rides between demanders and suppliers (Hereinafter referred to as “rideshare service”). When investigating operating conditions for ridesharing in low-density small communities where habitation-in-two-regions has occurred, there may be some problems with the implementation of conventional rideshare services without any changes to the service. This section examines conditions for implementing rideshare service, through a case study of ongoing and past examples.

3.1 North America

In North America, according to Chan and Shaheen (2012), there are approximately more than 600 services for ride-matching as of 2011. These ranges from using the community site “Craigslist” to target Slugging, to real-time rideshare services such as “Goose Networks”, “Avego”, etc. which have users matched within 15 minutes using smartphones. Moreover, “eRideShare.com” builds a huge rideshare-service network covering Canada, on which drivers/passengers make registrations and appointments on the website and the matching service itself is charge-free. On eRideShare.com, daily and scheduled usages for medium trips between cities are the most commonly occurrences, and there are a few cases for cross-border long trips or for inner-city short trips. In North America, including this service, most cases are that a demander of ridesharing takes a look at a notice board where suppliers offer rides, and if a satisfactory match is found, the demander and supplier negotiate mutually and voluntarily. There are not many examples of automatic ride-matching when compared with these “notice board-based” services.

3.2 Europe

In Europe, “Carpooling.com”, which was founded by 3 German MBA students, builds a huge rideshare-service network covering approximately 5,000 cities in 45 countries, including “carpooling.co.uk”, “mitfahrgelegenheit.de”, “carpooling.fr”, etc.. Although languages are different, registrations and appointments for ride-offers and ride-requests can be conducted on the website within a common format. In Germany, a company called “MitfahrZentrale” has mediation-offices near major stations around the country. These offices charge the mediation fees for ride-requests by arranging satisfactory matches with ride-offers registered in advance, in answer to the requested date and destination. At the pickup location, the person who has requested the ride pays the fare to the person who offers the ride. The pre-agreed fare is usually a cost split between the parties involved. In France, a NPO called “Allostop” offers a rideshare service for daily and scheduled trips between Paris and the environs. When receiving a ride-request, the NPO introduces a satisfactory match among ride-offers registered in advance. Afterwards, such persons who will share the ride negotiate the travel plan, the fare, etc., using a telephone. Concerning the merits of ridesharing, European rideshare services positively publicize a contribution to reduction of CO2-emissions from vehicles in addition to splitting the cost of gasoline. As there are a few services that indicate a trial calculation of the CO2-reduction effect on the registration/appointment website, such contribution becomes the incentive to offer and request the ride-share, in Europe.

3.3 Japan

In Japan, compared with the rise of mediation services of car-sharing, rideshare services have not penetrated much, with the inclusion of various legal aspects. Meanwhile, in Tokyo, a company called “Turnturtle” provides a web-service called “Notteko!” in Japanese, which means “Will you take a ride?”. On Notteko!, irregular holiday usage for young adults, such as for leisure or returning home, for occur most commonly, and up to 400 matches a month are founded. A supplier who offers a ride in Notteko! writes the trip OD and arrival time on the notice board, and if a demander who requests a ride in Notteko! finds a preferred supplier, then the demander writes the requested pick-up and drop-off location, itinerary, fare, etc. on the supplier’s comment column on the notice board, and the demander and supplier negotiate via the website. The negotiation process is one that all users can always view. Additionally, the results of mutual assessment after ridesharing are expressed on the notice board, which works to drive out malicious users. Compared with the private profiles on websites for European rideshare services, in which only a head-shot photo is printed along with personal information, users of Notteko! can describe a fruitful amount of content in their private profile on the website. This is designed to eliminate the user’s anxiety, similar to the anxiety that is felt by the demander in such situations as “I’m going to hitchhike with a stranger.” or that of the supplier in such situations as “I’m going to let a hitchhiker ride in my car.”

3.4 Operating Conditions of Rideshare Service

Reviewing not only ongoing examples but also past examples of rideshare services in North America, Europe, and Japan, the operating conditions of rideshare service with respect to dynamic ridesharing become visible. Firstly, it is necessary to enhance the probability of matching. This requires enhancing the chance of overlapping trips between a lot of demanders and a lot of suppliers. Secondly, even if the amount of demanders is small, it is necessary to share origins or destinations with the suppliers in the same time-slot. Thirdly, the suppliers of short trips do not always have the incentives to share the ride, so it is necessary to construct a mechanism for the incentives of the suppliers with short trips, although the suppliers with long trips have such incentives because of reductions of the cost of gasoline and CO2-emissions. In addition, it is necessary to construct a certification system between demanders and suppliers for security purposes, and to relieve psychological barriers for participation in ridesharing.

4. PRE-SURVEY

This section shows the results of pre-survey concerning operational conditions for dynamic ridesharing in a field. As for the field, this study targets the Harayama area located in Hara village, Suwa district, Nagano prefecture, Japan, which is said to be an area of advanced habitation-in-two-regions. To investigate the conditions, a survey targeting all residents in Harayama area has been conducted.

4.1 Surveyed Site

Hara village in Nagano prefecture is on the border with adjacent Yamanashi prefecture, and is situated on moderate-sloped highland, located from 900 to 1,300 meters a.s.l., spindling in the

east-west direction, and is also called “the village in Nagano closest to Metropolitan Tokyo” (See Picture 1). Currently, about 15 areas are approximately dotted every 2 kilometers in the village.

As of 2010, a census in Hara village shows that the population is 7,573 people (up 1.6% from 5 years before), the number of households is 2,568 (up 7.0%), the population density is 175 people per square kilometer (up 1.6%), the percentage of the elderly aged 65 or over is 26.9 % (up 7.2 percentage-points). The total population is currently increasing a little bit, while the population aging rate is also increasing. In particular, in the Harayama area of the village, the population is 581 people, up to 2.3 times higher than 10 years before. One of the reasons why Harayama’s population increases is due to the preservation of the landscape and the vista of Mount Fuji, as well as the comfortable climate with less moisture, which all make Harayama a famous location for vacation houses, or new houses after mandatory retirement, of residents from Metropolitan Tokyo.

Picture 1. Landscape of the surveyed site

Picture 2. Round-trip community bus called “Celeryn Bus”

The Hara village office, which developed a local public transport comprehensive cooperation plan with adjacent Chino city, has decided to introduce a round-trip community bus called “Celeryn Bus” (See Picture 2). The village office began the bus service in October 2010 after giving a taxi company a commission to operate it. The fare is 300 yen for adults, 200 yen for children, and 500 yen for out-of-village. Two buses a day are in operation every day except Saturdays and Sundays, and the interval between services is 1 hour at minimum. As the results of a change of bus-schedules, and the removal of some bus-stops in April 2011, the number of passengers increased as illustrated in Figure 1. Currently, however, the number has peaked. On the other hand, despite the fact that the population of Harayama has approximately doubled since 10 years prior, the round-trip route of the Celeryn Bus does not include the Harayama area.

This study examines the availability of dynamic ridesharing according to the actual situations of residents in the Harayama area, which fits as an area with no bus service. The residents in the Harayama area cannot even be afforded bus-stops of the community bus.

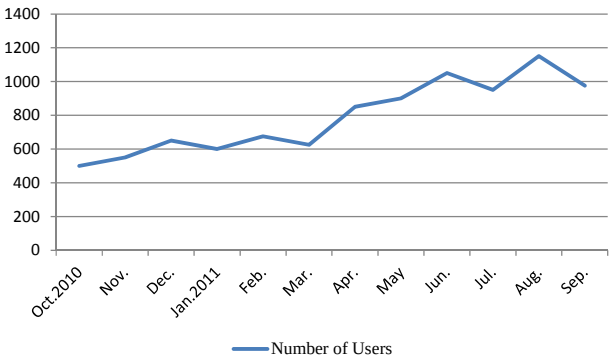

Figure 1. Transition of the number of Celeryn Bus users

4.2 Outline of Survey

In this pre-survey, the feasibility survey was administered to target all households composed of residents aged 20 or over in the Harayama area. Investigators visited every target household, and distributed and collected survey forms in person. The outline of the survey form is illustrated in Table 1.

To survey how many people that think “I will offer a ride to someone” or “I will request a ride from someone” potentially exist, we categorized potential demanders as potential suppliers of ridesharing, based on a judgment condition illustrated in Figure 2. In Figure 2, both the person who currently does not drive any private car and the person who currently drives a private car but wants to limit their driving are termed as “potential demanders”, and the person who does not want to limit their driving is termed as “potential suppliers”.

Judgment for the availability of ridesharing in the Harayama area was made based on the following particulars:

- Composition of the potential demanders and potential suppliers
- Synchronicity of the trip destinations and departure times
- Psychological resistance against riding with others
- Physical and psychological resistance against internet use

Table 1. Outlines of survey form

Method of survey	Distribution/collection of survey forms by household-visit
Periods of survey	From end of November 2011 to mid-December 2011
Question items	- Types of daily-life activities - Destinations and departure times in activities - Frequencies of neighborly ties - Usages of private cars - Psychological resistances against riding with others - Individual attributes
Distribution/collection	Number of households distributed: 250 Number of households collected: 189 (collection rate: 72%) Circulations of survey forms: 301

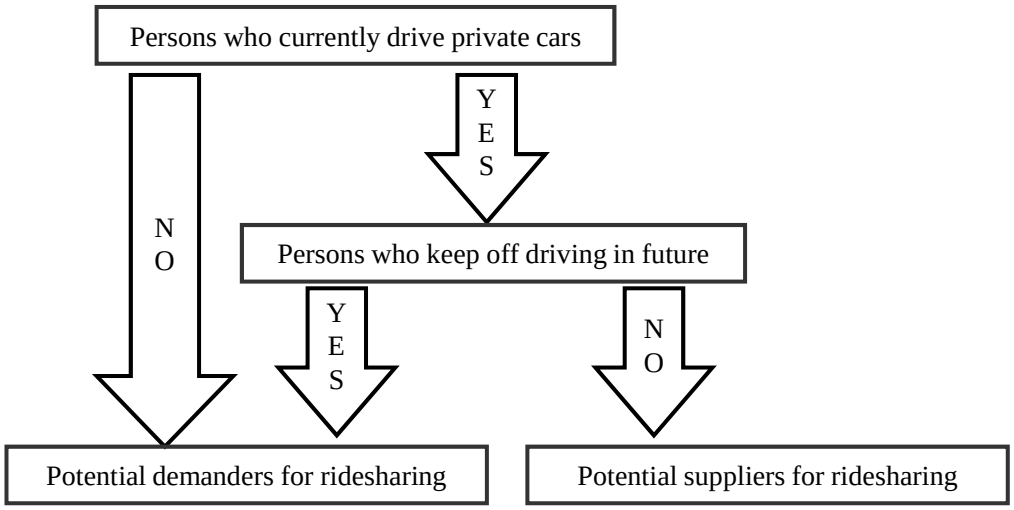

Figure 2. Judgment condition with respect to potential demanders and potential suppliers

4.3 The Results

4.3.1 Composition of potential demanders and potential suppliers

According to a judgment condition of Figure 2, the ratio of potential demanders to potential suppliers in the Harayama area was around 1 to 5, as the numbers of potential demanders and potential suppliers were 37 people and 193 people, respectively. The composition of them indicates that suppliers are potentially greater than demanders in number. In order to test the significant difference between two groups composed of the demanders and suppliers from aged 20 to aged 80 or over, chi-square test with Yates' correction was conducted. While test statistic was calculated to be 46.6, chi-square value was 12.6 in the significant level of 5% and 6 degree-of-freedom. Thus, the ratio of potential demanders to potential suppliers in the Harayama area was based on the statistically-significant difference between the two groups.

As illustrated in Figure 3, up to the age of 60, the number of persons who still want to drive is very high, which was 176 people, and the candidates of those who would be demanders come to be around 10%, because of 19 out of 176 people. Even among residents aged 70 or over, the number of persons who still want to drive is almost half, because 18 out of 35 people.

On the other hand, among the candidates of the demanders, the number of which was 37 people, the number of persons who are unhappy about their current mobility is 16 people (including 1 person in their 20's). As illustrated in Figure 4, the breakdown shows that residents in cottages and villas, and other residents, are the same in number and both of them are mostly the elderly. Consequently, the most elderly 15 people (except 1 person in their 20's out of 16 people) meet the definition of potential demanders for ridesharing.

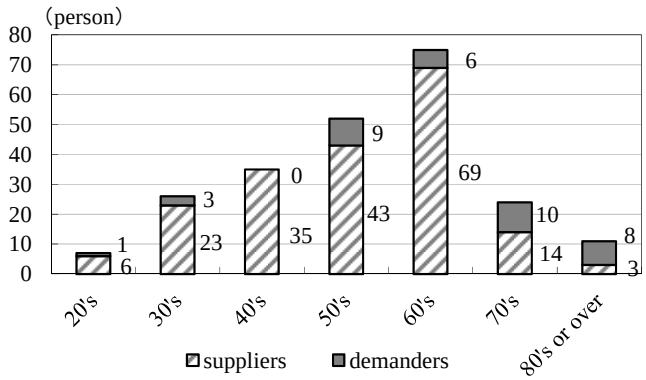

Figure 3. Composition of potential demanders and potential suppliers

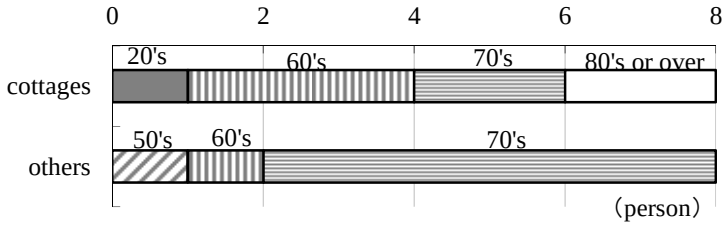

Figure 4. Persons who feel discontented with current mobility in demanders

4.3.2 Synchronicity of trip destinations and departure times

As illustrated in Figure 5, trip purposes composed of “shopping”, “hospital-visit”, and “work” account for 56% in the Harayama area. Focusing on elderly persons who listed “shopping” and “hospital-visit”, times to go out for these purposes have several peaks with respect to the number of people, so that the departure time for shopping has two peaks at 10 to 11 a.m. and at 15 to 16 p.m., and the departure time for hospital-visits has one peak at 9 to 11 a.m., as illustrated in Figure 6.

Figure 7 and Figure 8 show destinations for “shopping” and “hospital-visit” from the main 8 sections located in the Harayama area. As illustrated in Figure 7, with respect to the destination for hospital-visit, “Suwa city’s main hospital” accounts for almost half in every section. As illustrated in Figure 8, with respect to the destination for shopping, “A Co-op Hara”, “A Co-op Fujimi”, and “Seiyu Fujimi” account for the most part. In order to test whether the ratio of “Suwa city’s main hospital” is 50% in every section and whether the total ratio of “A Co-op Hara”, “A Co-op Fujimi” and “Seiyu Fujimi” is 50% in every section, t test was conducted. While both test statistics were calculated to be 0.021 and 1.072, t value was 2.365 in the significant level of 5% and 7 degree-of-freedom. Thus, because of no statistically-significant differences, “Suwa city’s main hospital” statistically accounted for almost half and “A Co-op Hara”, “A Co-op Fujimi”, and “Seiyu Fujimi” statistically accounted for almost half as well, in every section. “Suwa city’s main hospital” is located outside of Hara village but in Suwa city on the border with the village. Furthermore, “A Co-op Hara”, “Hara NHI Clinic”, ”Nakashinden Clinic” are all located in the center of Hara village, while “A Co-op Fujimi”, “Seiyu Fujimi”, “Fujimi highland hospital” are all located in Fujimi town.

Consequently, with respect to trip purposes for shopping and hospital-visits, the number of trip destinations is small and the departure times have one or two peaks a day, so that a synchronicity of the destinations and departure times can be seen in this survey. Accordingly,

as for ridesharing, matches of both the time of pickup and the direction to destinations are not thought to be difficult.

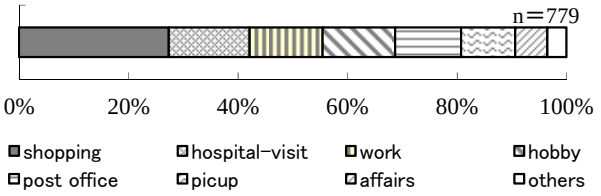

Figure 5. Trip purposes

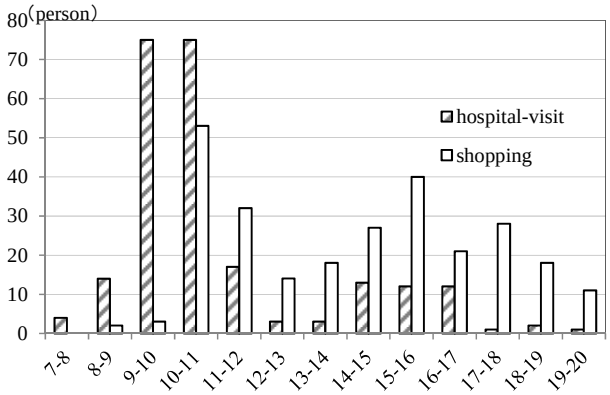

Figure 6. Departure times for hospital-visit and shopping

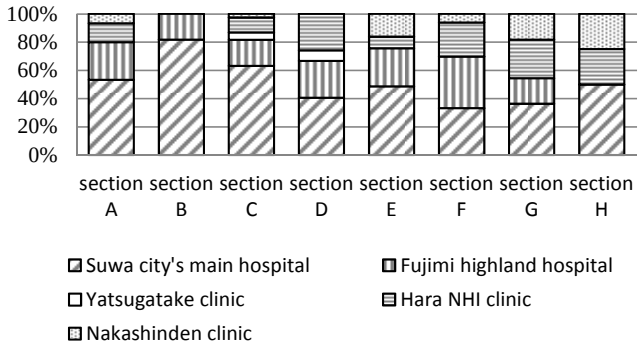

Figure 7. Destinations for hospital-visit

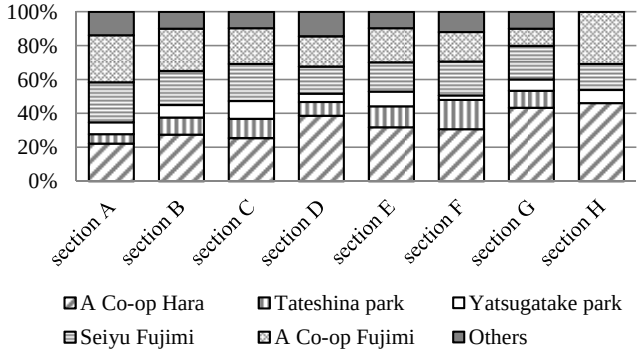

Figure 8. Destinations for shopping

4.3.3 Psychological resistance against riding with others

Figure 9 shows a tendency of psychological resistances of both the potential supplier against offering others a share-ride and the potential demander against requesting others a share-ride.

As illustrated in Figure 9, the potential demanders have psychological resistances against ridesharing greater than the potential suppliers. In particular, around half of the potential demanders have such resistances against even ridesharing with their nearest neighbors. On the other hand, around 80% of the potential suppliers do not have such resistances if their counterpart of the ridesharing is a creditable acquaintance. When inquiring about how many such creditable acquaintances are in the Harayama area, around 20% of the potential demanders answer “none”, as illustrated in Figure 10.

Consequently, in the Harayama area, the potential demanders who do not have resistances against ridesharing if their counterpart is a creditable acquaintance, yet do not have such acquaintances, account for around 20%. So, the implementation of ridesharing requires a system to assure creditability for counterpart of ridesharing.

In addition, persons whose motivation for being a supplier is the social contribution of “I will help neighbors in need, to the extent that I can.” were around 10% in the Harayama area. This suggests the possibility that, in the Harayama area, rideshare service can operate based on the supplier’s motivation for social contribution, if the use-frequency is adequate.

4.3.4 Physical and psychological resistance against Internet use

Figure 11 shows a tendency of physical and psychological resistances of both the potential suppliers and the potential demanders against internet use, when using a website to match users.

As illustrated in Figure 11, among the elderly aged 70 or over and considered as potential demanders, persons who have viewed any website at least once account for around 30% to 40%, and the reminder have no experience.

Consequently, although implementing ICT-based rideshare service in the Harayama area is an option as with examples of other rideshare services, a synergy with an offline system using human resources or a moderator is required as well.

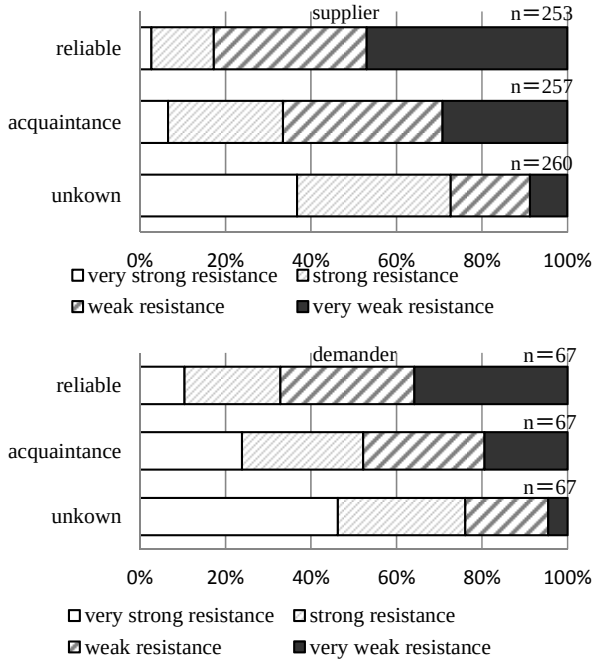

Figure 9. Psychological resistance against ridesharing

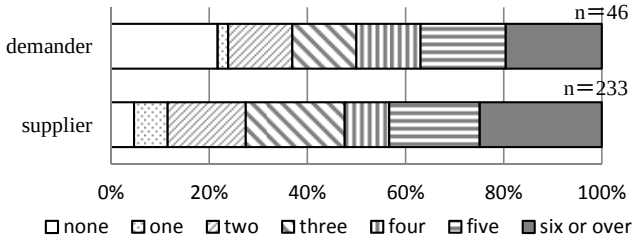

Figure 10. Number of reliable acquaintances

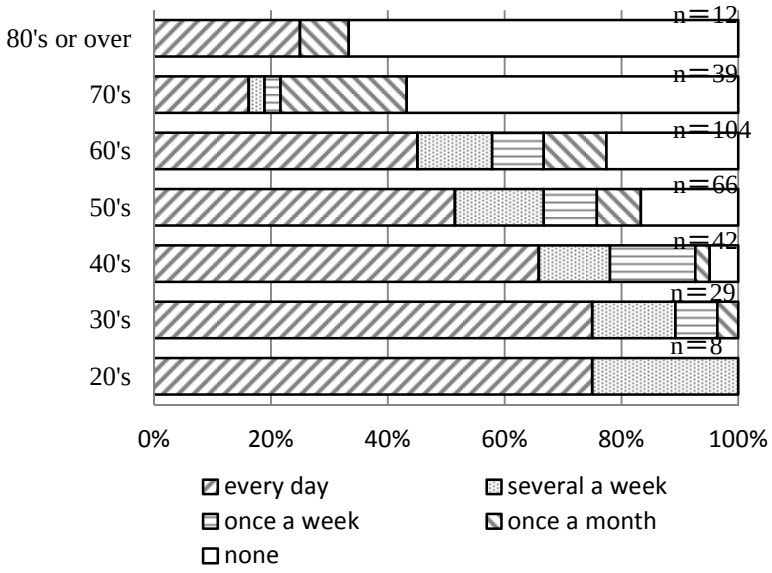

Figure 11. Situations of Internet use

5. FIELD EXPERIMENT

5.1 Proposed System

Based on the results of our pre-survey, a system of volunteer-based dynamic ridesharing with bipartite groups composed of the potential demanders and potential suppliers was constructed to suit the Harayama area, as illustrated in Figure 12. Now, in cooperation with an NPO practicing in the Harayama area, an implementation experiment is being conducted, examining the various subsystems involving certification between the demanders and suppliers, the matching of them, and the participation incentives of the suppliers, etc. Out of the potential demanders, 15 people have registered as experimental demanders as of September 2012. As for the suppliers in the experiment, around 20 people are temporarily registered, consisting exclusively of members from the NPO, due to their easy certification.

In the present phase, because the demanders are elderly and few in number, a notice-board-based matching system using websites made for tablet-computers and smartphones is provided as one of the subsystems. In this subsystem, after some ride-requests are filled out on the website, the supplier chooses their preferred one. Additionally, the NPO members also undertake the role of moderators, and accommodate ride-requests from a telephone, so that the participation of elderly members who cannot view the website is

promoted.

5.2 System Improvement under Experiment

Since the Harayama area has such a small community, the possibility cannot be ruled out that introduction of detailed private profiles such as another rideshare service “Notteko!” would present a psychological resistance to the participants.

In view of the circumstances in such backgrounds, the system is intended for pre-registered members of the Harayama area. Additionally, only pre-registered members are the chance to meet each other as the demanders and suppliers. At the current moment, there are no particular problems that occur with this system. On the other hand, as was reported, charge-free system itself becomes a psychological resistance for the demanders, and this must be improved as well as the incentives of the suppliers. Currently, in the improved system, demanders give suppliers “points”.

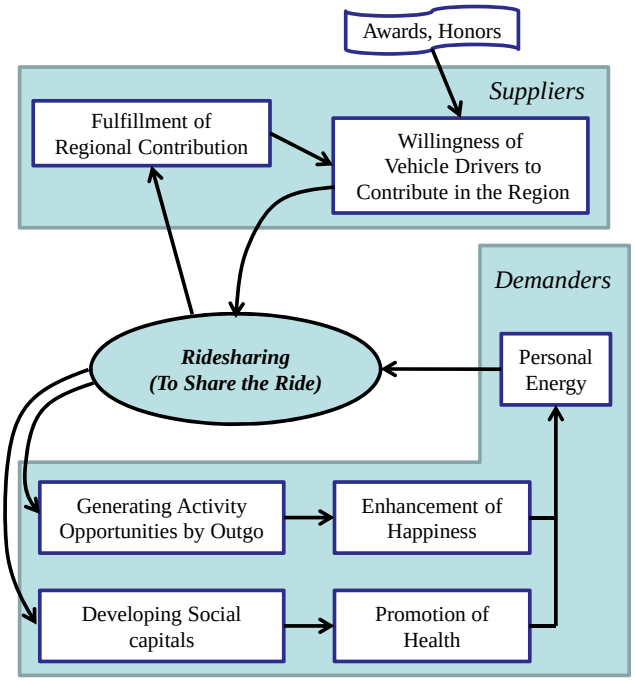

Figure 12. Ridesharing system employed in this study

6. SCENARIO ANALYSIS TOWARD FURTHER IMPROVEMENT

6.1 Worry and Hesitation of Volunteer-based Suppliers

As an improved version of the matching system, it is suggested that when a “preference profile” with respect to the demander and supplier’s preferred rideshare date, matching location, and destination is conveyed through the website to a moderator at the time of the demander and supplier’s rideshare reservation, the moderator finds a stable matching pair as needed. When considering the matching system for ridesharing with bipartite groups with respect to the demanders and suppliers as a “two-sided one-to-one stable matching problem”, we can apply the Gale-Shapley matching algorithm (Gale and Shapley, 1962; Roth and Sotomayer, 1990) to the system.

If the trip purposes are “shopping” and “hospital-visit”, then the trip purposes are categorized into either a regular-trip type or an unexpected-trip type. In the case that the demander requests the rideshare service of regular-trip type, the matching algorithm of preference-profile type is suitable. However, in the case that the demander requests the service of unexpected-trip type, an immediate-response matching algorithm is rather suitable, such as the “Boston algorithm” which matches like “first come, first served” as soon as the moderator receives the ride-request. The Boston algorithm can be executed by improving the matching algorithm’s preference-profile type.

On the other hand, when multi-cycle matching is executed in dynamic ridesharing, maintaining the same demander and supplier pair provides an externality of matching, as the supplier thinks “Even if I offer a ride, I cannot share the ride with various persons” or “Sharing with the same person every time gives me ~~a~~ worry or ~~a~~ hesitation”. This is considered to be the same as the externality against respective commitments between the demander and supplier without the moderator. After all is said and done, the moderator plays a major role in the ridesharing system.

When employing a kind of stable matching algorithm, although we can find a stable-matching pair for ridesharing, the “worry and hesitation of volunteer-based supplier who has no opportunity to match other demander but the stable-matching pair” cannot be eliminated because of such stability. In dynamic ridesharing, balancing between “removing the supplier’s burden of worry and hesitation by sharing the rides with many demanders” and “finding stably the optimal demander out of many suppliers”, a proper matching algorithm needs to be developed.

6.2 Incentives for Participation and Reservation

An improved version of the incentive system is suggested to make use of not charges or fares but “points”.

One is to apply to a reservation incentive for the demander. Because the rideshare system is charge-free, the demander has an incentive for declaring “tentative reservations” in every hour of the day and every day of the week, even though such reservations are unnecessary. To avoid this, the demander pays a point to the moderator once declared, and does not receive any points back regardless of matching. Moreover, the total number of points that each demander can obtain is constrained. By means of such a points-based system, the points work to inhibit the demander from wasting reservations. In addition, if the demander can save points through walking with pedometer at ordinary days, the demander themself can supplement their total point count.

Another is to apply to a participation incentive for the supplier. Providing the supplier with a point at the time of reservation becomes the incentive for the supplier’s participation. However, how, and to what the supplier uses the saved point for must be discussed. For example, it is suggested that a supplier who has saved a specific amount of points can receive “special praise by the village office”.

6.3 Sudden Cancellation of Suppliers after Reservations

Making use of a points-based system as a means of the incentives for participation and reservation is useful even to restrain sudden cancellation of a supplier against the reservation at the matching location.

In rideshare services involving a short trip, the cost per one trip (including gas) is not high enough to split it between demander and supplier. More important than cost, for a

volunteer based supplier, is being delaying on short errands, due to the trip not going according to schedule. This is the problem of up to how much time the supplier can stay at the matching location even if the demander does not appear after the set matching time. This concern arises from the fact that many of the demanders are elderly.

To avoid this, it is suggested that the supplier takes a penalty of a loss of points when the supplier suddenly cancels. On the other hand, it remains to be seen how the demander who was left behind can be rescued for the return trip. In this case, a moderator acting as a "pinch runner" is an option.

7. CONCLUSION

This study targets at a system implementation of a volunteer-based dynamic ridesharing with bipartite group in low-density small community in Japan, and chooses the Harayama area in Hara village, Nagano prefecture, as a site of the field experiment. Based on our survey for the feasibility of the system, this study discussed the results of the pre-survey. The results are as follows:

- Because there is a clear picture of how many suppliers can support the mobility of a few demanders, the situation of "Although I want to request to share a ride, there are not any persons who are offering the ride" is an unlikely situation to occur.
- Because of the synchronicity of trip destinations and departure times, it is not thought that matching the demanders and the suppliers with respect to main-trip purposes of shopping and hospital-visits will be difficult.

Based on these results, it is thought that the availability of the system is not particularly low, if the system can successfully match between potential demanders and potential suppliers. Following this, the results of surveying physical and psychological resistances against rideshare service or Internet use are as follows:

- The pre-registered membership system and the third-party certification system are required with respect to the participation and reservations of the suppliers, because the demanders tend to feel more resistance in ridesharing rather than the suppliers in the case that the counterpart of ridesharing is creditable.

In this study, from the results of the pre-survey, a dynamic ridesharing system was constructed. This paper showed several improvement items found in the currently ongoing field experiment. Although marked troubles have not currently come up, it is reported that a part of the demanders has psychological resistances against charge-free participation. Along the scenario analysis shown in this paper, further improvement of the system will be implemented.

In closing, we mention "system transferability" regarding general case such as villages in other countries in EASTS regions. In cities in EASTS countries, when car ownership cost, parking cost, and trip cost are high, there are examples of ridesharing by taxi or private car. On the other hands, in villages in EASTS regions, there are some cases of sharing voluntarily a bike-ride by family or between neighbors. However, to authors' knowledge, in such villages, it is believed that there are few cases of volunteer-based dynamic ridesharing by private cars. One of the reasons for this is the absence of service providers for facilitating a matching between the "mobility-needs" of the demanders who request the shared ride, and "offerability" of the suppliers who offer the shared ride. Further improvement of the system and accumulation of knowledge through field experiment are thought to be contributory to support persons of limited mobility.

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REFERENCES

Amey, A., Attanucci, J., Mishalani, R. (2011) Real-time ridesharing: Opportunities and challenges in using mobile phone technology to improve rideshare services. *Transportation Research Record*, 2217, 103-110.

Chan, N.D., Shaheen, S.A. (2012) Ridesharing in North America: Past, present, and future. *Transport Reviews*, 32(1), 93-112.

Deakin, E., Frick, K.T., Shively, K.M. (2011) Markets for dynamic ridesharing? Case of Berkeley, California. *Transportation Research Record*, 2187, 131-137.

Gale, D., Shapley, L. (1962) College admissions and the stability of marriage. *American Mathematical Monthly*, 69(1), 9-15.

Kleiner, A., Nebel, B., Ziparo, V. (2011) A mechanism for dynamic ride sharing based on parallel auctions. *Proceedings of the 22th International Joint Conference on Artificial Intelligence*, 266-272.

Roth, A.E., Sotomayer, M. (1990) *Two-sided matching: A study in game-theoretic modeling and analysis*, Cambridge University Press.