INTRODUCING MOBILITY SHARING WITH AUTOMATED DRIVING: REDUCING TIME AND SPACE FOR PARKING

HIDETO KATSUKI & MAMORU TANIGUCHI
Graduate School of Systems and Information Engineering, University of Tsukuba, Japan

ABSTRACT

Recently, "Mobility as a Service (MaaS)" has received much attention for transportation technology development because it can provide more convenient transport modes for users than their personal vehicles can. Moreover, it can transform the space used by and for cars to more comfortable living spaces used by and for people. Cars, as an important middle-distance to long-distance mode of MaaS, are being affected by waves of innovation that include car-sharing, ride-sharing, and automated driving for universal service (ADUS). This study specifically assesses the effects of introducing Shared-ADUS, a new mobility style that is expected to be an important part of MaaS. Shared-ADUS systems provide mobility services satisfying trip demand for cars today, with ADUS vehicles managed in prefecture units. Introduction of Shared-ADUS is expected to reduce the number of vehicles as well as time and space used for parking. We analyse the effects of Shared-ADUS introduction on parking time and space south of Ibaraki Prefecture, a suburban area of metropolitan Tokyo, located 40–60 km distant from central Tokyo. The modal share rate of private automobiles here is about 70%. The study objectives were (1) clarification of the degree to which parking time and space can be reduced and (2) areas in which Shared-ADUS can reduce parking time and space easily. Results show: 1) shared-ADUS can reduce the current number of vehicles by about 60%; 2) shared-ADUS can reduce the time and space currently being used for parking by about 70%; 3) People tend to waste time and space used for parking in urban areas; 4) Shared-ADUS can reduce time and space for parking in industrial and urban areas.

Keywords: automated driving, share mobility, parking space.

1 INTRODUCTION

Recently, a new transportation service called "Mobility as a Service (MaaS)" has received much attention together with the development of transportation technology. With this service, when one travels from point A to point B, some number of available transportation modes such as railroads, buses, car-sharing, and ride-sharing(RS) are combined according to one's preferences and are provided as a package service. MaaS provides users of transportation modes more attractive than owning a car. One of the objectives of its introduction is to convert "Space for using automobiles" to "Space for more comfortable life for humans" [1]. As the background for the appearance of MaaS, apprehension of bad effects by excessive dependence on automobiles, emergence of new methods of automobile utilization such as RS service as represented by Uber, car-sharing services typically represented by Car2Go, which is not based on owning automobiles, and an increase in the number of users who enjoy these share mobility services are described [2]. In MaaS, automobiles used for middle-distance to long-distance movement now face innovation by realization of autonomous cars as well as the emergence of shared mobility. Automated car driving that might allow transportation modes to be used in a friendly manner by everyone will become a core MaaS in the future if combined well with share mobility.

This paper then addresses shared mobility (Shared-ADUS) by autonomous cars, which might become an important transportation mode of future MaaS. By this new traffic mode, autonomous cars owned by regional units are operated as taxis conventional automotive trip demand is met in this mode. This traffic mode can strongly decrease of the number of vehicles through sharing and reduction of time and space for parking [3], [4]. Verification of the

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effects of introducing Shared-ADUS is made primarily by simulation analysis in virtual space, although analysis based on actual traffic conditions is scarce. Because of these situations, the objective of the present study is to identify the number of necessary vehicles after introduction of Shared-ADUS and examine effects of reducing time and space for parking.

2 CONTENTS AND BENEFITS OF THIS STUDY

To fulfil the objectives presented above, the influences of the introduction of Shared-ADUS upon time and space for parking were verified for this study in southern Ibaraki Prefecture (Fig. 1 and Fig. 2), a suburban area of metropolitan Tokyo, located 40–60 km distant from central Tokyo. The population of this area is about 1.63 million (as of February 2017) [5]. The car sharing rate is about 70% [6]. Three railroads connect southern Ibaraki prefecture and metropolitan Tokyo. People mostly use railroads for transport to and from central Tokyo, although automobiles are used as the transportation mode within the region. The present study then analyses automotive trips used in southern Ibaraki prefecture. Contents of the present study are the following.

1. An outline of Shared-ADUS and the simulation method are explained (Section 3).
2. The number of necessary vehicles after introduction of Shared-ADUS and effects of reduction of time and space for parking are identified (Section 4).
3. A summary of results and conclusions is presented (Section 5).

Based on the analysis presented above, this study has the following features.

1. Effects of the introduction of Shared-ADUS, which will become the core of future urban transportation, are verified before practical applications.
2. The act of parking is regarded as the consumption of time and space. Then a new evaluation index is proposed to reveal novelty.
3. Fluctuation of effects depending on plural introduction forms are verified to reveal usefulness.

Figure 1: South Ibaraki location.

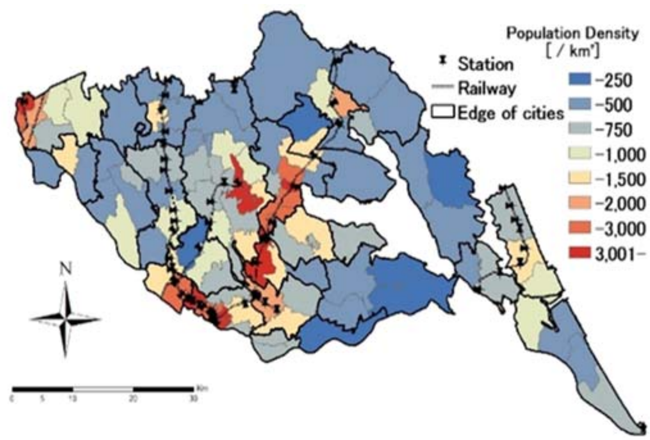

Figure 2: Population density.

3 ANALYSIS SUMMARY

3.1 Systems of Shared-ADUS

Shared-ADUS investigated in this study assumes a means of substituting trips performed primarily by personal cars. Therefore, those who use a taxi or a bus moving in the same road space are regarded as service users. Setting of the automated car driving level at which all people might use them irrespective of possession of a driver's license is necessary. In addition, when Shared-ADUS is regarded as one element of MaaS, RS to the same vehicle should be investigated as one menu. Based on these matters, Shared-ADUS as assumed for this study has the following features:

1. Automatic traveling performance of ADUS is Lev. 5 (SAE level), which allows perfectly automatic traveling.
2. Users travel using passenger cars, buses, and taxis.
3. All vehicles are owned by the entire target region; they are not privately-owned vehicles.
4. RS is established for the same origin–destination. Trips starting at nearly same time.
5. Up to two people are allowed to ride.

3.2 Analysis condition

RS establishment conditions are represented by eqns (1)–(3). Therefore, RS is established for trips having common time and space. For trips having the same origin–destination, direction of movement is unknown and RS is not established for trips of this category.

$$TOD_a = \mathrm{TOD}_b. \tag{1}$$

$$\mathrm{WL} \leqq \mathrm{TS}_b - \mathrm{TS}_a \leqq \mathrm{WH} \;\; \mathrm{c.f.}\; \mathrm{TS}_a < \mathrm{TS}_b. \tag{2}$$

$$0 \,\square\, \mathrm{WL} \,\square\, \mathrm{WH} \leqq 15\,. \tag{3}$$

In that equation, TODn stands for the place of origin and destination n, TSn signifies the starting time (min) of trip n, and WL and WH respectively denote the shortest time and longest time (min) of difference of the starting time of the trip.

The minimum unit of positional information of the PT data is a small zone. It is considered that whether RS is established or not depends on the probability and capability of moving between starting points both within the difference of starting time of the both. Then, in this study, parameter value "RS establishment probability" is set such that the smaller the zone area and the greater the difference of the starting time of the both, the more surely RS is established. Equations (4) and (5) are used for this calculation. This is a division of the difference of starting time of the two divided by "Time reachable within zone" that is calculated from the small zone area and vehicle average traveling speed. This value is multiplied to the magnification factor of the two, satisfying the RS conditions of eqns (1)–(3) to calculate the number of RS establishment sets.

$$RT_i = \beta d_i/v_i. \qquad \text{c.f. } \beta = 1.4. \tag{4}$$

$$di = \sqrt{dzi/3.14}\,. \tag{5}$$

Therein, Rt_i stands for the time reachable in zone I, B denotes the correction factor from linear distance to road distance, dz_i signifies the habitable area in zone I, di is the radius of circle having the same area of dz_i, and vi represents the vehicle average traveling speed in zone i.

The trip with established RS is deemed as one automobile trip. The number of vehicles necessary for transportation of all trips is calculated after the number of automobile trips is determined. Regarding allocation of cars, existing vehicles are allocated for the case in which vehicles exist in the trip starting zone. New vehicles are allocated for the case in which corresponding vehicles do not exist. Presumably a second round exceeding the zone does not occur.

3.3 Introduction scenarios

In Shared-ADUS, elements of plural transportation modes are integrated and every region might adopt different introduction forms instead of a single form. Therefore, it is considered that plural introduction forms are presumed for analyses. Therefore, four scenarios of (1) BAU, (2) RS, (3) SA_No RS (Scenario in which no RS is established at all), and (4) SA_RS are set. Effects produced by every introduction form are compared.

3.4 Data

Table 1 presents the data used. Urban area person trip study data, the results of investigation of dynamic state of transportation covering whole Tokyo urban area, are used as travel behavioral data of individuals. These are travel behavioral data by which outing behaviors per person per weekday can be ascertained comprehensively, with information about the purpose of movement, time of movement, transportation modes, and personal attributes of the individual who moves. Road network data by ESRI Japan are used for the vehicle traveling speed. Open data prepared by Ministry of Land, Infrastructure, Transport and Tourism are used for data related to regional characteristics.

Table 1: Data used in the research.

Out line	Source	Notes
Owned Car・Bus・Taxi Trip data	Person trip research of metropolitan Tokyo (2008)	Personal information: [Age/ Sex/ Car ownership] Trip information: [Origin–Destination/Trip time/ Transport mode/Purpose]
Travel speed data	GISRoad network data	Use average travel speed data of each zone.

4 RESULTS

The whole southern area of Ibaraki Prefecture is regarded as an aggregate unit. Effects generated by the introduction of Shared-ADUS are analysed. Fig. 3 presents the number of automobile trips by introduction form. Fig. 4 shows the number of necessary vehicles. Fig. 5 shows time and space for parking. The time and space for parking are the time and space consumed by the parked vehicle: If 10 vehicles are parked all day long, they count as 10 (vehicle • days). Fig. 6 shows the rate of parked vehicles in the total of all vehicles in every 30 minutes. The following findings were obtained from the above.

1. It is known from (2) and (4) in Fig. 3 that established RS is doubled in terms of the presence or absence of the introduction of Shared-ADUS because, although with (1), RS is not established by those who are unable to use automobiles (without a driver's license or vehicle). If automated car driving is made available, then the type of combination will be increased.
2. Figure 4 shows that the number of vehicles required for Shared-ADUS operation is approximately 40% of the current state. If current automobile users give up personal cars to use this service, then almost 60% of vehicles will become unnecessary. The effective utilization of the space once used by automobiles is possible.
3. It is known from Fig. 5 that as many as 70% of the time and space for parking can be reduced by reduction in vehicles through introduction of Shared-ADUS. It is also known from (3) and (4) that constant reduction effects are generated by the establishment of RS.
4. It is known from Fig. 6 that the rate of parked vehicles by time zone tends to decrease towards peak hours of commuting time and the time when returning home (7–8 a.m. and 17–19 p.m.). This trend is observed similarly even after the introduction of Shared-ADUS, although the rate of parked vehicles in the peak time zone is reduced by approximately 50%. The number of vehicles before the introduction is halved after the introduction. This is primarily attributable to the increase of the number of trips per vehicle.
5. In the meantime, reduction in the rate of parked vehicles in off-peak time zone is low. Even with scenario (4), for which the number of vehicles is minimum, more than 60% of vehicles are still parked off-peak. This difficulty is attributable to a timewise imbalance of trip demand. Therefore, some consideration should be devoted to daytime parking spaces for the operation of Shared-ADUS.

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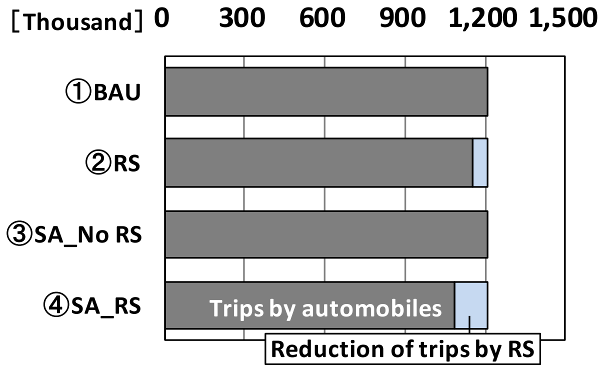

Figure 3: Number of trips by automobiles.

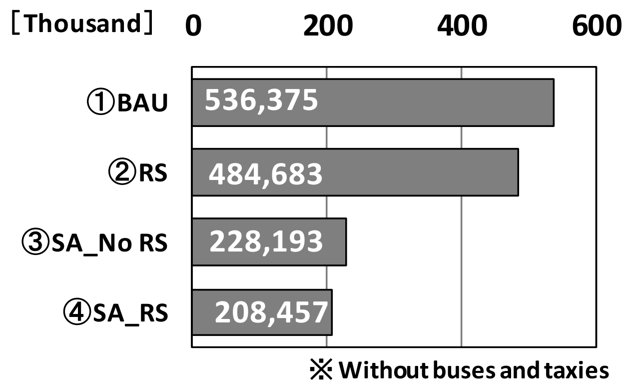

Figure 4: Number of vehicles.

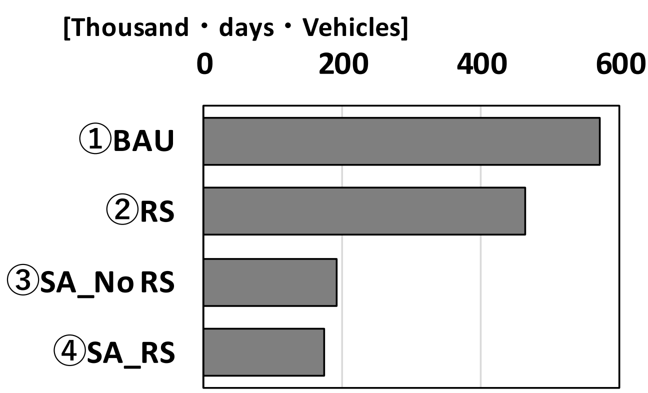

Figure 5: Time and space used for parking.

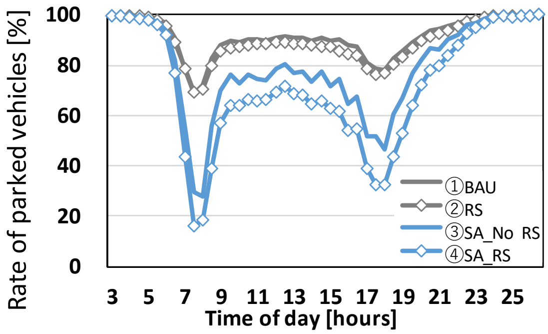

Figure 6: Rate of parked vehicles.

5 SUMMARY AND CONCLUSION

In this study, the effects of reducing the number of vehicles and time and space for parking by the introduction of Shared-ADUS. Major results obtained are presented below.

1. Approximately 60% reduction of current personal cars can be reduced by Shared-ADUS.
2. Approximately 70% of the current time and space for parking can be reduced by the introduction of Shared-ADUS.
3. The rate of parked vehicles in the daytime exceeds 60%, even after the introduction of Shared-ADUS, because numerous vehicles are necessary at the specific time band of commuting time zone.

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