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Consideration of Risks of Real-Time On-Demand Vehicle Operation and Verification of Methods for Safe-Driving

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Abstract

We study Supply and Demand Mediation type Transportation Service, which takes emotions of the service provider and the service user into account, mediates them, and dynamically changes transportation route and schedule. In this paper, we conduct simple simulations of existing and proposed transportation service, and show that the proposed service gives users shorter service usage time than existing services, however, we also confirm that driver's workloads of the proposed service increase. We remake and conduct a hands-on simulation of the proposed service, and clarify several operational problems of both the drivers and the users. The proposed service requires the driver to dynamically change routes in respond to the user requests, which are heavy burdens on the driver. In preparation for social implementations of the proposed service, we conduct an outdoor experiment on the campus of Yokohama National University. In this experiment, we implement two new routing methods and two reservation algorithms to reduce the driver's driving workloads and the user's troublesome operations, and interview the drivers, the users and, the operators at vehicle operation centers about their effectiveness. In conclusion, we verify that the new methods and algorithms resolve the problem of the proposed service.

Keywords: On-demand transportation service, Shared mobility, Supply and demand mediation, Hands-on simulation, Dissatisfaction, Outdoor experiment.

1 Introduction

In developed countries, the birthrate is declining and the population is aging, and it is difficult to maintain existing public services. Therefore more flexible public services that can respond to the increasing and decreasing of the population are required. In the future, it is expected that On-demand or shared mobility services are operated flexibly and dynamically to respond to the requests of users immediately.

We proposed on dissatisfactions of drivers, users and operators at vehicle operation centers, and studied demand management type transportation service which quantified their dissatisfactions and reflected them in the operation of public transportation services. We simulated the proposed

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service for a city of 120,000 people in Japan, and obtained the prospect that dynamic vehicle operations were possible by restricting user dissatisfactions [1].
In this study, it was necessary to mediate among drives, users and operators at vehicle operation centers, with requiring users to walk to the requested location or forcing the vehicle to change its route. When the mediation of the service was successful, the vehicle suddenly needed to be re-routed while in motion. The driving under such conditions was dangerous, but we had not quantified the amount of the dangers yet. Therefore, in this paper, we conducted simple simulations of the existing and proposed service and confirmed that the proposed service gave users' shorter service usage time than existing transportation services. On the other hand, we also noticed counts of steering operation of the driver increase. In addition, we remake a hands-on simulator based on the previous simulator, and showed the problems of both the users and the drivers, for example difficulties of getting in a targeted vehicle without watching the vehicle movement in real time, and risks of increasing the driver's steering counts.
In preparation for a social implementation of the proposed service, we thought of new features, and modified algorithms, and conducted an outdoor experiment on the campus of Yokohama National University in February 2020. In this experiment, we implemented two new routing methods and two reservation algorithm to reduce the driver's driving workload and troublesome, and interviewed the drivers, the users and, the operators at the vehicle operation center about their effectiveness. In conclusion, we showed that the proposed new methods and algorithms could avoid the risks of the proposed service.

We discuss the current state of On-demand and shared mobility service and algorithms in Chapter 2, and outlines of our study Supply and Demand Mediation type Transportation Service based on Dissatisfaction in Chapter 3. We present the results of simple simulations of the existing and proposed services to clarify the features of the proposed service in Chapter 4, and the feeling of burdens for both users and drivers with a hands-on simulation in Chapter 5. We show the concerns and measures about Safe and secure driving in Chapter 6. Then we explain about system configuration, service operation methods on Yokohama National University Campus outdoor experiment in Chapter 7. After showing the experimental results in Chapter 8, we present the discussion about Safe and secure driving in Chapter 9, and conclusions in Chapter 10.

2 Background

On-demand vehicle services are attracting attention from local governments in depopulated areas because they can efficiently operate vehicles through vehicle stops where there are no users. However the operating costs are higher than that of regular public vehicle services, and many services are forced to operate at a loss.
Studies conducted on the ground transportation service gap with the increase in rail and bus services [2][3][4], and a participatory transportation service planning program in which residents proposed solutions to local transportation problems [5]. Other studies investigated transportation service areas that may have service gaps in the future and may require regular monitoring [6], or estimated areas and populations that lack transportation services by using a demand-supply matrix to overlay areas and populations [7]. Illustrating the transportation connectivity using a Geographic Information System showed that many communities of rural areas with medium and large urban centers did not have any transportation options [8]. Transportation planning and facilities in developing countries showed that many people used motorized transportation, even though many non-motorized transportations were available in wide area [9]. In general, in low-

density areas, shared mobility services and On-demand vehicle services were proposed and operated to complement or replaced fixed-route transportation services [11]. The behavior change by shared mobility service [12][13][14] and the ways to improve the convenience and user experience of the service [15] were presented. For example, shared mobility had shorter waiting times and greater convenience than taxies. Shared mobility could be a good complement or alternative form of transportation service in underdeveloped areas and the average cost of waiting at home could be compared with the cost of walking to transportation from the user's psychological viewpoints [16].
However, at this time, there were no reports that mention the dangers of dynamic routing or operation with these algorithms with outdoor experiments.

3 Supply and Demand Mediation Type Transportation Service Based on Dissatisfaction

3.1 Expected Hypothesis

A hypotheses expected in this proposed service is as follow. User, drivers and operators at vehicle operation center exercise a spirit of reciprocity simultaneously to (1) reduce operational costs (for example, numbers of vehicle and driving distance) and (2) minimize the user service usage time. The spirit of reciprocity means, for example, that the users accept to change departure time or departure/arrival location, and the drivers and operators give priority to the user who accepted the changes.

3.2 Service Outline

In a traditional On-demand vehicle service, (1) Users requests are collected before the vehicle moves, (2) the best route is calculated according to the requests, and (3) the route and the departure time of each user are determined and notified to both the users and drivers. However, in some cases, the user request may be rejected when predetermined driving time or distance are exceeded. However, the proposed service is different from the above traditional On-demand vehicle service in that the vehicle operating center make counter-proposals to the user. The contents of counter-proposals are a little different from the original user requests of departure, arrival location, and time. They are determined by comprehensive values of the dissatisfaction of users, drivers and operators at vehicle operation center.

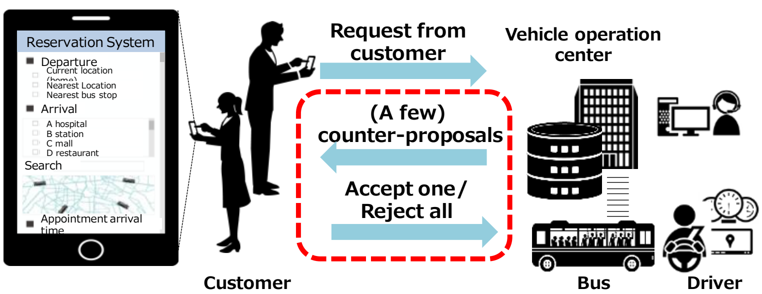

Figure 1: Service outline

3.3 Features of Proposed Service

The proposed service continues to mediate among the drivers, the users and the operators, and modify the route and the schedule dynamically. When the mediation goes in, the route of the vehicle is changed while in motion. The remaining dissatisfaction with the mediation is provided to each user as dissatisfaction points, and the points are used in the next mediation. In this way, the dissatisfactions of the three parties (the users, the drivers and the operators) are taken into consideration, and the service operations can continue that their dissatisfactions are not accumulated excessively in the short or long period.

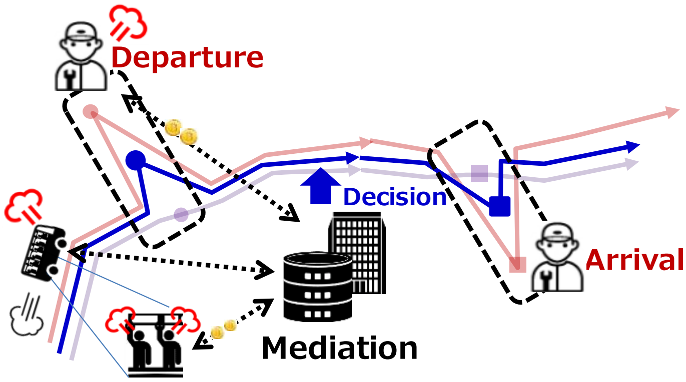

Figure 2: Changed route while in motion

4 Simple Verification of Proposed Service

In this chapter, we show the results of driving distance, service usage time and steering counts by simple simulators.

4.1 Purposes of Simple Simulations

We knew that the short service usage time benefited the users, and the driving distance and the steering counts increased the driver's workload, however we were not quantitatively measured them. Therefore, this time, we attempted to quantify the benefits to users and the burden on drivers in the proposed service by comparing three types of operation as follows.

4.2 Conditions of Simple Simulations

We simulated three types of operation services: (A) Regular bus route operation, (B) On-demand vehicle route operation, and (C) Proposed service route operation.

The simulation environments are as follows. A grid of roads is created to move buses or users as pedestrians. The length of the grid's sides is 250 meters. The speed of the vehicle is assumed to be 10.0 km/h, the walking speed of the users is assumed to be 3.6 km/h, and there are 36 stops (9 stops in the case of a regular route). The number of buses is 1 to 3, and 100 users who get in the bus are generated at randomly determined locations (departure/arrival) at an average interval of 36 seconds. However, the distance between the departure and arrival locations of users is assumed to be at least more than 1.0 km. Overviews of each service operation are given below.

(A) Regular bus route operation

Figure 3 shows that the buses move in order from the departure bus stop to the arrival bus stop (on the red line). Users depart randomly from a departure location (home), walk to a nearby bus stop, wait for a bus at the bus stop, get in the bus, get out at another bus stops, and walk to an arrival location.

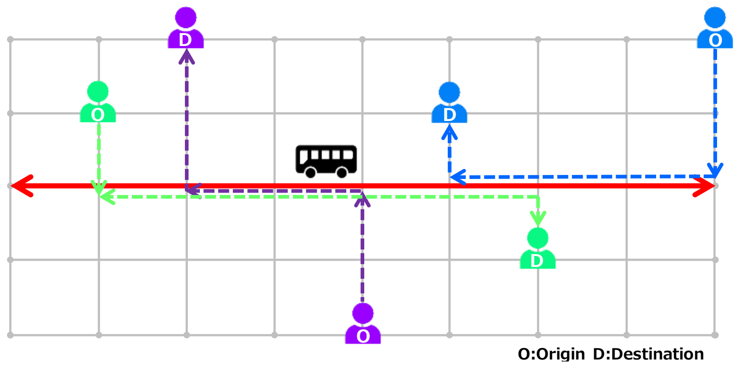

Figure 3: (A) Regular bus route operation

(B) On-demand vehicle route operation

Figure 4 shows that users wait for the bus at home, and the route of the bus is determined according to the user request. When the bus comes, the users get in the bus, and get out at the arrival location.

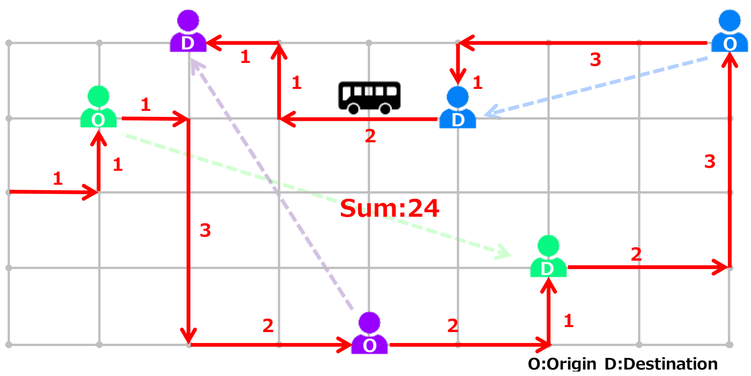

Figure 4: (B) On-demand vehicle route operation

(C) Proposed service route operation

Figure 5 shows that both the bus and the users go to the designated location at the designated time, and the user gets in the bus. The users to get in the bus are asked to walk for several minutes.

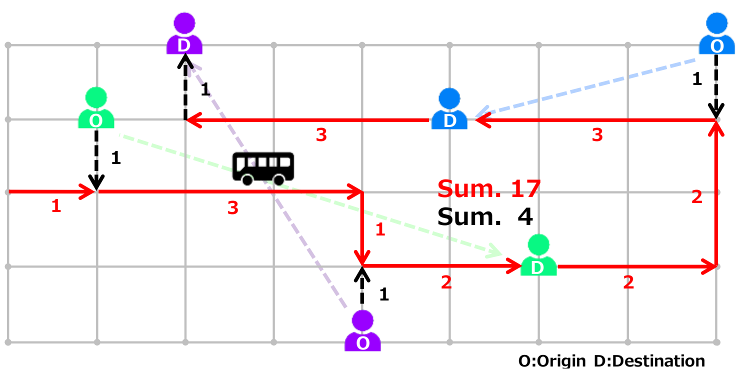

Figure 5: (C) Proposed service route operation

4.3 Verification of Total Driving Distance

Figure 6 shows that the total driving distance of the operation (B) and (C) to transport the 100 users.

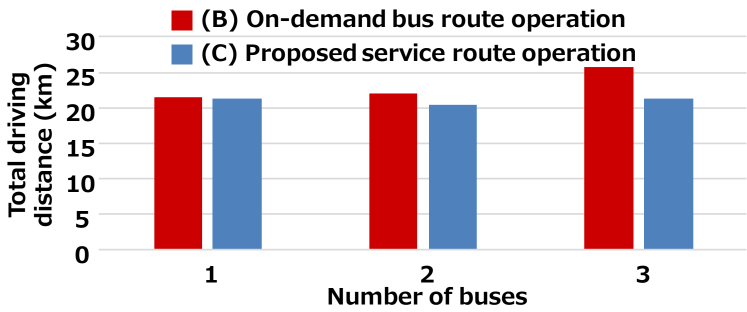

Figure 6: Verification of total driving distance

The operation (C) has a shorter distance than the operation (B), and the number of buses increases, the differences become larger.

4.4 Verification of Service Usage Time

Figure 7 shows that the results of measuring the user average service usage time (from the request time to the arrival time, including getting-in to getting-out) for each number of buses.

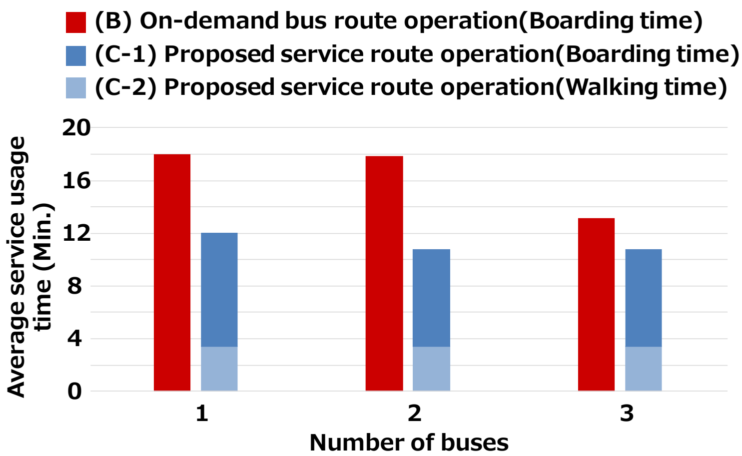

Figure 7: Verification of service usage time

In the operation (C), the users are required to walk an average of 3.43 minutes, however, the total service usage time is less than that of the operation (B). This indicates that the operation (C) is more efficient than the operation (B), even when the number of buses is small.

4.5 Verification of Steering Counts

Figure 8 shows that the total number of steering count (left turns, right turns, and reversals) for each operation. The reason why the counts for the (A) regular bus route operations is smaller than other route operations is that only reversals at the end of the regular route are counted.

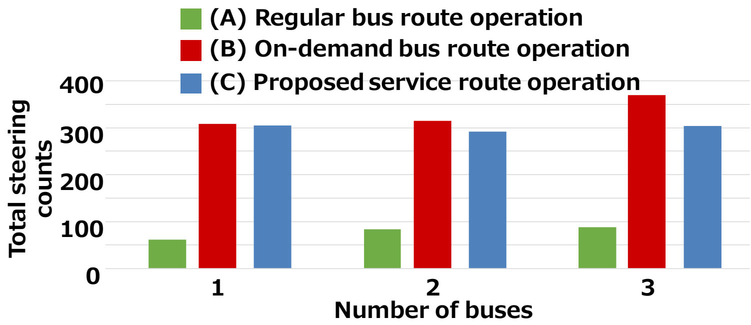

Figure 8: Verification of steering counts

The reason for the large steering count in both the operation (B) and (C) is to move through various routes. Although the counts of the operation (C) is less than that of the operation (B), in the case of the operation (C), the vehicle accepts the users request and reroutes dynamically while the vehicle is still in motion. Then, the operation (C) is burdens for the driver.

4.6 Consideration of Simple Simulations

Although the operation (C) requires users to walk, the average walking time was only about 40% compared to that of 8.33 minutes in the operation (A). Also, compared to the operation (B), the service usage time was also about 70%. In addition, the fewer the number of buses, the better the effects were. From the above, the operation (C) was superior to the other operations in terms of both economic efficiency of operation and user convenience. Thus, we confirmed the spirit of reciprocity in 3.1 was realized. On the other hand, the operation (B) and (C) required more steering count. In the case of the operation (C), the drivers accepted the users request and reroutes dynamically while the vehicle was still in motion, which became burdens for the driver and risks for the users.

5 Hands-on Simulation of Proposed Service

A previous simulation [10] of a domestic city with a population of 120,000 showed that it was possible to operate dynamic On-demand vehicle services based on the above operation (C) that decrease user dissatisfaction by changing vehicle routes dynamically.

Items	Numbers
East-West	6.02km
North-South	5.03km
Land area	30.2km^2
Assumed population	119,256
Assumed max passengers per day	4770

Figure 9: Environment for previous simulation

5.1 Features of Previous Simulation

In the simulation, 5000 users, 5 buses and an operator in this city were created as virtual agents. The virtual user agents had each decision-making algorithm that included simple emotions (e.g., dissatisfaction of delay, noise, crowded vehicle), and they went processes of request, counter-proposals, and mediate among the virtual users, the virtual drivers and the virtual operators at the vehicle operation center, as shown in Figure 9.

5.2 Challenges of Hands-on Simulation

We confirmed the proposed service was feasible with the previous simulator, however we found that we could not feel complaints and inconveniences of the proposed service as real users. Therefore, in order to actually experience, we decided to remake the previous simulator into a hands-on simulator for real users to participate in the simulation with their own personal smartphones.

5.3 Features of Hands-on Simulation

In the hands-on simulation, the real users becomes one of the virtual user agents and participates in the simulation. The participating real users can check the operation status from their smartphones and makes a departure/arrival requests. In response to this request, the virtual operators at the vehicle operation center makes counter-proposals for both the real users and the virtual user agents. Upon the user's acceptance, the vehicle routes are changed dynamically.

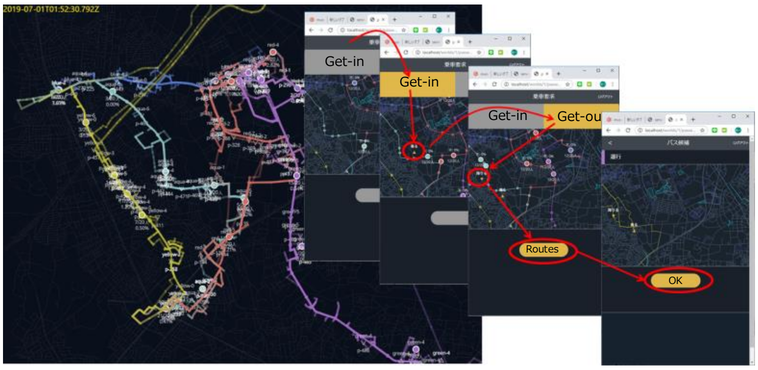

Figure 10: Hands-on simulation

The timing of getting-in/out is display on the user's smartphone, and at that timing, the real user is considered to be in/out. After getting out, a questionnaire is displayed on the real user's smartphone, and the real user responds to it, the series of hands-on processes is completed. In order to shorten the time required for the hands-on simulation, we run the simulator about several times faster than the real world.

5.4 Comments of the Hands-on Simulation Participants

The comments of the participants of this simulation were as follows. (1)They understood that it was difficult to get in the targeted vehicle without watching it in real time. (2) If failing to get in the target vehicle, they sometimes had to wait the next vehicle for a long time (more than 30 minutes). (3) They got an impression that vehicle driving of this simulation seemed to be too dangerous. One of the reason was the virtual vehicle driver in the simulation tended to force to pick up many users. Therefore the participants suggested us to enhance features to reject the getting-in/out requests of the real users or virtual user agents intentionally.

5.5 Consideration of Hands-on Simulation

From the results of the hands-on simulation, the problem with the proposed service, as well as the consideration described in above 4.6, was the burden of the drivers. We thought that a fundamental solution to this problem was essential for the social implementation of the proposed service.

6 Measures for Safe and Secure Driving

In preparation for social implementations of the proposed service, we decided to conduct an outdoor experiment. However, we were concerned about some problems. One of them was safe and secures driving. At the proposed service, the route may be changed while a vehicle is in motion suddenly. It is difficult and risky for a driver to follow the rerouting.

6.1 Five Measures of Operations and Implementations

Prior to starting this outdoor experiment, we discussed the following five measures from the viewpoints of operation and implementation.

(1) Reducing burden of driver terminal operations

The drivers are required to perform the following two tasks simultaneously. (a) Driving while watching the vehicle terminal displays that are changing in real time, and (b) Supporting users getting in and getting out (ticketing, for example). Thus, the drivers are always overloaded. Therefore we decided to employ a driver's assistant in passenger seat to perform all operations except for driving in an outdoor experiment.

(2) Shorting user's getting-in/out process

An in-vehicle system that supports user's getting-in/out, delay the schedule of vehicle operation, especially when the users use this service for the first time. As a result, the driver's driving workloads and risks increases. Therefore, we decided to do the getting-in operation at the getting-in location only and to skip the getting-out operation at the getting out location. Because, the drivers and the users can confirm the getting-out operation on the navigation display and their smartphone.

(3) Omitting cancellation process

Depending on the situations of users, they may have to cancel their request. However, in order to accept their cancellations while a vehicle in motion, rollback operations of requests are required, and the operations take much time. Furthermore, if route changes occur frequently, drivers force to drive in a dangerous situation. Therefore, we decided to omit the cancellation process and the users who don't arrive at the getting-in location, are considered to have canceled the request, and to realize fairness by forfeiting the user's dissatisfaction points.

(4) Limited timing for accepting requests

The proposed service requires a direct mediation among the users, the drivers and the operators at the vehicle operation center, while a vehicle in motion. It is very burdensome for the driver to make the drive in passing areas or the opposite direction of their current driving. However, if these requests were just rejected, the advantage of this real-time dynamic routing of the proposed service would be lost. In order to give the driver to change the route safely, the following three conditions are required: (a) the driver must be able to recognize the route change, (b) the driving

location at that time must not interfere with the route change, and (c) the timing of the route change must be safe and secure, regardless of the driver's experience and skills.
Therefore, we decided to divide the route into three areas depending on the current position of the vehicle, namely, prohibited request area, buffer area, and permitted request area in order to determine whether or not the request from the user can be accepted, by making it look like the route tree in Figure 11.

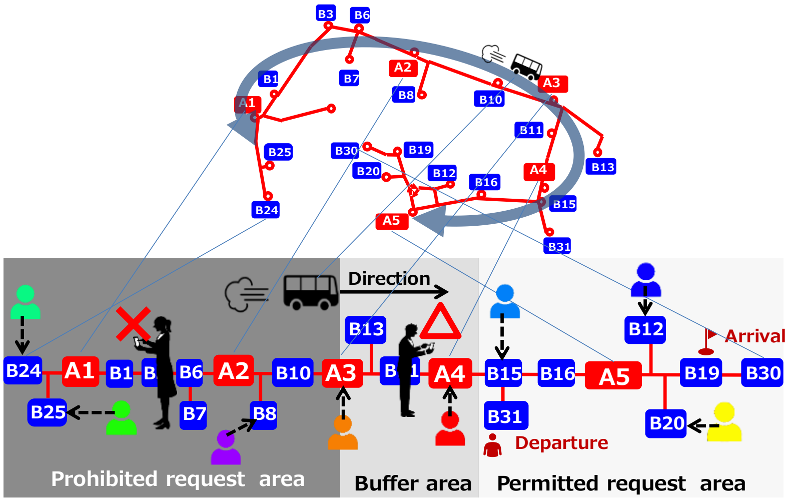

Figure 11: Route tree

(5) Routing to give drivers more discretion
It is difficult for the vehicle operation center to collectively understand each driver's experience and skills in the above (4)(c), and to set the appropriate parameters of the above three areas for each driver. As a result, the drivers may not be able to drive with as much room in the outdoor experiment, according to the driver's driving skills. Thus, we thought to need a new routing method that allows drivers to reroute with the margin.
Therefore, we developed a new routing method called geofence routing, which indicates only the area to be passed and the order number in which the driver should be passed. Geofence is an area surrounded by a virtual boundary (circle or rectangle), and is used to determine whether a target enter or exit the area. The drivers may use any road as long as they pass through the area and follow the order number.

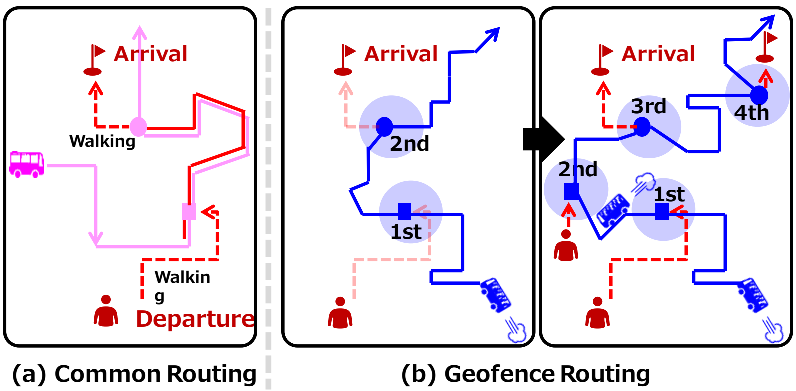

Figure 12: Geofence routing

We implemented the following two additional functions to reduce the driver's driving workload. (a) One is to keep the vehicle operation even if the vehicle passes through the same geofence more than twice, or uses any routes in the campus. (b) Another is to continue operating even if the driver skips the geofence sequence. In general, Geographic Information System (GIS) contains nodes and ways information [17]. However, drivers can use other areas that GIS does not recognize as nodes and ways. For example, drivers can change direction in material yards, wide intersections, or parking lots. Thus, using this routing becomes the advantage of utilizing the local geographic information of drivers.

Figure 13: Locations for changing direction.

7 Yokohama National University Campus Outdoor Experiment

In this chapter, we describe the outdoor experiment of the Supply and Request Mediation type Transportation Service based on Dissatisfaction on the Yokohama National University campus.

7.1 Purposes of Outdoor Experiment

The purposes of this outdoor experiment are, as preparations for the social implementation of the proposed service, to make the proposed service system, including the vehicle operation center system, in-vehicle system, and user information terminals, to verify the effectiveness of the proposed service, and to validate the solution to the above problems in Chapter 6.

7.2 Outdoor Experimental Field

This outdoor experiment was conducted on the Yokohama National University Tokiwadai campus.

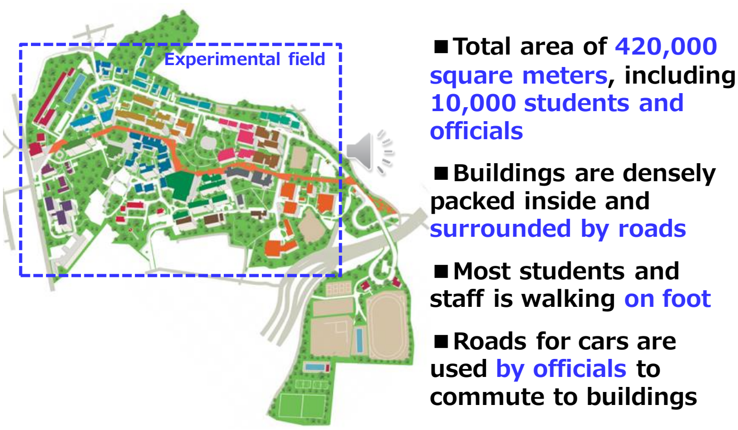

Figure 14: Yokohama National University Tokiwadai Campus

7.3 System Configuration for Outdoor Experiment

This system consists of (1) Vehicle operation center system, (2) In-vehicle system, (3) User information terminal in Figure 15.

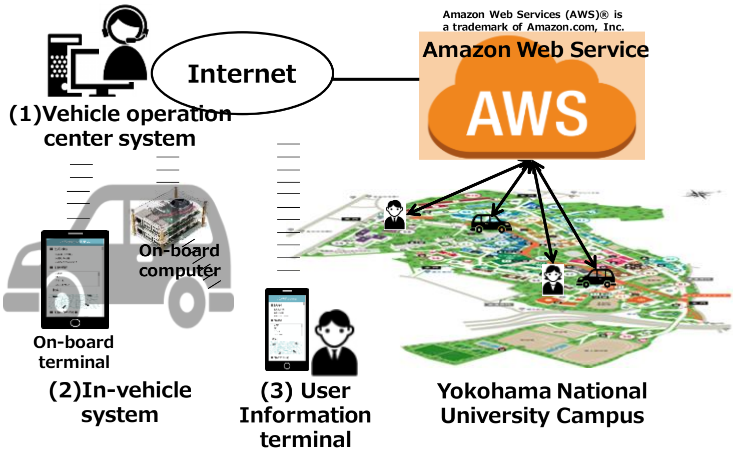

Figure 15: System configuration

(1) Vehicle operation center system
Since this system is designed to be used by smartphones of students and officials, we adopted AWS (Amazon Web Services)®[18] which is the Internet cloud server system for a vehicle operation center.
(2) In-vehicle systems
The in-vehicle system consists of three subsystems: (a) Driving navigation system, (b) QR code display system, and (c) Vehicle status display system. Figure 16 shows the system installed in the experimental vehicle (Nissan SERENA®[19]).

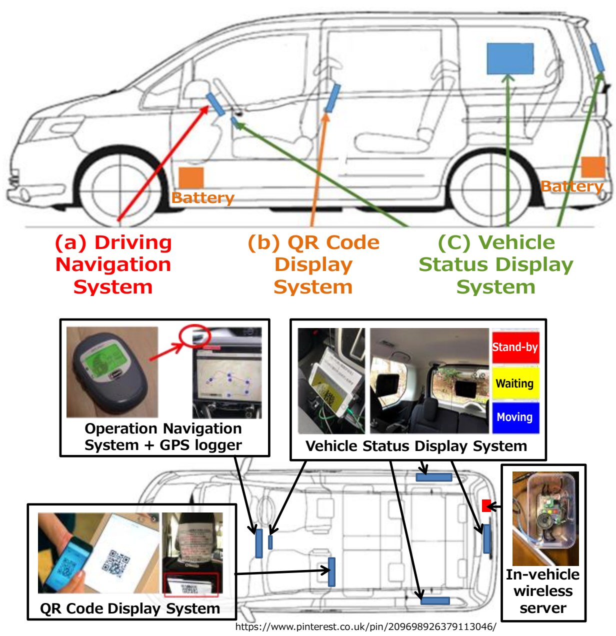

Figure 16: Experimental vehicle and In-vehicle devices

(a) Driving Navigation System

This system is a driving navigation system that provides the driver with dynamic real-time map information and driving directions provided by the vehicle operation center. This system is composed of Apple iPad®[20] and Bad Elf®[21] 2300 (high-precision GPS logger).

(b) QR code display system

The QR code display system confirms that user's getting-in/out in this experimental system. The tablet displays a different QR code for each unit of operation, and the user can scan this code with the user's smartphone to inform the system whether the user gets on or not.

(c) Vehicle status display system

The Vehicle status display system displays the operational status Standby, Waiting, and Moving outside the experimental vehicle using the smartphone and tablets installed in the driver's seat or the window of the experimental vehicle.

(d) On board computer

Raspberry Pi®[22] is an in-vehicle on-board computer that provides the following functions, (i) Services for the in-vehicle systems, (ii) Wireless LAN communication in the vehicle, and (iii) Internet communication with AWS.

(3) User information terminals

In this outdoor experiment, the user terminals are their smartphone and the application is used on the web browser. The purpose of this application is to allow a number of people on the campus to participate in this outdoor experiment.

7.4 How to Use Proposed Service

After the registration of this outdoor experiment system by smartphone, the users request the departure and arrival locations on the map displayed of their smartphone, and they select one route from multiple candidate routes.

The feature of this request method is that the vehicle operation center offers some different getting-in/out location the user requests. The user select one of the offers or reject all of them.

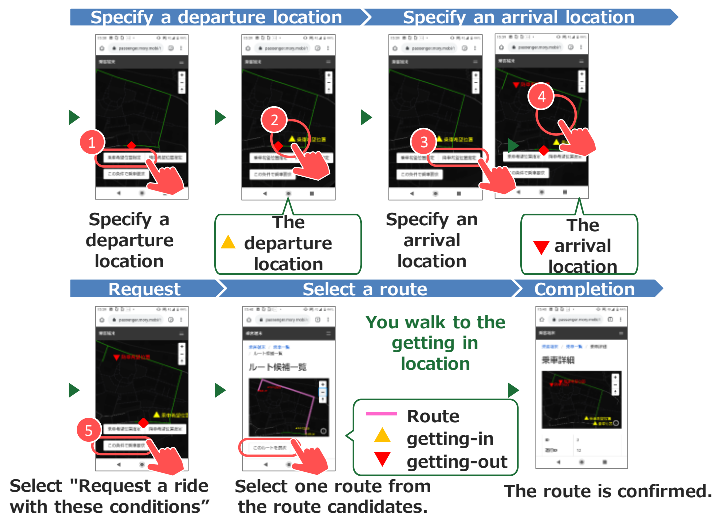

Figure 17 : Requests and counter-proposals

When the experimental vehicle arrives at the getting-in location, and the user get in the vehicle with reading the QR code from their smartphone. The user answers a questionnaire from the vehicle operation center after getting-out the experimental vehicle.

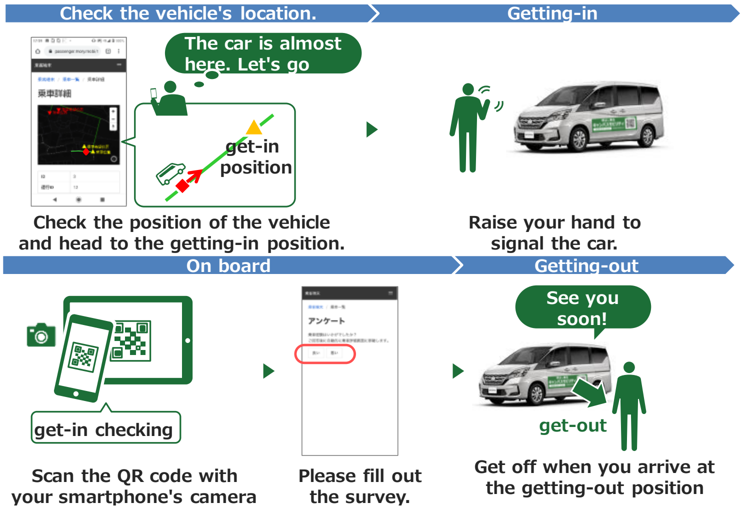

Figure 18: Usage of the service

7.5 Routes and Stops

The stops on the main route are called Fixed stop (A stop), and the stops on the route of branch lines are called Temporary stop (B stop). In addition, these stops are not disclosed to users, because these stops are not to be treated like regular bus stops. The distance between the stops are at least 50 meters. Finally, the routes and stops in Figure 19 were decided to be designed.

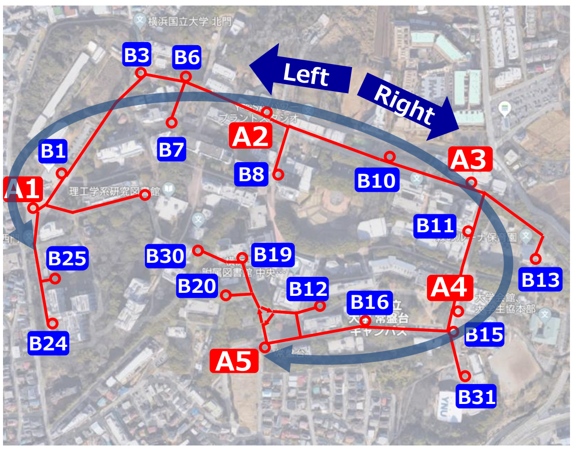

Figure 19: Routes and stops

7.6 Number of Vehicles and Operation Schedule

One vehicle was used for the experiment. The experimental period was 10 days from February 5, 2020, and the service period was from 10:00 to 17:00, approximately every 30 minutes. The users were students, officials of Yokohama National University, and the service was free of charge.

7.7 Reservation Algorithm

7.7.1 Installation of standby reservation

Since the vehicle operation time of one-way is about 10 minutes, the handling of reservations during the In-standby period in Figure 20, is an important problem. The reason is that prohibiting reservations during the standby period significantly loss the opportunities to make reservations for users. On the other hand, it is extremely unreasonable to cancel a standby reservation after a later user makes a reservation. Therefore, during the In-operation period, we decided to give First-come, first-served priority during the In-standby period.

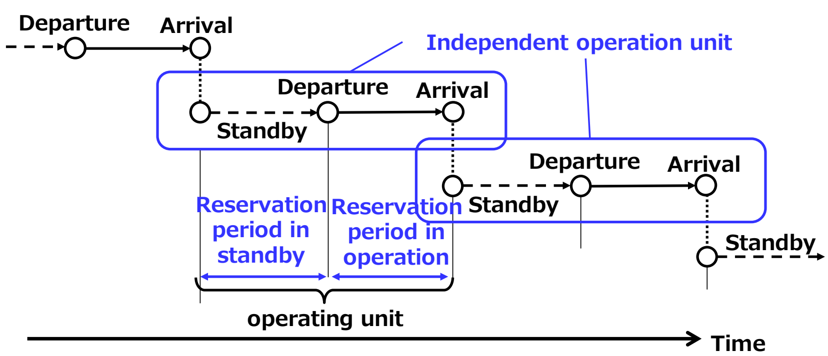

Figure 20: Reservation Algorithm (1)

7.7.2 Installation of dissatisfaction points

In this outdoor experiment, we didn't had to think about crowding and noise in the vehicle. Therefore, the dissatisfaction points are assigned by the results of the user questionnaire, and are handled as follows. (i) If the request is not accepted during In-standby reservation, the Dissatisfaction point is +1. (ii) If the request is not accepted during In-operation, the Dissatisfaction point is +0. Because it is not necessary to give the dissatisfaction point to the user who make a reservation during In-operation, (iii) the Dissatisfaction points are reset to 0 when a reservation is successfully made.

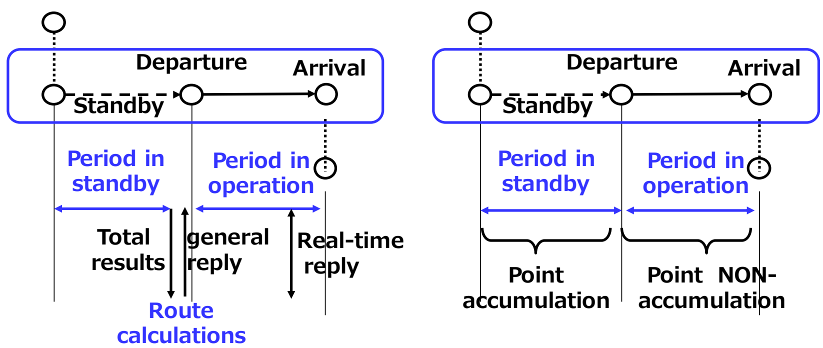

Figure 21: Reservation Algorithm (2)

8 Experimental Results

The results of the outdoor experiment were described below.

8.1 Quantitative Results of Experiment

The following was the overview of the experiment. A/B test in Figure 22 referred to the experiment of comparing two measures each other in order to determine whether the measures were good or bad.

■ **Number of Operation: 14 op./day x 9 days = 126 op.**

■ **Number of registrants : 56 people**

■ **Results of use**

(1) Total number of users (including experiments) 107 people
(2) Number of observers: 16 people

■ **A/B test of satisfaction with two cases**

■ Case 1 Experiment for A: Users who stop only at Fixed stops B: Users who stop both at Fixed and Temporary stops	This experiment was dropped, because the number of users was small (16).
■ Case 2 Experiment for A: without "dissatisfaction points" B: with "dissatisfaction points"	The point system was installed in the second half (2/11-), but the user's points were not accumulated because all users got in the experimental vehicle.

Figure 22: Quantitative results of the experiment

8.2 Interviews with Participants

We interviewed the users, the drivers and their assistants

(1) As passengers

The following comments were obtained from the users as passengers. (a) The service was convenient because it came almost as close to the getting-in locations as possible, even if the request was made far from the main route. (b) The accuracy of the experimental vehicle's current location was high, and they were able to get in the reserved vehicle without lost.

(2) As smartphone application users

There were following comments from the smartphone application users. (a) It was difficult to find their location on the map, (b) It was annoying not to know the approximate time when the vehicle arrives, (c) It was troublesome not to know the general schedule of the service, (d) The notification system was needed not to forget to fill out the questionnaire, (e) It was difficult for the users who were not affiliated with the university to confirm where they were on their smartphone.

(3) As driver's assistants

There were the following comments from the driver's assistants. (a) All user's real-time location information might be disclosed on driver's navigation display because of picking them up easily. (b) It might have been better to have the vehicle start when a user request occurs, because of reducing empty vehicles.

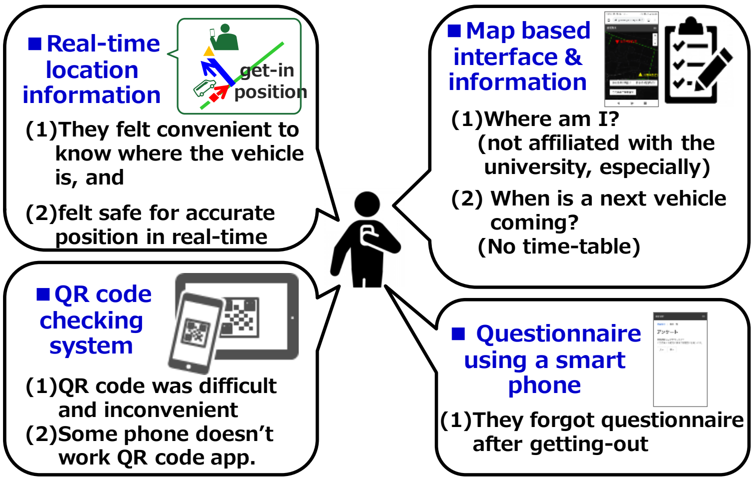

Figure 23: Interviews with the users

8.3 Interviews with Operators at Vehicle Operation Center

There were following comments from the operators. (a) This system was really complex, and it took much *time to* find the cause of failures. (b) Since only a few people could fix the troubles of the systems, they had to have heavy burdens for the operation.

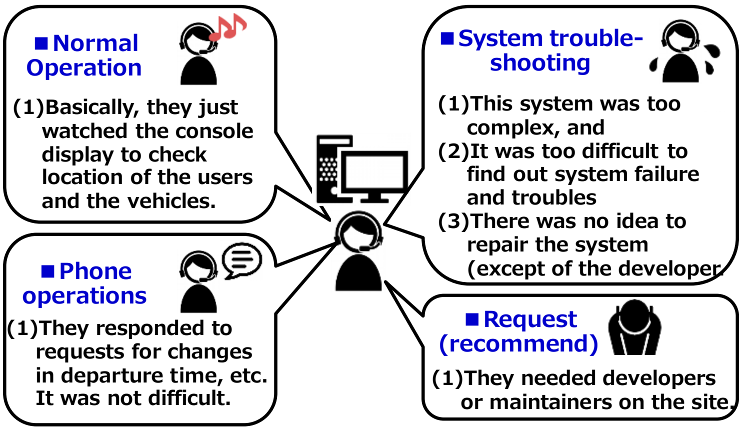

Figure 24: Interviews with operators

8.4 Interviews with Drivers

The following comments corresponded to the contents of Chapter 6.

(1) About reducing burden of driver terminal operations

Some drivers said that they were able to concentrate on driving thanks to the driver's assistant, while others said that the operation of the terminal was not so difficult that they soon got used to it and were able to operate it by themselves.

(2) About shorting user's getting-in/out process

This time, we decided to use the QR code display system when getting in the vehicle, but the following problems occurred. (a) QR code authentication worked differently on iPhone and Android, and sometimes did not work well. (b) This system was difficult for users who were not familiar with the QR codes, and sometimes the departure time of the vehicle was delayed.

(3) About omitting cancellation process

No cancellation without notice occurred during the experiment period. Therefore we could not confirm the effect of the cancellation process.

(4) About limited timing for accepting requests

Of the 126 total operations, all user request which overloaded the driver were rejected by the vehicle operation center and the drivers did not interfere with vehicle operations. In this outdoor experiment, there were three backtracking operations, but the distances were short and no delay occurred in this outdoor experiment.

(5) About routing to give drivers more discretion

About the geofence routing, the geofence skip occurred once a day on average, but did not stop the operation. Some drivers said that (a) As long as they followed the order number of the geofence, they could drive any route of their choice, so they felt a relief, (b) They didn't have to mind the sequential order number of geofence seriously, so they felt less pressure.

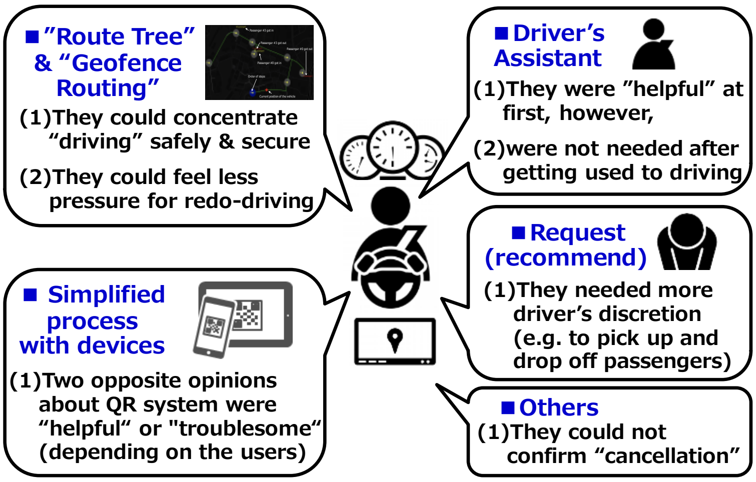

Figure 25: Interviews with drivers

9 Discussion

9.1 About Simple Simulation and Hands-on Simulation

Through the simulations in Chapters 3 and 4, we confirmed that the proposed service (1) reduced operational costs and (2) minimized user usage time quantitatively, and the service were benefit for users, drivers and operators. At the same time, we also confirmed that the drivers accepted the users request and reroutes dynamically while the vehicle was still in motion, which became burdens for the driver and risks for the users (in Figure 8, for example).

9.2 About Safe and Secure Driving

With regard to Safe and secure driving which was the biggest concern for the proposed service in the outdoor experiment, we concluded that the five measures and two new routing methods and two modified algorithms shown in Chapter 6 were effective. In particular, we confirmed that the Geofence routing was suitable for the proposed service.

9.3 Reflections on this Outdoor Experiment

In this outdoor experiment, we did not disclose the Geofence routing to the users. However, we could have got interesting feedback from users, if we had disclosed it. If we can get the permission from users and drivers, we open their personal information on the display of smartphone or navigation system in order to observe the behavioral changes of other users. We also consider the cooperation with commercial taxies and buses as future challenges.

10 Conclusion

We studied Supply and Demand Mediation type Transportation Service, which takes the emotions of the service providers and the users into account, mediates them, and dynamically changes the route and schedule.
For the proposed service, we conducted the simple simulations of three services of the existing bus route operation and the proposed service route operation, and we confirmed that the proposed service is effective in reducing the service usage time of users and total distance of vehicles, however, the driving workload of drivers is high. In addition, we made the hands-on simulator and confirmed that the users also need their own strategies to get in/out the vehicle, and the driver's workloads are really serious.
In order to verify the effectiveness of the proposed service, and to validate the solution to the above problems, we conducted that the outdoor experiment on the campus of Yokohama National University. We confirmed the operations of the system comprising the proposed service and assured to work the service functions. In particular, we found that five measures of operations and implementations, two new algorithms and two new routing methods are efficient to resolve dangerous driving.

Reference

[1] T. Ebata, S. Hori, K. Suzuki, K. Yano (2020), Proposal of Supply and Request Mediation type Transportation Service based on Dissatisfaction: 9th International Congress on Advanced Applied Informatics

[2] G. Bouladon (1967), The Transport Gaps, Science Journal April, Associated Iliffe Press, London, trid.trb.org

[3] G. Bouladon (1970), Technological Forecasting Applied to Transport, Futures

[4] Joseph P. Schwieterman, C. Scott Smith, Riley O'Neil (2017), Ground Transportation Gaps: The Most Heavily Traveled Intercity Routes Without Express Coach or Rail Passenger Service in the United States, Chaddick Institute for Metropolitan Development at DePaul University Policy Series, Transportation Working Paper Series No. 82317

[5] T. Knudsen (2004), Community-based Transportation Planning in the San Francisco Bay Area, APTA Bus & Paratransit & Bus Rapid Transit Conference proceedings, 2004 Denver, Colorado

[6] David Ripplinger, J. Mielke(2007), City of Brookings: Transportation Gap Analysis & Recommendations, Small Urban & Rural Transit Center, Upper Great Plains Transportation Institute, North Dakota State University, Fargo

[7] Ilir Bejleri1, Soowoong Noh, Zongni Gu, Ruth L. Steiner, Sandra M. Winter (2018), Transportation Research Record: Journal of the Transportation Research Board, Volume: 2672 issue: 8, p649-661

[8] Madani Larijani, M. , Nahornyi, T. , & Crizzle, A. M. (2019), Using GIS to examine transportation connectivity in Saskatchewan, The Journal of Rural and Community Development, 14(3), page 87-99

[9] C. Jotin Khisty (2010), A systemic overview of non﹣motorized transportation for developing countries: An agenda for action, Journal of Advanced Transportation Volume37, Issue3 Autumn (Fall), pages 273-293

[10] Tomoichi Ebata, Kojin Yano, Yoshiyasu Takahashi, Tatsuhiro Sato (2019), An On-Demand Alternate Transportation Service System for Public Transportation using Real-Time Multiagent Technology, Information Engineering Express, Vol. 5 No. 2 (2019): Published on November 30, 2019, pages 109-119

[11] Errico, F. , Crainic, T. G. , Malucelli, F. , & Nonato, M. (2013), A survey on planning semi-flexible transit systems: Methodological issues and a unifying framework. Transportation Research Part C: Emerging Technology

[12] Clewlow, Regina R. , Mishra, Gouri S. (2017), Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States, UC Davis Institute of Transportation Studies, Research Report UCD-ITS-RR-17-07, p. 38

[13] Charlotte Frei , Michael Hyland , Hani S. Mahmassanic (2017), Flexing service schedules: Assessing the potential for request-adaptive hybrid transit via a stated preference approach, Transportation Research Part C: Emerging Technologies, Volume 76, p. 71-89

[14] Henao, Alejandro (2017), Impacts of Ridesourcing - Lyft and Uber - on Transportation Including VMT, Mode Replacement, Parking, and Travel Behavior, University of Colorado at Denver ProQuest Dissertations Publishing, 2017.10265243

[15] Colin Murphy, Sharon Feigon (2016), Shared Mobility and the Transformation of Public Transit, https://doi.org/10.17226/23578

[16] Feng Qiu, Jinxing Shen, Xuechi Zhang, Chengchuan An (2015), Demi-flexible operating policies to promote the performance of public transit in low-request areas, Transportation Research Part A: Policy and Practice, Volume 80, p. 215-230

[17] OpenStreetMap's conceptual data model of the physical world, https://wiki.openstreetmap.org/wiki/Elements

[18] Amazon Web Services (AWS)® is a trademark of Amazon.com, Inc.

[19] SERENA® is a trademark of Nissan Motor Co. , Ltd.

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