Int. J. ITS Res. (2010) 8:188–200
DOI 10.1007/s13177-010-0014-9

Development and Evaluation of New Interface for Registration of New Bus Stops for the On-Demand Bus System

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Received: 22 March 2009 / Revised: 8 October 2009 / Accepted: 4 June 2010 / Published online: 24 June 2010

Abstract On-demand Bus is a new public transportation mode which has flexible schedule and flexible routes. Users can ride the bus only after making reservations. It is difficult for the On-demand Bus system without any operators to realize full demand typed service because there is no interaction between users and drivers to inform the concrete information about waiting spots. This paper proposes the new interface for On-demand Bus system through which users can register new bus stops by themselves. The developed interface, namely the developed system realizes CSCW (computer-supported cooperative work), which is a collaboration with the Internet. By developing the new interface, the full demand typed On-demand Bus service is realized and users evaluate the service positively.

Keywords On-demand bus · Full demand service · CSCW

1 Introduction

On-demand Bus is a new public transportation mode which has flexible schedule and flexible routes. Users can ride the bus only after making reservations.

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According to Hirata (2003) [1], On-demand Bus can be divided into three types that are turn-around type, semi demand type, and full demand type.

Turn-around typed On-demand Bus is simple system. It has fixed route and fixed time table like route bus system. Adding the fixed route bus system, there are some unscheduled bus stops for demand response. Passengers who want to ride the bus from unscheduled bus stops call the bus by pushing the button. Then, the bus turns around for the customers.

Semi demand typed On-demand Bus is defined as the On-demand Bus service which has some constraints like bus stops or time table. For example, the service which has no time table but fixed bus stops is categorized in semi-demand type. In the same way, the service which users can ride at any points with following time table is also categorized in semi-demand type. This case is the most typical On-demand Bus service.

Full demand typed On-demand Bus is defined as the On-demand Bus service which has no constraints in bus stops and time table. Users can use the bus from any points to any points at anytime in defined area. We call the transportation service which vanishes the area constraints from the full demand typed On-demand Bus as a taxi.

Though the full demand typed On-demand Bus service is the most comfortable service from users' view points, the implementation of the service is very hard from two reasons. Firstly, it is concerned with the troublesome confirmation of the pick up points between users and drivers. In existing system, operators are employed in order to decide and inform the accurate waiting points of passengers. When drivers cannot find users at waiting spot, drivers call to operators and operators contact to users. This confirmation procedure is troublesome and the operators are required the sense of locale in order to explain the concrete information. Odaka e-town taxi service does not specify the waiting spots thanks to the existence of operators. This service is semi typed On-demand Bus service because its schedule is fixed.

The second difficulty is the calculation system. The calculation system for uniting many passengers' demands and creating the route is required because there is no route and no time table. In usual taxi service, the operators search the optimal vehicle and order the vehicle to pick up the passengers. As for the full typed On-demand Bus service, the manual calculation is difficult because it has a share-ride function unlike the taxi. Yamato (2008) [2] and Tsubouchi (2009) [3] developed the calculation system for On-demand Bus scheduling. The system can update the route dynamically with ensuring the informed arrival time to passengers. Moreover, any users can use the calculation system and reserve their seats by themselves through the web site. However, the calculation system requires the fixed bus stops.

This paper describes the development and evaluation of new interface with which users can register new bus stops for On-demand Bus system. In this paper, the word of "interface" does not mean just web page but means the total registration process. Thanks to this interface, users can ride the On-demand Bus from anywhere to anywhere within area. Since the developed interface is employed in the system which Yamato (2008) developed, everyone can reserve their seats when they want to ride. It means that the providing service can be full demand typed On-demand Bus.

The rest of the paper is as follows. The overview of the developed system is explained in Section 2. Then, the scheduling algorithm and the new interface for registration of bus stops, which are important for full demand typed service, are described in Section 3 and Section 4. After that, the result of computer simulation is described in Section 5 and that of field test is shown in Section 6, and then Section 7 concludes this paper.

2 Developed on-demand bus system

Figure 1 shows the overview of reservation system. At first, passengers access gateway in reservation via phone or web. Gateway relays passengers' demands to calculation system in which the original algorithm is implemented and the algorithm updates the route. After updating route, system announces new route to communication device. And the communication device stores up actual moving time into the database. Passengers can confirm the location or the situation of the bus via web (Bus Location system). The detail explanation and user evaluation of developed system are evaluated by Tsubouchi (2008) [4].

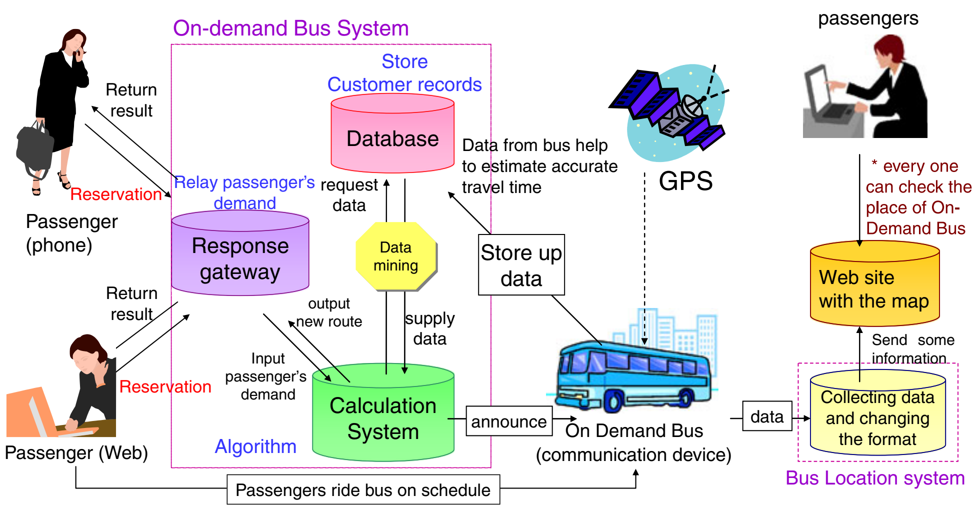
2.1 Gateway

The task of Gateway is to exchange the information between users and calculation system. The demand information of passenger is inputted in Gateway by users. Demand information consists of five types of information: who inputs the information, when does he / she want to move, from where to where, with whom.

After calculation the system returns the output to users. System answers four information, pick up time, arrival time, confirmation ID, and vehicle ID.

Gateway can be customized flexibly according to fit with each user's status. Figure 2 shows that two types of gateway as examples, the gateway from PC access and that the one from mobile phone access. The number of steps for reservation and the size of each page are totally different but it exchanges the same information between the users and calculation system.

Fig. 1 Developed on-demand bus system



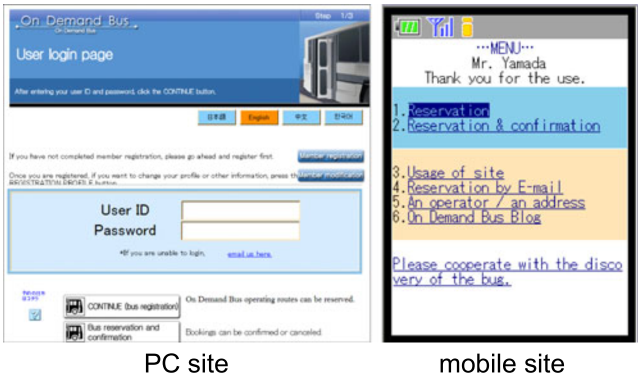


Fig. 2 Two types of Gateway (the left one is for PC access, the other is for mobile phone access)

2.2 Calculation system

The original algorithm, which is explained in detail in Section 3, is implemented in calculation system, and the algorithm updates the route.

In the existing On-demand Bus service, the operators calculate and update the route by manual. The developed calculation system does not need manual operation at all.

When the system gets the demand information from gateway, calculation is started automatically and the updated schedule is returned to gateway and communication devices.

2.3 Communication device

Communication device is used to exchange the information between bus and server. Communication device tells the driver the information of when and where the bus should go next and who waits for the bus and tells server the information of who gets on/off the bus. Figure 3 shows the images of communication device. FOMA (Freedom Of Mobile multimedia Access) network, the famous network service in Japan, is used to exchange the data between server and bus. Software is implemented on PDA (Personal Digital Assistant) and drivers are able to operate it by touching the displayed three buttons. Customers get the accurate position of bus by GPS (Global Positioning System). Drivers know bus route from the navigation screen. Passengers' information are displayed in customers list screen. These screens are helpful for drivers to drive On-Demand Bus. The kind voice guidance and three button operation realize easy manipulation for drivers.

3 Scheduling algorithm

Scheduling Algorithm takes an important role for the realization of full demand typed On-demand Bus service without any operators. With the routing algorithm used in the existing On-demand Bus calculation system, the delaying often occurs in every insertion because the new customer's reservation lengthens the travel time of the bus. The developed routing algorithm does not allow this delay and it can ensure the informed arrival time to users. By scheduling algorithm, the bus will not delay on announced arrival time and the bus can transport lots of diversified customers to their destination together.

3.1 Related research

Stein (1978 [5]) and Psaraftis (1980 [6], 1983 [7]) examined Dial-A-Ride problem when no defined time windows exist during which the service is to begin, and also when the service is done with one vehicle only. Cullen et al. (1981 [8]) dealt with Dial-A-Ride problem also in case of absence of time windows, but when the service is performed by a greater number of vehicles. Sexton (1979 [9]) studied the static version of Dial-A-Ride problem with defined time windows and one vehicle service. Yet, the most common problems encountered in practice are static Dial-A-Ride systems with specified time windows and performed by a greater number of vehicles. These systems were, among the others, researched by Jaw et al. (1986 [10]), Alfa (1986 [11]), Rhee (1987 [12]), Kikuchi and Rhee (1989 [13]).

Another important consideration in the formulation and solution of vehicle routing and scheduling problems is the required computational effort associated with various techniques. Virtually all vehicle routing and scheduling problems belong to the class of NP-hard problems. This indicates that it is difficult to solve even small instances of a problem to optimality with a reasonable computational effort. As a consequence, finding an optimal solution

Fig. 3 Developed on-demand bus system

should not be insisted in the solution process of real-life problems, but instead on finding an acceptable solution within an acceptable amount of computation time. To accomplish this, approximation algorithms are required. Moreover, in order to obtain a solution to a vehicle routing and scheduling problem, two types of decisions have to be made: assignment decisions to determine which vehicle serves which customers and routing decisions to determine in which order the customers assigned to the vehicle should be picked up. Therefore, in this paper, two approximate reasoning algorithms to make both assignment decisions and routing decisions within an acceptable amount of computation time are proposed.

3.2 Problem formulation

3.2.1 Mathematical notation

Mathematical notation is confirmed as follows. There are three types of variables such as variables to be determined by solving the problem formulated, variables given by customers' reservation process and variables concerning the parameters determined by operators.

1. Variables to be determined by solving the problem formulated

N	the total number of customers requesting service
n	the indicator of a customer
EPT_n (EDT_n)	the earliest pick-up (delivery) time of customer n
LPT_n (LDT_n)	the latest pick-up (delivery) time for customer n
APT_n (ADT_n)	the actual (scheduled) pick-up (delivery) time for customer n
IPT_n (IDT_n)	the informed pick-up (delivery) time of customer n

2. Variables inputted by customers at the reservation process

DPT_n (DDT_n)	the desired pick-up (delivery) time of customer n
$+n$ ($-n$)	the event "pick-up (delivery) customer n" "$+n$" ("$-n$") also denotes the point of origin (destination) of customer n
ST_n	the slack time of customer n

3. Variables regarded as parameters

$D(x, y)$	vehicle direct travel time from point x to point y using the shortest route
$TT(x, y, hour)$	the travel time from point x to point y at a specific time
$p(x)$	the place where event × occur. i.e. $p(+n)$
Bus_n	bus number which serves customer n
$DRT_n(hour)$	the direct ride time of customer n
MRT_n	the maximum acceptable ride time for customer n
V	the total number of vehicles

3.2.2 The problem

In this problem, N customers have to be transported by V vehicles or less. Each customer, customer n, has to specify pick-up bus stop, $p(+n)$, and delivery bus stop, $p(-n)$. He also has to specify either desired pick-up time (DPT_n) or a desired delivery time (DDT_n). Most individuals are constrained in the morning by a desired "delivery" time (e.g. work start time) and select their trip starting time accordingly. Such a Dial-a-Ride customer will be a "DDT-specified" customer and will rely on the system to tell him at what time he will be picked up so that he will be delivered by time DDT. The reservation is true for DPT-specified customers. After calculation, informed pick-up time (IPT_n) and informed delivery time (IDT_n) will be informed to the customer.

3.2.3 Time window setting for the first time

Given a subscription list of N customers, each specifying either a DPT_i or DDT_i (i=1, 2... N) and a fleet of V vehicles, the system find an effective allocation of customers among vehicles and associated time schedule of pick-ups and deliveries such that:

1. for all customer n;

$$EPT_n \leq APT_n (= IPT_n) \leq LPT_n \tag{1}$$

$$EDT_n \leq ADT_n \leq IDT_n \leq LDT_n \tag{2}$$

2. For DPT-specified customers:

$$EPT_n = DPT_n \tag{3}$$

$$LPT_n = EPT_n + ST_n \tag{4}$$

$$DRT_n(hour) = TT(p(+n), p(-n), hour(DPT_n)) \tag{5}$$

$$EDT_n = EPT_n + DRT_n(hour) \tag{6}$$

$$LDT_n = LPT_n + DRT_n(hour) \tag{7}$$

3. For DDT-specified customers:

$$LDT_n = DDT_n \tag{8}$$

$$EDT_n = LDT_n - ST_n \tag{9}$$

$$DRT_n(hour) = TT(p(+n), p(-n), hour(DDT_n)) \tag{10}$$

$$EPT_n = EDT_n - DRT_n(hour) \tag{11}$$

$$LPT_n = EPT_n + ST_n \tag{12}$$

Time window will be set as shown in Fig. 4.

3.2.4 Time window setting after reservation completion

When one reservation is completed, the time window will be set by the constraints below.

$$IPT_n = APT_n = EPT_n \tag{13}$$

$$LDT_n = IDT_n \tag{14}$$

$$EDT_n \le ADT_n \le LDT_n (= IDT_n) \tag{15}$$

$$LPT_n = LDT_n - DRT_n(hour) \tag{16}$$

In order to guarantee that the actual riding time will not exceed the maximum acceptable riding time, the following constraint is also introduced.

$$0 \le ADT_n - APT_n \le MRT_n \tag{17}$$

New time window will be set as shown in Fig. 5.

Since IPT_n and IDT_n are introduced by calculation and confirmed by customers, time windows are narrowed by calculation because the bus cannot leave the bus stop before

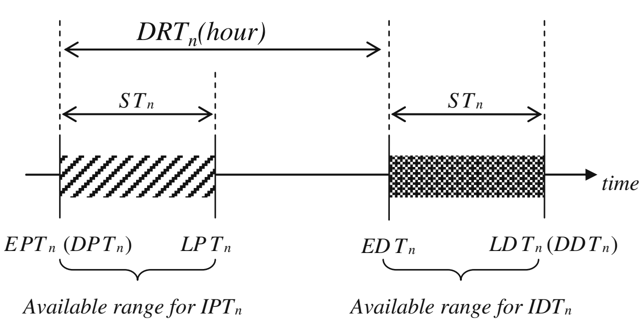


Fig. 4 Initial time windows before IPT_n defined

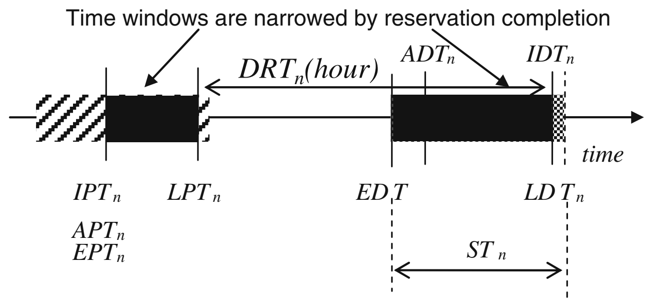


Fig. 5 Time windows after IPT_n defined

IPT_n and may not delay at IDT_n. The time windows solidly painted are new time windows setting after reservation completion.

3.3 Algorithm outline

In developed On-demand bus system, two algorithm combined together as shown in the following figure are introduced. Using the first algorithm, Vehicle choosing Algorithm, the system decides which vehicle will accept the new request. The second algorithm, Routing Algorithm, is used to design the new route and schedule for the vehicle chosen to serve the new request (Fig. 6).

3.4 Vehicle choosing algorithm

In the Vehicle choosing Algorithm, an effective algorithm with less calculation time should be introduced, especially when solving big problems. The direction variable is selected as a decision criterion.

First, the direction vector (A_n) of customer n is defined as

$$\overrightarrow{A_n} = \overrightarrow{p(-n)} - \overrightarrow{p(+n)} \tag{17}$$

On the other hand, the bus direction vector (B_i) is defined as

$$\overrightarrow{B_i} = \overrightarrow{p\left(s_i^*\right)} - \overrightarrow{p\left(t_i^*\right)} \tag{18}$$

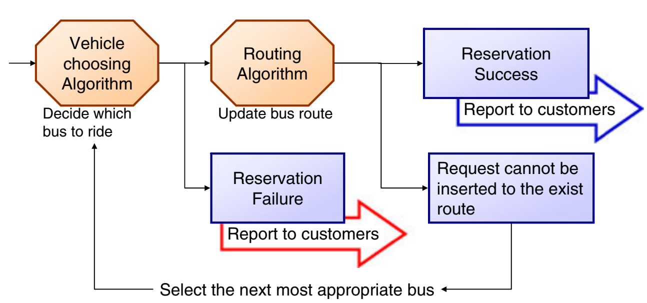


Fig. 6 Algorithm outline

In this case, s_i and t_i shows the event, which is sequence number s and t, of the bus i. s_i^* and t_i^* are the nearest event to the LPT_n and LDT_n, respectively.

Then the direction decision variable (θ_i) is defined as

$$\cos\theta_i = \frac{\overrightarrow{A_n}\cdot\overrightarrow{B_i}}{\left|\overrightarrow{A_n}\right|\left|\overrightarrow{B_i}\right|} \tag{19}$$

When a new reservation comes into the system, the vehicle-choosing algorithm will be executed for each available bus. Since the bus with the most value of *cosθ* is the one with the closest direction to the new demand, that bus will be firstly selected to be executed by the next algorithm, routing algorithm.

In usual case, On-demand Bus runs in about 25 km^2 areas. Therefore the system does not have to consider the distance between initial position of passengers and each vehicle. For the operation in large area, vehicle-choosing algorithm can be extended in order to consider the distance between the initial positions. In this case, the evaluation function is changed as follow;

$$\min \quad \theta_i + a \times D\left(p(+n), p\left(s_i^*\right)\right) \tag{20}$$

where, α shows the weight constant variable. The comparison between the longest direct traveling time in the area and the slack time can be one border line whether the distance between initial position should be considered or not.

3.5 Routing algorithm

3.5.1 Routing algorithm outline

For routing algorithm, a heuristic algorithm which can be described in Fig. 7 is developed. In this example, there are *n-1* passengers who have already reserved the bus. Then there is a new reservation from customer *n*. The "Insertion and time adjustment algorithm", which will insert event *p(+n)* and *p(−n)* into the planned route, is proposed. After the insertion process, some passengers' APT_i or ADT_i (i=1,2,3... *n-1*) will be changed within their each time windows.

3.5.2 Variables declaration

In this "Insertion and time adjustment algorithm", three new variables are defined. *TimeLimit* and *Repeat* define conditions that the calculation will be finished.

S(e)	Feasibility of event e; which is explained in details in the next part
TimeLimit	Limitation of searching time
Repeat	Maximum number for iteration

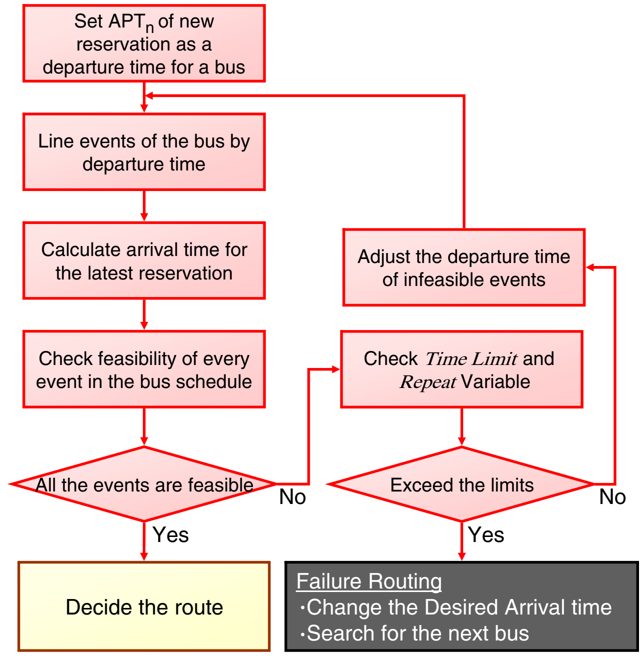


Fig. 7 Insertion and time adjustment algorithm

3.5.3 Insertion and time adjustment algorithm

The procedures of the algorithm are shown by the following flowchart. There are completed route for *n-1* customers. Then customer *n* request for a bus. The time windows of all events {*P*(+*1*), *P*(−*1*), *P*(+*2*), *P*(−*2*), ... , *P*(+ *n-1*), *P*(−*n-1*)} will be calculated. With this algorithm, the APT_n (IPT_n) and ADT_n (IDT_n) will be decided.

First, the algorithm will set APT_n and try insertion. After insertion, the feasibility check will be performed. If all events are feasible, the route will be decided. If there are some infeasible events, the *TimeLimit* and *Repeat* will be checked. If the two variables don't exceed the limitation, the iteration will be executed by adjusting the departure time of infeasible events. However, the processes will stop if one or both of the variables exceed the defined limitation (Fig. 7).

3.5.4 S(e) explanation

S(e) is set up for event's feasibility checking. There are possible value of *S(e)* with different meanings which is shown in Table 1.

3.5.5 Time adjustment for infeasible events

When there is an infeasible event and the iteration does not violate the *TimeLimit* and *Repeat* constraints, then the time adjustment is performed. Table 2 shows that the way of time adjustment by each *S(e)* value.

Table 1 *S(e)* explanation.

S(e)	Explanation
0	Event *e* is feasible.
−1	Event *e* is infeasible because of fault events consequence ($APT_e > ADT_e$)
−2	Event *e* is infeasible because of late delivery time ($ADT_e > LDT_e$)
−3	Event *e* is infeasible because of early delivery time ($ADT_e < EDT_e$)
−4	Event *e* is infeasible because of late pick-up time ($APT_e > LPT_e$)
−5	Event *e* is infeasible because of early pick-up time ($APT_e < EPT_e$)

3.5.6 Conditions to finish calculation

There are two conditions to finish calculation. First, there is feasible route found.

$$\sum_{e}^{N} S(e) = 0 \tag{21}$$

Another one is the calculation time exceeds *TimeLimit* or the calculation iteration exceeds *Repeat*.

4 new interface for bus stop registration

Thanks to the developed scheduling algorithm, users can assign arrival time whenever they want to travel. So the providing service is semi-demand typed On-demand Bus which there is no fixed time table. Moreover, the performance of the developed algorithm does not depend on the number of bus stops because there is no variable specifying the bus stop in the algorithm. It means this algorithm itself corresponds to the On-demand Bus service which there is no bus stops.

However, the confirmation of accurate position of bus stops between users and drivers remains as an assignment to realize full demand typed service. In existing service, there are operators and the drivers can confirm the accurate location of pick up points of passengers by manual operation. In developed On-demand Bus system, there is no operators who have the sense of locale. Common understanding of the location of pick up points between drivers and users is required.

Table 2 Time adjustment by *S(e)* value.

S(e)	Adjustment
0	No adjustment
−1	$APT_e^* = LPT_e$
−2	$ADT_{e-1}^* = ADT_{e-1} - (ADT_e - LDT_e)$
−3	$ADT_{e-1}^* = ADT_{e-1} + (EDT_e - ADT_e)$
−4	$APT_e^* = LPT_e$
−5	$APT_e^* = EPT_e$

In order to solve this assignment, the developed On-demand Bus system employs the system of bus stop so as to define the location information concretely and be able to confirm the location information after all. Adding to this system, the system that users can register the new bus stop easily leads the developed On-demand Bus service to realize full demand typed service.

4.1 Requirement to the system

In designing the bus stop registration system, easy registration process and exactness of the information are required.

If the registration process is complicated or troublesome one, no one will register the new bus stop and the number of bus stops will not increase. One record of bus stop consists of five factors: name, latitude, longitude, concrete information of waiting point, and the acceptable vehicle size. It is required to the system that users can register such information by easy manipulation.

The accuracy of registered information is also the important point to keep the reliability of the service high. The system cannot request users to register the accurate information and computer cannot recognize whether the registered information is correct or not. When the users register the wrong information, someone has to correct the information.

4.2 Development of the system

In order to fulfill the requirements, the registration system in Fig. 8 is developed. The developed system realizes CSCW (computer-supported cooperative work), which indicates a collaboration with the Internet.

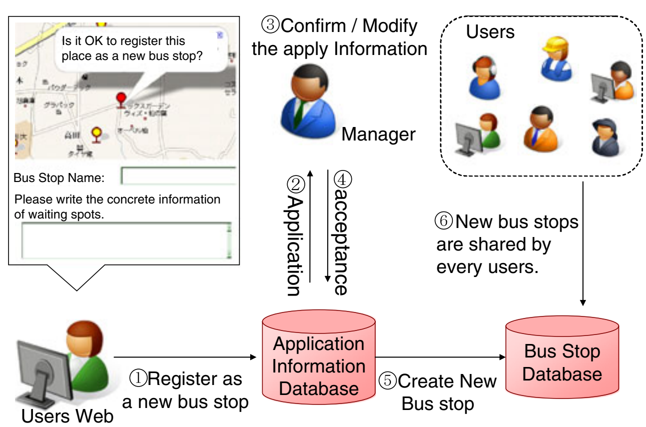


Fig. 8 The process of bus stop registration

Users who want to register the new bus stops apply for new bus registration through the developed web page. The developed web page is very simple with map. Figure 9 shows the web page and required information. All users have to do on the site is to set the icon on the map and to input the name of bus stop and information of pick up point. Google Map API is used as map interface. Through this site, PC users can apply the bus stop information which they want to add easily by clicking on the map and inputting bus stop name and waiting spot information via free text forms, category and width of road by selecting listed options. The information width of road leads to judge the size of vehicle which can stand.

The application information is stored in the application database on the On-demand Bus server. Then the managers check the application information whether the information is correct or not. The way of confirming the information is not decided in formal process, the manager visits the suggested place actually and checks the information in Kashiwa experiment. If the information is incorrect, the managers can rewrite the information and the application information becomes correct through the management tool which only the manager can use.

After checking by the managers, the applied bus stops are add to the bus stop list, and every user can share the new bus stops.

This developed stream realizes CSCW and supports the collaboration between users who want to register new bus stop and managers.

4.3 Expectation from the system

New scheduling algorithm enables users to ride the On-demand Bus at any time, and the developed interface enables them to move from anywhere to anywhere in the area. So, the developed service can be the full demand typed On-demand Bus service. The most important things of the developed service are that this service does not need the operators and that this service does not narrow the category of users because the calculation system can ensure the arrival time.

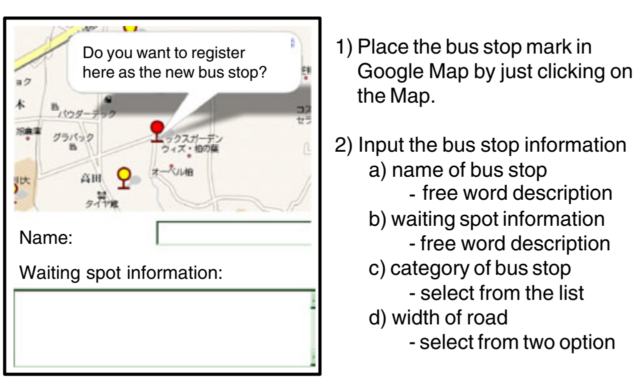


Fig. 9 Developed web page of registering new bus stops

Moreover, the high-frequent use of the registered bus stops is expected as the adding value of this system because managers often do not know which place is popular to the residents. Managers do not have to choose the bus stops carefully since users can apply the bus stops which they need.

5 Experiments in computer simulation

5.1 Computer simulation

In order to validate the scheduling algorithm, computer simulation is demonstrated. Simulator creates On-demand vehicles and passengers in the computer. In the simulation, the scheduling algorithm is validated by 1) calculation time, 2) difference between IPT_n (IDT_n) and APT_n (ADT_n).

5.2 Simulation condition

The personal computer for the simulator has Pentium 4 (3.2 GHz), 3.00 GB RAM. The simulation is executed in virtual Moriyama City, Shiga Prefecture, Japan. In about 55 km^2 field, 256 bus stops are set. As for variables, ST_n (Slack Time) is set Direct Ride Time ($DRT_n(hour)$) and *Repeat* is 30. *TimeLimit* should not be set because to measure the calculation time is one of simulation objectives. Total number of passenger are 200 (N=200). The demand information (origin, destination, desired arrival time) of each passengers is created randomly. The service time is 8 h, and V is changed from one to six. All vehicles created in computers are eight seats available. ±30 min from desired arrival time is set as the maximum search area. It means that the calculation is successful when the time gap between DDT_n and IDT_n is less than 30 min. The results of simulation as shown in the following chapters show the result of the simulation of eight times repetition.

5.3 Simulation result

5.3.1 Calculation time

Figure 10 shows the result of calculation time. X-axis indicates the reservation case, the number of On-demand Vehicle (V) and the calculation result (OK/NG), where OK means the case of successful reservation and NG shows the case that the calculation algorithm cannot update the schedule with satisfying the users' demand information. The reason why the result is divided by calculation result is that calculation time becomes longer by increasing irritation of "Insertion and time adjustment algorithm" when the result is returned as NG.

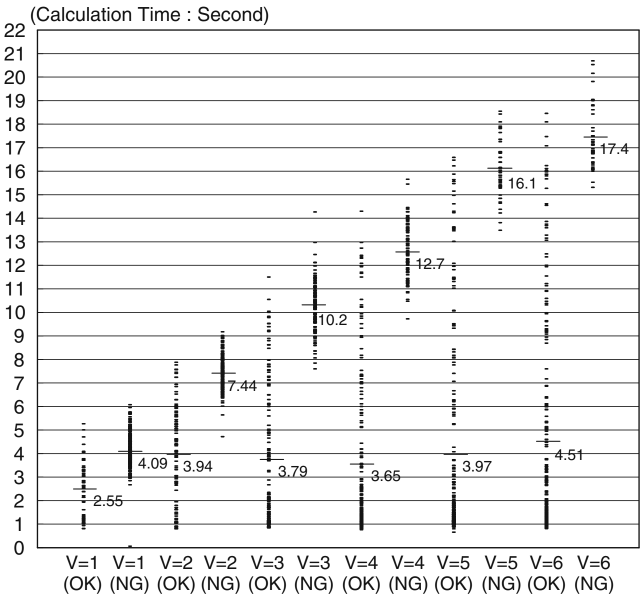


Fig. 10 The result of calculation Time (sec.)

The figure shows that longer calculation time is needed as the number of vehicle increase. However the increasing rate is almost linear, though the calculation time for On-line DARP increases exponentially in usual. It means this scheduling algorithm is practical because passengers can get the result during practical waiting time.

5.3.2 IPT_n (IDT_n) and APT_n (ADT_n) difference

APT_n should not be earlier than IPT_n because it means that passengers arrive at the bus stops after the bus leaves. On the other hand, ADT_n should not be later than IDT_n because this service ensures the arrival time.

Figure 11 shows the distribution of APT_n–IPT_n. Positive figure shows APT_n is later than IPT_n. There is no negative figure so the vehicles do not leave from the bus stop before passengers arrive at there.

Figure 12 shows the distribution of ADT_n–IDT_n and negative figure shows ADT_n is earlier than IDT_n. There is no

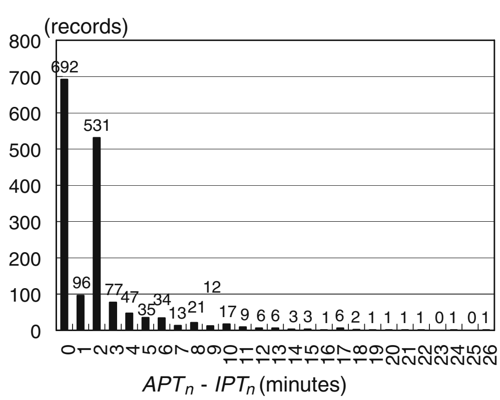


Fig. 11 The distribution of APT_n minus IPT_n

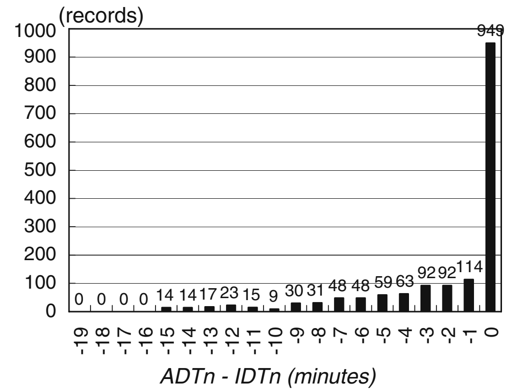


Fig. 12 The distribution of ADT_n minus IDT_n

positive figure so the vehicles arrive at passengers' destination before the arrival time that system informs to passengers.

5.3.3 Computer simulation result

Calculation time does not increase exponentially but in almost linear when the problem scale becomes large. The calculation times in each OK case are almost same. It shows the efficiency of vehicle-choosing algorithm. Moreover, the calculation does not violate the time window constraint, because IPT_n is not later than APT_n and ADT_n are not later than IDT_n. The calculation system is confirmed to perform as designed.

6 The evaluation in Kashiwa field test

In order to evaluate the developed service, field test was held in Kashiwa City, Chiba Prefecture, Japan.

6.1 Overview of the Kashiwa City

Kashiwa City is located to the north-east to Tokyo, and one of the bedroom town cities of Tokyo. It has a population of

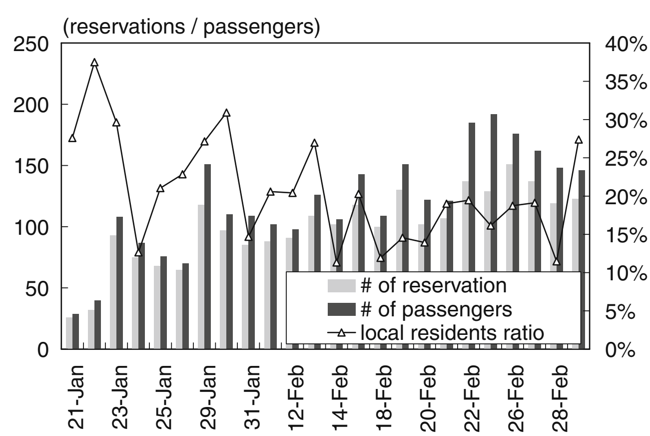


Fig. 13 Transition of number of passengers

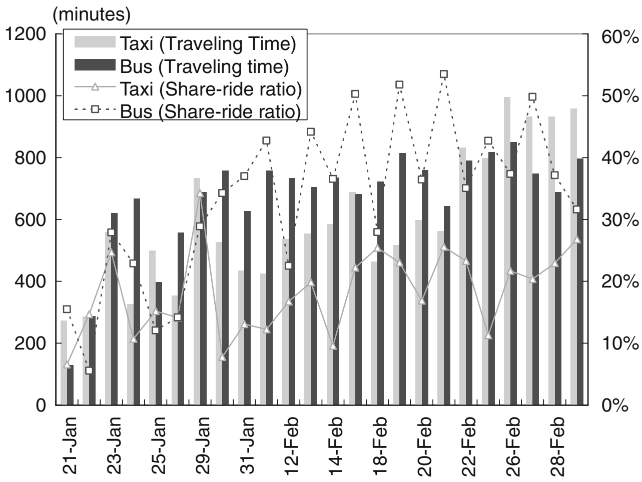


Fig. 14 Transition of traveling time and share-ride ratio

380,000 and occupies about 110 km^2 area. Those 65 years or older accounted for 16% of Kashiwa population.

The community test site included residential and industrial areas, parks, schools, train stations and hospitals in a 25 km^2 area. The opening of the Tsukuba Express railway in August 2004, expansion of the University of Tokyo's Kashiwa Campus in April 2005, and completion of large commercial facilities in November 2006 and March 2007 greatly changed population traffic and movement.

Most train commuters use Japan Railways' Kashiwa Station, to which fixed bus routes provide important transportation. The aging of the area's population has also introduced new traffic and transportation needs.

6.2 Overview of the field test

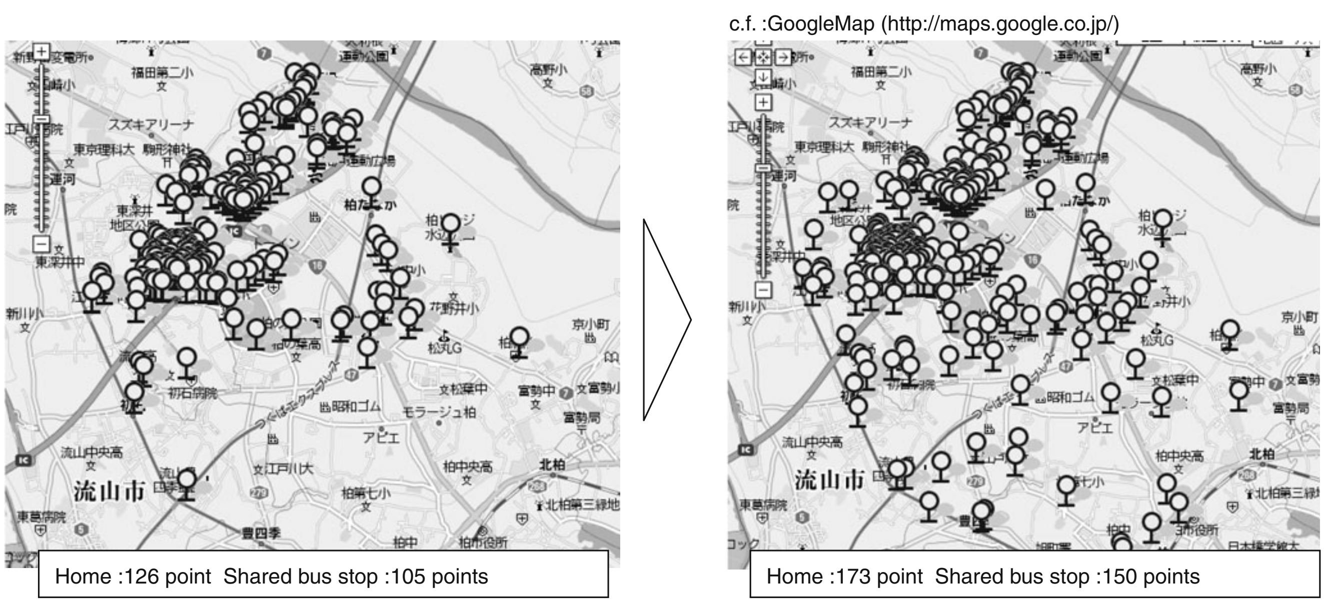
The field test was carried out in 10 days in January and 14 days in February, both in 2008 with 2 microbuses (authorized strength: 20) and 10 sedan type taxis (authorized strength: 4). Two microbuses were in service in the 7–10 and 18–21 time zones because of the anticipated large demands with no taxi service available, and 3 taxis and 1 microbus were in service in the 10–18 time zone because of limited demands anticipated.

The passengers were divided into two groups; one group commuted to the University of Tokyo's Kashiwa Campus and the other was composed of the local residents including aged persons. The registered residents could call for the On-demand Bus in front of their residences.

The test dates were notified by various means, e.g., circulars, e-mails, web site and blogs. The briefing sessions were held for residents before the test was started.

Services during tests were free and users were registered through telephone or the Internet and received IDs and passwords.

A total of 591 members were registered before completion of the field test. 55% of them, 328 members, actually used the On-demand Bus in 24 days. 2,402 reservations were successfully contracted between the system and users, and 2,867 members were transported by the vehicles. The number of passengers was highly influenced by the weather. It was rainy on January 23rd and 29th from morning to night and it was partially rainy on February 12th and 26th. We did not have rain other field test days.



The registration of bus stops before the community test (2008/1/21)

The registration of bus stops after the community test (2008/2/29)

Fig. 15 The difference of the number of registered bus stop in the former period of field test and the latter period

6.3 The transition of number of passengers

Figure 13 shows the transition of the number of passengers and local residents ratio. The number of passenger increases day by day and especially many customers ride the bus in rainy day. The number of residents did not change considering from the increase of the number of customers and decrease of the local residents ratio.

Figure 14 shows transition of traveling time with passengers and share-ride ratio in each type of vehicle sizes. In this paper, the definition of share-ride is not the situation that more than two passengers ride the vehicle but the situation that more than two different reservations are transported. So the case that a passenger reserves two seats in one reservation is not called as share-ride in this paper.

According to the figure, the increase of share-ride ratio is confirmed in the both case of taxi sized vehicle and bus sized vehicle. The average in the last week, taxi sized vehicles run 924 min in total and share-ride ratio is 21% and bus sized vehicles run 781 min in total and share-ride ratio is 40%. The higher share-ride ratio shows the more efficient operation. Since the bus sized vehicle is traveled in commuting hour, the share-ride ratio of bus sized vehicle is higher than that of taxi sized vehicles.

6.4 Evaluation of new interface with which uses can register new bus stops

Figure 15 illustrates the registered bus stops. Bus stops provided by managers before tests were at 126 homes of registered users and at 105 facilities the users likely want to go to. Managers registered only bus stops at homes of new registered members during tests. During the 24 days of test, 92 bus stops were added to the system and among of 92 new bus stops, 45 stops were at locations other than homes. Managers first set the bus stops in the northern test site and new stops concentrated in the south, where services were in more demand.

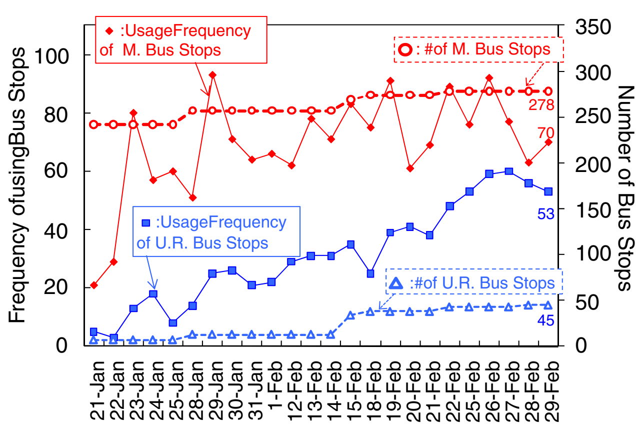


Fig. 16 Usage frequency and the number of bus stops

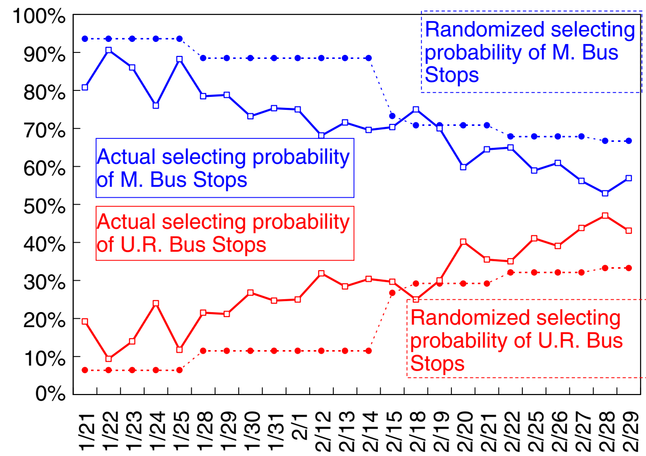


Fig. 17 Selecting probability of each type of bus stops

In this paper, the bus stops which managers registered including the home of passengers are labeled as "Management Bus Stops (M. Bus Stops)". On the other hand, the bus stops which users registered through the developed web site are labeled as "Users Registered Bus Stops (U.R. Bus Stops)". So, in the field test, the number of Management Bus Stop is 278 in total and that of Users Registered Bus Stop is 45.

Figure 16 shows the usage frequency and the number of each bus stops. According to the figure, M. Bus Stops are prepared 6.2 times of the number of U.R. Bus Stops. However, passengers used M. Bus Stops more than U.R. Bus Stops by 1.8 times. So, U.R. Bus Stops are more attractive than M. Bus Stop from the users' view point.

In order to the effect of U.R. Bus Stops more remarkably, evaluation by selecting probability is introduced. Figure 17 shows the difference of selecting probabilities between M. Bus Stops and U.R. Bus Stops. The motivation of evaluating this difference is to evaluate the effectiveness of U.R. Bus Stops.

Randomized selecting probability shows the probability of selecting bus stops as origin or destination when users select origin and destination at random. In order to calculate the randomized selecting probability, it is assumed that the users use the bus stop randomly. Moreover, it is defined that users select the U.R. Bus Stops when users select U.R. Bus Stops either as origin bus stop or as destination bus stop.

For example, the case that eight M. Bus Stops and two U.R. Bus Stops are registered can be considered. Then the randomized selecting probability of U.R. Bus Stops is calculated as 18.9% because there are 90 patterns combination of selecting

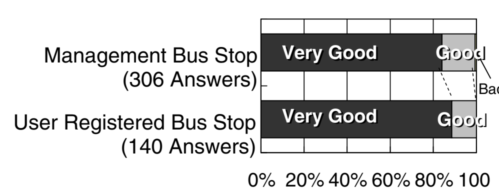


Fig. 18 Evaluation to the door-to-door function of on-demand bus

origin and destination in total, 17 patterns of combination of selecting the U.R. Bus Stops (1 case is from U.R. Bus Stop to U. R. Bus Stop, 8 cases are from U. R. Bus Stops to M. Bus Stops, and 8 cases are from M. Bus Stops to U. R. Bus Stops).

The following two unrealistic cases should be out of scope in the calculation of randomized selecting probability. First one is the case which the origin and the destination are the same. Second one is the case that users move from someone's home to someone's home.

What Figs. 16 and 17 tell us are two things. Firstly, M. Bus Stops are actually chosen in low probability compared with the randomized selecting probability of them. On the other hand, U.R. Bus Stops have the opposite tendency. In the last day of the field test, the number of M. Bus Stops is about six time of that of U.R. Bus Stops. However, the actual selecting probability is almost same. It means U.R. Bus Stops are more popular than M. Bus Stops because users can register what they want to move.

Secondly, the time gap between creating the new bus stops and being started to use the new bus stops is about 4 days in the Kashiwa field test. This time gap means the period to be informed new bus stops to users.

Figure 18 shows the result of evaluation from users to the door-to-door function of On-demand Bus service. Most of users are satisfied with the developed On-demand Bus service in terms of the function of door-to-door. Moreover, they answered the service is good in terms of the function of door-to-door strongly in five percentage when users use the U.R. Bus Stops.

7 Conclusion

The interface for registering new bus stops is developed and evaluated by the field test in Kashiwa City.

The developed system of registering new bus stop is one of CSCW typed application. By supporting the collaboration between users and managers thorough the Internet, managers can add new bus stops which correspond the users' demand and which are correct information. And this registration scheme with web page supported by CSCW is novelty idea for the registration of bus stops for On-demand bus.

From field test, two important considerations are confirmed. Firstly, the User Registered Bus Stops are highly frequently used by passengers compared with the Management Bus Stops. This is because the registered members have the sense of locale and they know where residents want to use as bus stops. The effectiveness of CSCW is confirmed.

Secondly, user evaluation of the developed service in terms of door-to-door become high when they use the User Registered Bus Stops. They feel the On-demand Bus service provide door-to-door service, it means the providing service can be said as full demand typed On-demand Bus service.

To clarify the relationship between service level and system efficiency is one of future works. The increase of number of bus stops is improved service level from the passengers' viewpoints. However, it is expected that system efficiency gets worse as the number of bus stops increase.

Thanks to the developed system, the service is near to the full demand typed On-demand Bus service because users can choose the origin and destination as they want to move. With two technologies, already developed scheduling algorithm and the developed interface, full-demand typed On-demand Bus service without any operators are realized.

Acknowledgments This study was supported in part by the Japan Science and Technology Agency's CREST Program, and the program assisted by Ministry of Land, Infrastructure, Transport and Tourism. The system was arranged and serve was operated through collaboration rendered by JUNPUZI Co., Ltd. Community tests were conducted by assistance provided by CHODAI Co., Ltd and the Kashiwa City Planning Division. We thank Mitsutaka Nomata, director of Japan's Land, Infrastructure, Transport, and Tourism Ministry National Planning Division.

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