Realization of Mobility as a Service in View of Ambient Intelligence

Hideyuki Nakashima, Keiji Hirata, and Junichi Ochiai

Abstract

The concept of a new public transportation system, Smart Access Vehicle System (SAVS), for *mobility as a service* (MaaS) is introduced.

SAVS project is a typical example of the practice in serviceology in the sense that new service emerges in a design-service-analysis loop. Mobility itself is not the goal – mobility is a service, or service platform, on which other services are provided. Mobility enhances activities of people and thus increases the value of other services.

We conducted the field tests of SAVS three times in Hakodate and achieved the world's first full automatic management of real-time multiple demand-responsive transportation. The next step is to enhance its usability and utility. We hope it is possible with the help of ambient intelligence (AmI).

Since SAVS works in outdoor environment citywide, we believe many new and interesting research issues arise from AmI point of view. It will be a city version of intelligent rooms. At the same time, SAVs themselves act as probe cars to collect information about traffic situation.

In the paper, we first briefly describe SAVS and its implementation done so far. We then address the design concept of MaaS in the light of AmI. Combining information and mobility significantly increases the quality of urban life. We present the concept of citywide realization of AmI.

Keywords

Smart Access Vehicle System (SAVS) • Mobility as a service • Ambient intelligence • Demand-responsive transportation (DRT)

1 Introduction

We are developing a new public transportation system, Smart Access Vehicle System (SAVS) [1], under the concept *mobility as a service* [2]. The Internet significantly improved our life in terms of information access and utilization. The next target is enhancement of the mobility of people.

SAVS project is a typical example of the practice in serviceology in the sense that new service emerges in a loop of design, practice/production, and analysis/modeling [3]. Mobility itself is not the goal – mobility is a service on which other services are provided. Mobility enhances

H. Nakashima (✉) • K. Hirata
Future University Hakodate, Kameda-Nakano 116-2, Hakodate, Hokkaido 041-8655, Japan
e-mail: h.nakashima@fun.ac.jp

J. Ochiai
National Institute of Advanced Industrial Science and Technology, Tsukuba, Ibaraki, Japan

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activities of people and thus increases the value of other services.

The service provided by SAVS can be combined with other services such as food, medical, educational, and entertainment services. People just request to receive a restaurant service or hospital service, and necessary mobility to receive those services is automatically provided by SAVS.

We so far conducted the field tests of SAVS three times in Hakodate, and achieved the world's first full automatic management of the demand-responsive transportation, which assigns multiple passengers to a vehicle in response to users requests in real time.

One of the problems we found through the field tests is that a SAV (we use "SAV" to denote an individual vehicle used in SAVS) sometimes fails to pick up a passenger at a meeting place when the place is vast and crowded. We can use augmented reality to indicate the location of SAV for the user and user for the SAV driver if we have proper information environment. To improve the user interface of SAVS, we should extend our research into ambient intelligence.

Many of the researches in the ambient intelligence (AmI) are for systems operating indoor environments, such as an intelligent room. Since SAVS works outdoor environment citywide, we believe many new and interesting research issues arise from AmI point of view. It will be a city version of intelligent rooms.

In the rest of the paper, we first briefly describe SAVS and its implementation. As the basic SAVS is operational and we have some feedback from the users, we are ready for the next step. We address the design concept of MaaS in the light of AmI. Combining of information and mobility significantly increases the quality of urban life. We present the concept of citywide realization of AmI.

2 SAVS as a Demand-Responsive Transportation

2.1 Classification of DRTs

SAVS falls into a category called demand-responsive transportation (DRT) system, which is further classified into the following:

1. *Detour and/or free stop*
   Usually operates on fixed route with fixed schedule. When requested, the vehicle detours to the requested location or stops at any place on route. Vehicles operate by pre-scheduling, i.e., the route is determined before the vehicle starts.
   This system operates in many rural areas where the demand is very low.
2. *Flex-routing*
   The set of stops is fixed, but the route among them is determined according to the demand. Vehicles operate along the predetermined route and schedule.
   Examples: EU project DRTs [4], Souja city (総社市), and Convenice (コンビニクル) [7]
3. *Full-demand DRT*
   Full-demand DRT has no fixed route or stops. It operates in response to demands. It is further categorized as follows:
   3.1. *Low-demand area DRT*
      Most of DRTs in the world are in this category (Fig. 1) [5].
      3.1.1. *Full-demand bus*
         In underpopulated areas of Japan, many small-sized full-demand bus systems have been introduced. Example: Nakamura city bus (中村まちバス) [6] and Convenicle (コンビニクル).
      3.1.2. *Shared taxi*
         In Japan, the law does not allow shared ride for taxis. It is operated only in designated areas.
   3.2. *Urban area DRT*
      3.2.1. *Special purpose DRT*
         DRT is often operated in urban areas for special purposes, such as transportation of disabled person or elderly people.
      3.2.2. *General-purpose DRT*
         General-purpose urban area DRT has a potential to replace current public transportation vehicle systems (taxis and buses).
         Example: SAVS only.

SAVS is classified as in 3.2.2 above, but it is *outside of the usual classification of DRT* as depicted in Fig. 1. SAVS is designed to replace current public transportation systems, i.e., bus systems and taxi systems. Although trams cannot be

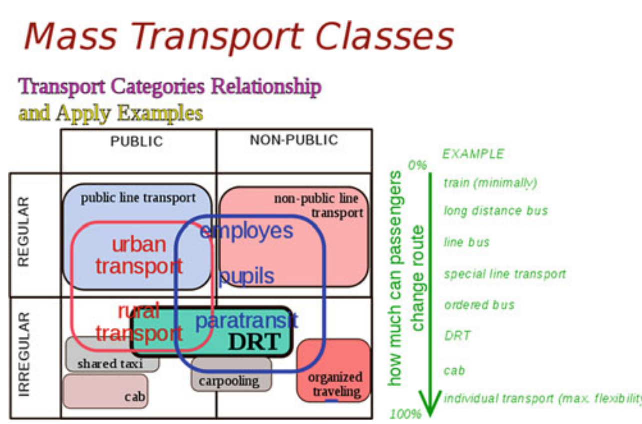

Fig. 1 Mass transport classification [5]. Note that SAVS does not fit into DRT in this classification, but covers the whole PUBLIC area

operated by SAVS, SAVS can coordinate with other transportation systems such as trams, inter-city trains, and airplanes. As far as we know of, SAVS is the only DRT designed to cover whole city areas.

The differences between 3.1 and 3.2 include the size of the operation area, the number of vehicles in service, and the density of demands arisen; the differences also affect many other aspects of service because there are many other services provided in urban areas and DRT service can be combined with them (more in Sect. 3).

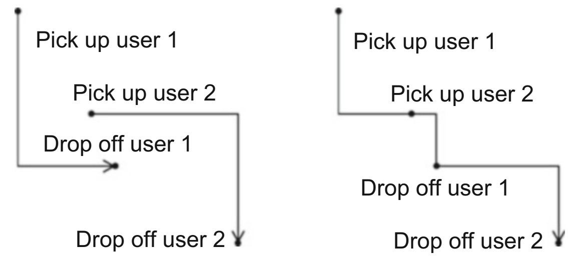

Fig. 2 Routes of uberX (*left*) and uberPOOL (*right*). SAVS also operates in the right-hand side mode

2.2 Convenicle

Convenicle (convenient and smart vehicle) is a full-demand bus system proposed and implemented by a group at the University of Tokyo [7]. It falls into category 3.1.1. The operating system is quite similar to SAVS. However, Convenicle is designed to operate in rural areas with a small number of vehicles, while SAVS is intended to be used in urban areas to replace *all* buses and taxis. Convenicle lacks the viewpoint of total public transportation system and thus does not need large-scale simulation or AmI environment.

2.3 Uber

Uber is a taxi-based service and therefore is not categorized as a DRT. However, when it is extended to shared taxi or car pool, the distinction becomes blurring.

Uber was founded as a dispatching limousine company in 2009, which used a smartphone application to order vehicles. Uber is expanding its services and overseas operations including Japan.

Table 1 classifies Uber services in terms of the vehicle/service types, vehicle capacity, and luxuriousness.

uberBLACK, the original service, is a limousine service. uberLUX is a luxury version of uberBLACK, and uberSUV provides more passenger capacity. uberTAXI and uberTAXILUX dispatch taxies and cost less than uberBLACK.

uberX and uberXL use private cars and drivers to carry users (these service types are not allowed in Japan). The users pay a lower cost than a taxi fare to the private drivers. The drivers can decide the duration of their own operation. After each trip, the user evaluates the driver by use of the smartphone application. Uber unregisters poor grade drivers based on the users' feedbacks.

Table 1 Uber services

	Four seats		
Service class	Standard	Luxury	Six seats
Limousine	uberBLACK	uberLUX	uberSUV
Taxi	uberTAXI	uberTAXILUX	–
Private car	uberX	–	uberXL

The latest service of Uber is uberPOOL, which is uberX with ride-sharing option. It rolled out in San Francisco, Paris, and New York City. Figure 2 illustrates the difference between uberX and uberPOOL. Since uberX vehicles carry only one (or one group) of passengers, most of them run with some empty seats. uberPOOL can carry several (groups of) passengers having similar routes together. Passengers can save up to 50 % per trip because of sharing, and the drivers spend more time earning money on longer trips. Uber claims that efficient usage of uberPOOL causes fewer cars on the road, fewer emissions from cars, and less traffic jams.

Uber, as Convenicle, is an individual vehicle-based operation and does not have the view of MaaS.

2.4 Smart Access Vehicle System

SAVS is designed to replace current urban public transportation systems – taxis and buses.

From users' point of view, the process of calling a SAV is very similar to reserving a demand bus:

1. A user contacts the system with the demand (the current location and the destination).
2. The system searches for the best vehicle considering their current position and future route.
3. The system tells the user the pickup place, the estimated time of pickup, and the estimated time of arriving at the destination (with a small margin of delay). The user has a choice to either accept or decline the service.

The features are:

1. SAVs operate in real time (reservation is optional). A user may call a SAV when the actual demand emerges. (In the future, when SAVS is unified with other services, it may be automatically called or reserved.)
2. Many (in the order of 1000 or more) vehicles are involved so that the operation is efficient.

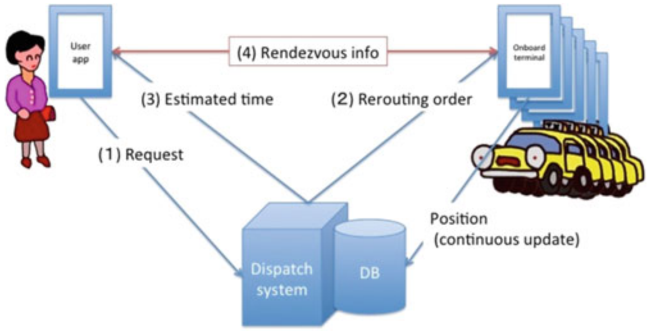

Fig. 3 Communication network and operations of SAVS

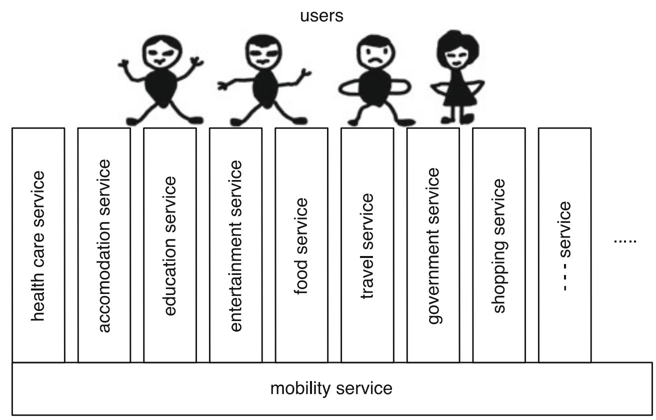

Fig. 4 Service combination over mobility

A central computer system manages all vehicles in SAVS. The system knows the locations and routes (destinations of passengers on board) of all vehicles. When a new demand arrives, the system searches for a vehicle that can pick up and deliver the passenger with minimum detour [8].

Figure 3 depicts the communication scheme of SAVS. When (1) a user request (pickup and deliver places and optional time limit to the destination) is sent to the dispatch system, SAVS selects the most appropriate vehicle and (2) informs the vehicle its new route and (3) tells the user estimated times for pickup and delivery. When the vehicle approaches, (4) rendezvous information should be presented to both of the user and the vehicle driver, but this rendezvous mechanism is not implemented yet (see Sect. 4.2).

We conducted field tests three times in Hakodate: a week in October 2013 with 5 SAVs, 1 day in April 2014 with 16 SAVs during the domestic annual conference of Society for Serviceology, and four days in May 2015 with 25 SAVs. We succeeded to operate SAVS in full automatic mode for the whole days in both tests. The basic operation system of SAVS has been completed. The next step is to enrich human interface of the system and enhance the system for better mobility services.

3 Mobility as a Service

Information processing and the Internet significantly changed our life by giving information to anyone, anywhere and anytime. The next step is to use computer power to enjoy mobility of things and people. Just like the Internet is a tool on top of which other services are provided, transportation systems are tools to provide mobility.

When we regard mobility as a service, not the goal, we can think of many kinds of service integration with other services, such as education, entertainment, tourism, accommodation, food, and medical care (Fig. 4).

Since SAVS is completely controlled by a computer system, it is flexible enough to be unified with other services with ease. For example, when a user books a restaurant, a SAV can be assigned automatically to pick up the user at home. And when the user is ready for paying the bill for the meal, a SAV is automatically called for the return trip.

Our first target is to use SAVS for hospital services. In many local cities where the public transportation is not very convenient due to small number of operation frequency and/or routes, hospitals have their own buses for patients. One of the hospitals in Hakodate is operating buses for the family of patients in the hospital.

When SAVS is unified with all other city-area services, SAVS becomes part of the blood vessel system of the city, as the same way the Internet forms the neural system of the city.

Once we come to this concept, mobility and information accessibility together form an intelligent infrastructure of a city, and become a base for AmI of the city environment.

4 Ambient Intelligence for Mobility Services

Ambient intelligence (AmI) [9] is a research area as well as a concept to make our environment “intelligent” by using sensors and actuators embedded in the environment.

4.1 SAVS and Ambient Intelligence

The relationship between SAVS and AmI is twofold. SAVS need AmI for better operation and interface, and SAVS can contribute to AmI as probes.

SAVS Needs AmI One of the problems we found through the field tests is that a SAV sometimes fails to pick up a passenger at a meeting place when the place is vast and crowded. For example, a large supermarket has many exits, and the driver could not identify the location of the passenger, or there are so many taxis at a larger train terminal and the user could not locate the SAV. Indicating the location of the target on map is a minimum solution, but we need a better indication that is physically embedded in the environment (see Sects. 4.2 and 4.3).

SAVS Contributes to AmI Many of the researches in the AMI are for systems operating indoor environment, such as an intelligent room. Since SAV system works outside citywide, we believe many new and interesting research issues arise from the AmI point of view. It will be a city version of intelligent rooms. SAVs themselves act as probe cars to collect information about traffic situation; many sensors embedded in the city also provide useful information for SAVS operation; traffic lights act as actuators to control traffic. Moreover, SAVs can relay the information to drivers and passengers.

For example, as other vehicles run in a city, they may encounter unforeseen accidents and/or problems, including traffic jams, road works, and vehicle malfunctions. The traffic information is relayed to the operation center, and SAVS re-plans the routes of the SAVs in real time, combining incoming information with the traffic simulator. At the same time, a SAV functions as a user interface that collects the ambient information around the SAV and provides a passenger with service in the real world.

4.2 Augmented Reality

To enhance the user interface, the use of augmented reality (AR) should be considered. Here, we define AR as displaying and/or annotating the scene with useful information using some devices such as smartphones with camera.

One of the immediate applications is to support rendezvous of a passenger and the SAV assigned to the passenger. Rendezvous is particularly difficult where many people are waiting for many vehicles, such as train station and shopping plaza. In those cases, when the passenger picks up the smartphone used to call a SAV, and view the scenery through the camera of the phone, the target vehicle is indicated on the screen.

Another example is the use of head-up display of cars. Road and traffic information gathered by other cars and citywide sensors may be displayed to the driver using the HUD. There are many intelligent transportation system (ITS) researches in this direction, but they are based on peer-to-peer communication of individual vehicles. When we talk about AmI, we need citywide information gathering and processing such information with simulation.

4.3 SAVs as Probes

Since SAVs are running throughout a city in high density (e.g., in Hakodate, we estimate about ten vehicles per square kilometer), they are ideal for probe cars. Basically, they monitor traffic conditions – how fast they can move along streets. This monitoring is not only important for SAV operations; they can provide useful information to other vehicles or people who need transportation.

For example, in large cities, traffic controls for smooth flow is important. Adjusting timing of traffic signals is effective. But it needs sensors for traffic status at every intersection, which costs a lot. In contrast to the expensive sensor system, traffic information from SAVs comes free. Furthermore, sensors fixed at intersections cannot track one vehicle to coordinate the signal timing at the next intersection. A SAV can be traced all the way, and traffic signals along the route can be coordinated so that vehicles may not need to be stopped here and there.

Monitoring traffic condition is extremely important in case of irregular conditions such as snow or storm, traffic accidents, earthquake, flooding, and fire. It is well known that after large earthquakes in Japan, roadmaps of usable roads is maintained from actual drive data and proved useful [10, 11]. SAVS can do the same in its operational area.

5 Summary

The current status of SAVS and its future enhancement plans are shown. The basic operation system for SAVS is proven effective. The remaining task is improvement of the system's service (operational features and user interface).

Mobility itself is not a goal. It is means to support other services. Central computer control of SAVS is flexible enough to coordinate with other services.

The concept of ambient intelligence helps improve both SAVS usability (user interface) and utility (probe). This paper outlines improvements.

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