Driverless Vehicle-Based Urban Slow Transportation Service Platform

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Abstract. Driverless vehicles have brought dramatic changes in many aspects of transportation, as an irresistible trend. And there was also abundant research on transportation service design based on driverless vehicles. However, specific to slow transportation, studies on driverless vehicle-based service design are few. In this paper, we selected four typical using contexts of low-speed environments: campus, airport, communities far from city center, and industrial park. And then we discovered the pain points and common demands of urban low-speed environments, as well as the characteristics of driverless vehicles, it was found that, in the guidance of service system design, driverless vehicle can address these problems of slow transportation. We used the logic of service system design as important approach to develop driverless vehicle-based slow transportation service system. This slow transportation service platform took an in-vehicle smart system as the control system. Based on this smart system, mobile phone app and in-vehicle AR screen, this platform could satisfy the pain points and demands of urban slow transportation. Moreover, this driverless vehicle-based urban slow transportation service platform could integrate people, environment and vehicles coherently, to meet users' needs, improve service process efficiency and make sustainable influence on environment.

Keywords: Driverless vehicle · Slow transportation · Service platform design

1 Introduction

The development of driverless vehicles will fundamentally change the current vehicle's driving style, using mode, riding experience, etc. And it will change driving into a complicated system. In this system, people, environment and vehicles are closely integrated together to create a higher-efficient transportation service system., which transforms the previous "vehicle-road-driver" closed-loop system. Based on levels of automation for on-road vehicles from SAE, the current development of driverless vehicle is in Level 3 (conditional automation) [1]. Level 3 and Level 5 require vehicles to drive and interact with people highly relying on the driving environment. While among a variety of circumstances, it is urban slow transportation environments that have the most frequent and deepest interactions with people.

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Meanwhile the methods for constructing a slow transportation service platform based on driverless vehicles are different in various using contexts [2]. Typical using contexts contain metro stations, parking lots, outdoor gyms, campuses, airports, parks and so on. In this paper, based on driverless vehicle, four typical using contexts in urban low-speed environment are discussed as the research objects. We summarize corresponding characteristics of different contexts, with service system design approaches as methods, aiming to design a driverless vehicle-based service platform to solve the pain points of urban slow transportation environments, and satisfy people's needs in low-speed environments.

Nowadays, the research and development of driverless vehicles primarily focus on three directions: urban slow-transportation environment, special conditions and urban expressways. Since the driving environment under these three conditions is relatively simple and suitable for the operation of driverless vehicles at this stage, there are many studies on these three environments [3]. Urban slow transportation environment is the most related to peoples' lives, but there are few studies on it based on driverless vehicle. In urban slow transportation environments, campuses, airports, communities far from city center, and industrial parks are the four typical using contexts. They have some common problems and demands. The following section will be elaborated on these.

2 Four Typical Using Contexts of Urban Slow Transportation

Slow transportation, also called non-motorized transportation, refers to non-motorized transportation systems that are mainly bicycles and pedestrians and supplemented by environment-friendly motor-assisted vehicles, it primarily lies in urban low-speed environments [4]. The using contexts of urban slow transportation are diverse, while campuses, airports, communities far from city center, and industrial parks are the most representative of today's slow transportation circumstances. As an important component of transportation system, slow transportation deeply penetrates our lives, however it is always not valued and remains many burning issues.

2.1 Pain Points of Urban Slow Transportation

The Contradiction Between the Narrow Space and the Needs for Transportation with Flexibility and Rich Forms. For the slow transportation environment, it is generally in the range of 3 km, and the space is relatively small. In this short-distance transportation map, the main part is the scattered-spot user: individuals. Most of their demands for transportation is related to "the last kilometer" or "the first kilometer", namely the transportation path is more about "multiple points-to-single point" route. Therefore, large-volume transportation tools cannot be a good way to flexibly connect the distributed demand subject in the limited space. This situation is especially common in airports. Such as in this always crowded environment, how to transport many passengers to check-in desk in the departure hall, how to transport passengers from

security checkpoint to boarding terminals and how to deliver luggage to the parking lot at the arrival place. But large vehicles cannot flexibly connect the scattered demand entities in a limited space, it requires a smart and precise dispatching system to meet the needs of users who are dispersed and with different time urgencies.

Moreover, how to dispatch transportation resources based on the current conditions of environment to the maximum efficiency, and how to save parking and driving space and release more slow transportation space for people are two important issues that need to be solved [5].

Lack of Continuity Among Service Phases. Taking campus as an example, nowadays many campuses own shared bicycles, which are the important means of transportation for teachers and students in campus life. But due to the regularity of campus activities and the large number of users, there always no bicycles near the starting point when using, or need to walk a while to search for available bicycles. These problems are highly time-consuming, which prolongs the utilization time of transportation services. How to closely link the pre-stage, in-stage and after-stage of the slow transportation service and ultimately improve the overall efficiency is the key to improving the utilization rate of slow transportation service.

Lack of Communication Between the Transportation Tools and Users. As mentioned above, slow transportation is the most basic transportation tool compared with motor vehicles, which penetrate every aspect of people's life and exposed to the widest group of users. Between the slow transportation with people, a mutually beneficial relationship could be established with proper human-robot interactions. If designed well, transportation tools can access data from the user, and then based on these data transportation tools can provide some information for interested people, which works like a local information hub. However, the relationship between slow transportation vehicles and users is remained to be established. And the current transportation vehicles don't have the function of local info platform, which is not conducive to interpret users, understand the users and entertain users.

Nowadays, the industrial parks are bigger and bigger. The development of landscape construction and enterprise culture are flourishing. Many industrial parks have become an important tourist attraction for cities, such as Google and Apple, so they need to receive many foreign visitors or business partners every day. However, under the existed slow transportation environment of many parks, there is no effective transportation tool as a bridge to connect passengers to the external environment well. So, it lacks a bridge to let users understand the environment better and make the environment serve users better.

2.2 Common Demands of Urban Slow Transportation

Slow Transportation Requires a Flexible Transportation Service System. Slow transportation vehicles should occupy less parking space as much as possible, and at the same time, improve the flexibility of driving in a short distance. Set reasonable "point" such as stop and scheduling point. Set reasonable "line": In view of the current situation of high path repetition rate in the slow transportation environment, design the

most efficient driving path. Set reasonable "face": Maximum the degree of connection to the scattered users, thus expanding the use of vehicle range and user group distribution.

There Needs More Interactions Between Slow Transportation Tools and Users. Interactions between slow transportation with people aims at constructing a positive relationship, creating values mutually. In the digital network time, digital information can help to strengthen the relationship between people and objects, people and people, people and the world, and in this situation, even reconstruct the interactive relationship between people and transportation system. As discussed above, slow transportation environment connected to all aspects of people's lives to more deeply than other types of transportation, so if constructing an effective information transmission mechanism in slow transportation service system, it will make the platform and people have deeper interactions. This kind of information transmission could be by texts, voice, visions, movements, environments and so on. Once people use the offerings, the interaction get started: the service platform could understand and learn from people through collecting data, imported data or various kinds of communications. People also get learned the features of the platform based on some feedbacks.

Slow Transportation Services Should Satisfy Diverse Demands Through Comprehensive Functions. In the same scenario, different users may have different needs. For example, the same user will have different requests of service time under different time periods, or under the same urgency of time, there will be different service routes and service forms under different using scenarios. Taking the community which far away from the city center as an example, this environment needs a slow transportation service system, which includes rush commuting to the downtown area, daily transportation in the district, patrolling of security personnel, and sightseeing in the leisure time. Therefore, the demand for the comprehensiveness of functions on this slow transportation service platform is also very high.

And many characteristics of slow transportation environment determine that driverless slow transportation vehicles can well promote the development of slow transportation. After our research, it was found that driverless vehicle could effectively improve slow transportation system efficiency and user experience.

3 Advantages of Using Driverless Vehicle in Slow Transportation Environments

Driverless Vehicle (also known as an autonomous car, self-driving car, robotic car [6]) and unmanned ground vehicle is a vehicle that is capable of sensing its environment and navigating without human input [7]. [8] Driverless vehicle can provide people with transportation function and entertain value, also be helpful to shape a positive relationship among people, vehicle and environment.

3.1 Driverless Vehicle Functions Well in Short-Distance Environment

Short-distance transportation environment has many characteristics, such as strong flexibility, high transfer frequency, short driving time and many participants. Moreover, under slow-transportation environment, people are more closely related to surrounding environment. In such a low-speed and relatively narrow environment, driverless slow transportation vehicles can set up automatic docking and connection, calculate and arrange reasonable paths, also flexibly connect people and environment to the maximum. Because driverless vehicle is manipulated by the in-vehicle controlling system, cloud platform and the service platform itself, it could be more sensitive to be deployed and managed in limited space.

Driverless vehicle defaults to be in continuous operation on the road, except the recharging time. This continuous operation can maximize the use of and liberate transportation resources to some extent: On one hand, this continuous operation can improve vehicle utilization, realize the real sharing of resources of public vehicles. On the other hand, it can greatly save parking spaces, which is more meaningful than the past when the slow transportation spaces were being occupied, eventually enlarging capacity of area for transportation. This also provides advantages of external environments for good operation of driverless vehicles.

3.2 Driverless Vehicle Is Suitable for Environments with High-Path Repetition Rate and Simple-Driving Conditions

In urban slow transportation environments, campus, airports, communities far from the city center and industrial parks are the typical ones. The driving path repetition is high and driving environment is relatively simple in these typical using contexts. In campuses and industrial parks, the driving path has a certain regularity and repeatability in different periods. Walking is the main way of transportation in the airport and some residential communities where cars and people are separated. These environments are closed, which does not involve in urban transportation regulations, and the driving environment is relatively simple. Driverless slow transportation vehicle can improve the efficiency of vehicle utilization and serve more people in this environment.

3.3 Driverless Vehicle Can Contribute to the Interaction Between Vehicle and People

The current slow transportation tools are only the carrier of transportation services. Both the vehicles and the users do not understand each other, and the interaction between the two is passive. Transportation tools do not collect user data, do not learn user data, do not optimize services and benefit other users. Users can't feedback their experience, personal data and schedules to vehicles timely, which can't help transportation vehicles to know more about users' information and surrounding environment. However, the slow transportation vehicle and a driverless service platform should be a university's local information hub. Therefore, in this driverless vehicle, an in-vehicle smart system was embedded. This smart system functioned like a virtual character, to enable the vehicle to interact with people more naturally. Through this

interaction, users can input their own data or information, help transportation vehicles penetrate real needs and optimize it services in a very natural way. And this service platform can provide relevant information to help other users based on recorded data. Active interactions between vehicle and users will be helpful for the platform to provide on-demand services satisfying diverse needs.

3.4 Driverless Vehicle Can Support Better Function Integration

Nowadays, many environments are becoming more and more functional-compound, especially for different users. For example, the campus is not only a daily workplace for teachers and students but also the collection and distribution of environmental information around the campus. At the same time, it also bears certain social functions, such as holding some public exams or lectures, and being visitors' tourist destination on holidays. Therefore, taking the campus transportation service as an example, we need to meet routine, way-finding, information guidance and campus visiting. Driverless slow transportation vehicle can provide corresponding services to these different needs, through integration of functions. The driverless vehicle is directly controlled by in-vehicle smart system and service platform, not by people. Therefore, for driverless vehicles it is easier to be integrated into the whole system, easier to be dispatched, and easier to compound functions. This advantage helps driverless vehicle, based on different users and needs, to provide personalized routes of slow transportation.

3.5 Driverless Vehicle Can Enhance Transportation Comfort

Slow-transportation environment is always the last stop away from the user's destination, acting a role of transmitter. Improving riding comfort can greatly help users faster access to new environment and switch to new state. Because of the smooth-running speed, the use of clean energy, and the small transportation noise, driverless vehicles can greatly improve the driving comfort.

4 Driverless Vehicle-Based Urban Slow Transportation Service Platform Design

Campuses, airports, communities far away from city centers, and industrial parks are representative using contexts in slow transportation system. In response to their common demands, we propose a driverless vehicle-based urban Slow Transportation Service Platform (STS Platform) made up of with several function modules, under the designing approach of service system. And each of them have unique features in different urban low-speed using contexts.

Besides the offerings, on driverless vehicle-based STS Platform, an in-vehicle smart system was embedded to control the vehicle, together with various techniques in vehicle to detect the surroundings. This smart system can not only make driverless vehicles easier to be controlled, make driverless vehicles collect people's input, also be helpful for the STS Platform to provide multiple services.

4.1 The Working Principles of Driverless Vehicle-Based Urban Slow Transportation Service Platform

As the above discussed, urban low-speed environments, representative of campuses, airports, communities far from city centers and industrial parks, have some common demands, like requiring a flexible control system, building interactive relationship with people, providing multiple services meeting diverse needs. So, building STS Platform to satisfy so many integration of demands, which kind of designing methods is the proper one?

Service system design, as an effective designing logic, is good at dealing with varieties of relationships in complicated systems. On STS Platform, both the relationship among "people-environment-vehicle" with its inner relationship are important components. Any components will make effects on the whole transportation system, service system design can use some approaches to call on this complexity. The designing approach of stakeholders and task analysis grid can make an overall consideration of participants, combing them up into different categories, firstly to expand the service coverage, and then to filter or optimize core services based on the importance level of stakeholders (primary ones/secondary ones/others) [9].

In slow-transportation, there are many transportation transfers, high-frequencies of get on/get off, frequent passenger change, and large amount of traffic of passenger in this system. This requires systematic design thinking to arrange these multiple using contexts and touch points into a coherent using experience. Experience prototype in service system design is a simulation of the service experience that foresees some of its performances using the specific physical touchpoints involved [10, 11].

Under the designing approaches of service system, STS Platform can build proactive relationship between vehicles with people through smart interactions. Firstly, experience prototype can evaluate the whole service experience, help STS Platform make people interact with driverless vehicle more naturally; secondly, the approach of stakeholders can help driverless vehicle take a full consideration of diverse users, which contribute driverless vehicle to acquire more information from uses in a proper way, eventually to make STS Platform provide more accurate services for users. Under such a highly interactive relationship, it can help both people and STS Platform to establish the cognitive model of each other, for people to simplify the use of services and optimize the experience of services, for STS Platform enrich the types of services (see Fig. 1).

4.2 The Modular Functions of Driverless Vehicle-Based Urban Slow Transportation Service Platform

After discussing the methods of driverless vehicle-based slow transportation service system design, how to address the pain points and common demands of slow transportation will be elaborated in the following as a form of four modular functions?

STS Platform could base on the cloud information, such as personal schedule, campus timetable, local guidance information, to supply people with diverse functions: summon and book, parcel delivery, route customization and information hub service.

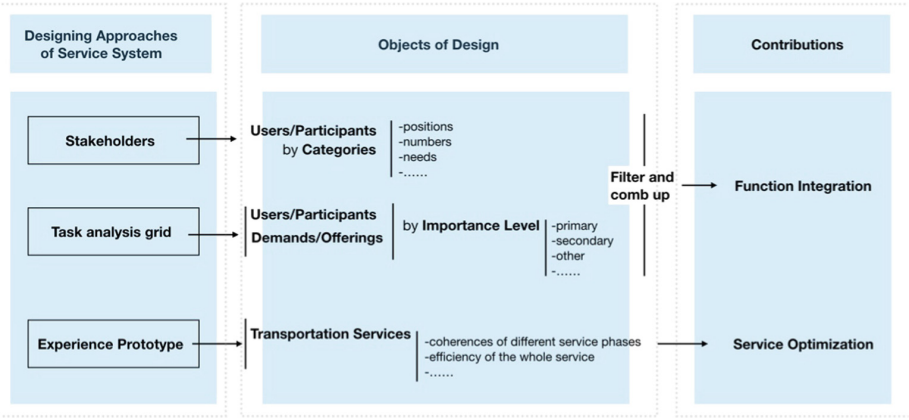

Fig. 1. Designing approaches of STS platform

Based on the in-vehicle smart system, STS Platform is armed with four modular functions:

Time-Based Sharing Mobility Service. This platform supports booking or summoning driverless vehicle based on conditions of people (personal schedule, time urgency, students class timetable, etc.) For example, in campus, teachers could book the vehicle through App at a certain time, and they just wait for being picked up at the nearest boarding point; Meanwhile, the platform could base on the class time and dormitory information to arrange some hitchhiking for relevant students or staffs.

Route Optimization Sharing Mobility Service. Based on the environment conditions of campus (transportation status, roads, navigation signage, buildings and so on) and requirements of users, driverless vehicle-based slow transportation service platform can provide different people with different on-demand services. In airports, transportation service demands could be sorted by various categories: sorted by user type, services could be classified to single user demands, group user demands, and family demands, different type of users have different requirements of vehicle type and capacity. Sorted by time urgency, activities in airports could be classified to emergency, rush for boarding, normal boarding, and casual airport shopping. Once users' boarding card scanned by the vehicle, it will provide customized route for users based on their own time urgency. Sorted by luggage, service demands could sort into with carry-on luggage and no hand luggage. In this situation, the system will allocate driverless vehicle with proper capacity or turn on the function of luggage storage for single passengers while they away temporarily. There is a variety of transportation needs, and after permutation and combination of these specifications, this driverless vehicle-based slow transportation service system could give customized routes for them.

Local Information Sharing. People could import to or connect their personal data with this platform, and the in-vehicle smart control system could also base on the sensory data and cloud data, not only helpful to understand users more, for providing customized slow transportation services; but also, the driverless vehicle works as a

moving information hub, to give relevant information recommendations about local mobility, local life and other aspects to visitors.

The in-vehicle smart system detects the environment of the driverless car based on the in-vehicle sensors and other hardware, and it can detect information including road network, vehicle, parking lot distribution, building distribution, signage, pedestrians and other information. At the same time, the driverless vehicle can support users to import personal calendar, residential information, personal preferences and other data. Through the analysis of multiple users' personal data, the driverless vehicle will have a basic understanding of the local transportation, life and service status. Supported by the STS Platform, the driverless vehicle works like a "driver": it can communicate with people and collect data through the communication, meanwhile the collected information can be shared with other people as guidance. Based on these information, on one hand, it can provide real-time and optimized transportation services for individuals in need. On the other hand, the driverless vehicle can also serve as a mobile local info hub, providing public information to people in need [12].

For example, the community far away from the downtown area, because the land price is relatively low, often covers a large area. There are often some commercial facilities such as supermarkets, gyms, which forms a relatively independent living ecosystem. So, the daily commuting within the community is also an important problem. In such an urban low-speed environment, STS Platform can do the most reasonable and efficient route planning, and do not take up too much capacity. At the same time, in the basis of different user's travel schedule, reasonable distribution of multiple users with vehicles, can reduce the waiting time, the repetition rate of paths and vacancy rate, thus to improve flexibility in slow transportation effectively.

Parcel Delivery Service. This driverless vehicle cannot only carry people but also help deliver the parcel. People can make reservations through cell phone app, or directly use the available driverless vehicle, set the destination and arrival time to deliver goods, and view the running path of the current driverless vehicle at the mobile phone side. This service can help students carry luggage during the start of the school season or the end of the school season. Or for residents living in large communities, when they come back home after shopping, they can use the driverless vehicle directly to help them carry their goods to their home. For items that are not able to pass the airport security check, people can also use this service through the mobile phone app and transport them to the airport mailing place with the driverless car, then mail or deposit their items (see Fig. 2).

4.3 A Use Case of Driverless Vehicle-Based Urban Slow Transportation Service Platform on Campus

Slow Transportation Demands on Campus. Currently, as more and more Chinese universities are expanding, the number of students and teachers is increasing. So, the campus is becoming more and more functional to meet the daily needs of many students and teachers. At the same time, campus daily activities have certain regularity in time distribution and spatial distribution, which can help unmanned cars plan more

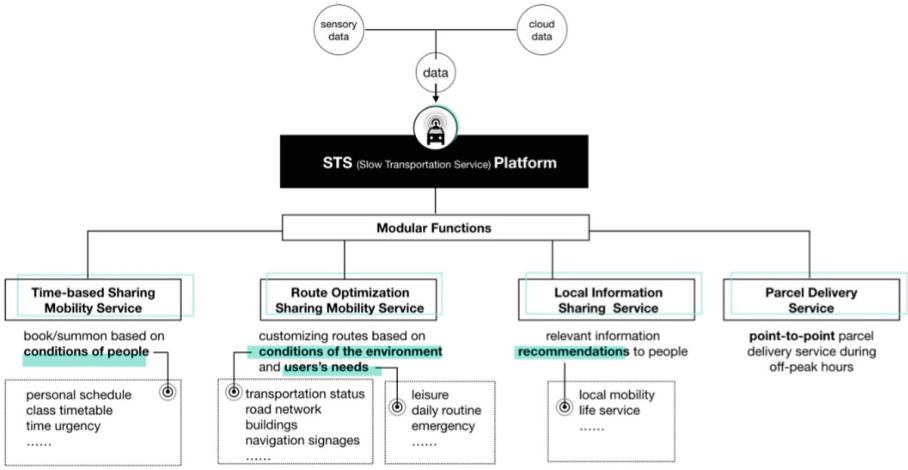

Fig. 2. Functional modules of STS platform

efficiently and serve daily commuting time and line between teachers and students (see Fig. 3). Based on their purposes of using the vehicle, the campus transportation service users could be mainly divided into four categories: students (for going for class), teachers (for going for work), visitors (for navigation), and visitors (for sightseeing).

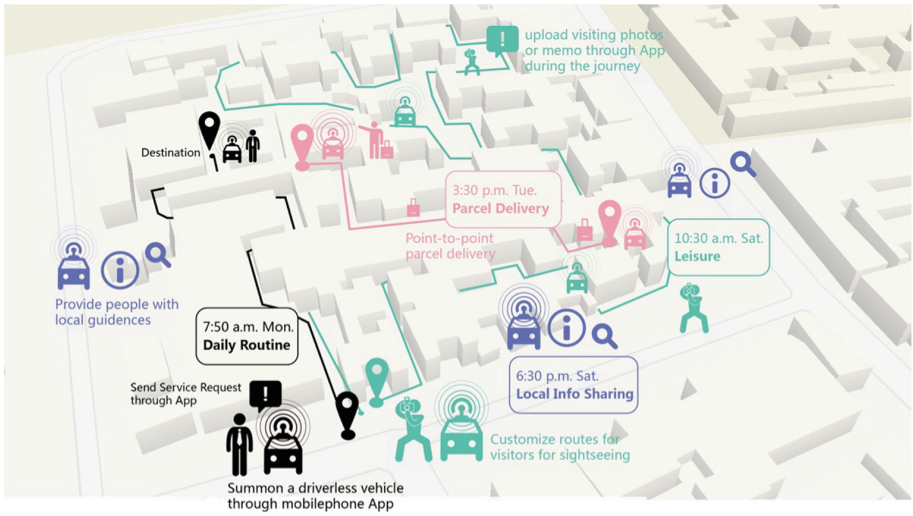

Fig. 3. Functions for campus slow transportation service system

Functions for Campus Slow Transportation Service System. Driverless vehicles can provide customized routes and services based on different needs. For example, when the teachers and students are running for the class, driverless vehicles will run the

nearest line, and at the same time, the in-vehicle screen will provide the news or life service voice information of the campus today. When an external visitor comes, the in-vehicle screen will show a campus map with detailed campus information, and support text input, touch input and voice input. Even for external visitors who only have little information of destination, driverless vehicles can also help them reach their destinations fast. When carrying with leisure visitors, driverless vehicles will choose the route which is the most suitable for viewing. During the tour, passengers can see the introduction of the site and the traveling mood of other tourists through mobile phone AR or in-vehicle AR screen. They could also upload texts, travelling notes, photos, videos or share music on cloud through mobile phone to leave digital travelling footprints. This service can help visitors get to know this environment better.

Through the detection of the campus environment and the connection of cloud data, the driverless vehicle can also be used as the campus life information point, it can provide information of transportation, catering, leisure, people flow and other information near the campus to students, teachers, and visitors. The parcel delivery function of the driverless vehicle can not only serve the teachers and students but also assist the logistics transportation department of the campus in the non-peak period.

User Journey. The above are some typical functions for campus slow transportation service system, and a user journey on campus, taking a period from 8:50 a.m.–10:00 p.m. as example, will be elaborated in the following part, which can help readers to have a better comprehension of the services:

This morning, Patrick made an appointment with his friend Sonia to take a tour at his campus, and they agreed to meet at campus gate at 9:00. He booked a driverless vehicle for two seats through mobile phone app in advance of 10 min, and waited at his dormitory for picking up. Sonia arrived at Patrick's campus gate, got learned some campus food recommendations through a driverless vehicle. At 9:58, Patrick is taking a driverless vehicle to pick her up. After boarding, the driverless vehicle customized a campus touring route based on their demands. At the campus cafe during the tour, Sonia noticed some travelling notes from other visitors about the café on in-vehicle AR screen, saying that "the coffee here is great" and "I like the interior design style of this café." These notes reminded Sonia that she also viewed some hot recommendations about this café through a driverless vehicle at the campus gate, so she decided to go for a cup of coffee. One hour later, their campus tour finished. After the driverless vehicle sending Patrick and Sonia to campus gate, Sonia gave a big toy to Patrick as present. Patrick request the same driverless vehicle to deliver the parcel to his dormitory, and sent Sonia to the nearest metro station (see Fig. 4).

5 Conclusions

Driverless vehicle-based urban slow transportation service is a new also valuable research direction. The features and advantages of driverless vehicle determine it could serve people well, in urban slow transportation environments. In this paper, we designed a driverless vehicle-based slow transportation platform (STS Platform) to provide people with multiple services adapted do diverse using contexts. Besides the

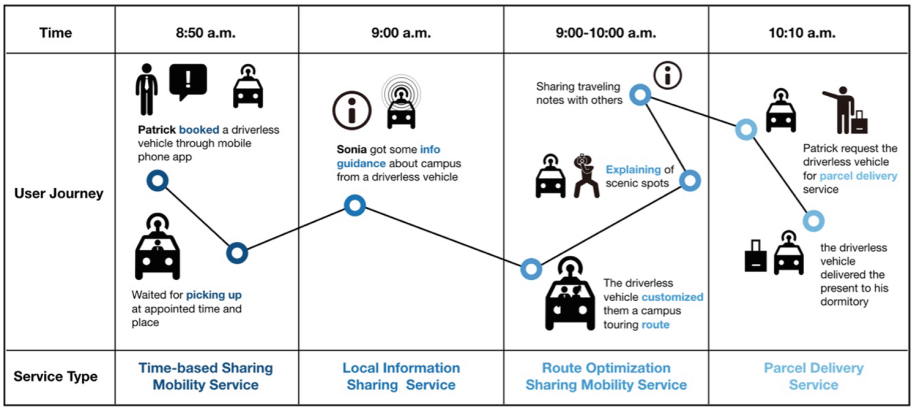

Fig. 4. A user journey of campus slow transportation service system

multiple services at in-front stage, at the back stage, driverless vehicle as a mobile carrier of sensors, the collected information can also support the platform to make some real-time visualizations of evaluations for the transportation, population traffic, the validity, population distribution status and other indicators of the region. The simulation and analysis of the development and potential of a certain region, could play a role in a broader area. And we will continue to research on this area in the next research plan.

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