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An Operation Model of Carsharing Service: Application of Simulation Method

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***Abstract*—A carsharing service has been highlighted as a sustaining service in the environmentally friendly economy. However, the operation model was not compared among potential options in order to provide successful service models to customers, devising a profitable business model. Thus, this paper aims at proposing a simulation model by evaluating the performance of possible service models. The factors of service operation models include trip type, driving duration, relocation and destination. In order to compare various operation models, this paper suggested two criteria such as reservation failure rate and car utilization rate. The simulation model is applied to derive the outputs of two criteria with artificial data. The simulation approach and results of this paper can help the researchers and practitioners devise a successful carsharing service model.**

***Index Terms*—carsharing service, simulation, operation model, comparison criteria**

I. Introduction

Environmentally friendly economy has highlighted the importance of an alternative transportation due to scarce size of energy and air pollution problem. Thus, a carsharing service is considered as a good candidate of solutions that has become increasingly popular in a lot of countries such as Germany, Japan, USA and so on. Existing studies has demonstrated the advantages of carsharing systems such as cost savings and reduced gas consumption [1]. Moreover, the similarities and differences of carsharing implementation in each country are examined to stimulate future growth of the service [2]. Recently, users enable to access a portal of a carsharing company, easily making a reservation via a website. The dedicated system of carsharing services can save travelled distances and rent duration [3]. An intelligent transportation system is critical in rendering a carsharing system easy to manage, and efficient. A broad spectrum of functions of such systems includes a whole cycle of services, including registration, reservation, monitoring, and vehicle communication. A prototype of a shared electric vehicle system has been set up at UC Riverside [4].

The sophisticate carsharing systems can provide enhanced services that allow a car to be driven among multiple stations. This service can be called as a one-way service. In a round-trip, customers can use a car and return it to the same station. Even though the one-way service is convenient for customers, the distribution of cars in each station is subject to be biased because the popular destinations spontaneously have many cars. Therefore, the concept of vehicle relocation is necessary to provide sufficient cars to each station. The carsharing system must be efficient, user friendly, easy to manage, and advantageous to both companies and customers [1]. Thus, the relocation techniques were suggested to sort out the problem of biased cars, namely inventory balancing [5] and static relocation [3]. Furthermore, a forecasting model for relocation was suggested to optimize the results of relocation and predict efficient routes [6] - [8]. Schwieger & Wagner [9] has proposed an open-ended car-sharing, offering flexibility to users without identifying the ending time for reservation.

Thus, this paper aims to focus on suggesting an operation model and developing a simulation tool that can evaluate the performance of possible carsharing service models. For this ends, a carsharing simulation was developed to evaluate operational issues such as car distribution, and relocation techniques to validate the performance of the aforementioned techniques and help managers to select an operation model. The previous studies on simulation of carsharing systems only focused on round-trip and one-way techniques for specified return time [3], [5] and open-ended reservation [9]. Thus, this paper considers flexible destination and a relocation technique. Therefore, the performance of both traditional and new service models needs to be evaluated by a simulation approach. Several criteria for evaluation have been proposed and evaluated to decide the successful service model that can be implemented.

II. Theoretical Background

A. Carsharing Service

The carsharing service can be described as an intermediate transportation between public transit and

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private vehicle ownership. The objectives of this service is to reduce the number of cars and provide cost saving, parking demand and other benefits. Carsharing was first implemented in Europe but has gained popularity in the U.S. and Asia. After members subscribe to a carsharing company, they can drive a carsharing car and then pay a fee each time they use a vehicle, covering all the cost such as vehicle use, insurance, maintenance, and fuel. A carsharing study categorizes users into home-based users, work-based commuters and work-based day users [10]. A customer can select a service option that a carsharing company has offered to. Various service options provide different advantages to customers, satisfying customer requirements. Since the one-way trip between stations is possible to users, the type of trip needs to be compared with a round-trip. Existing studies hardly dealt with the issue. Companies that run the carsharing services have their own stations in highly dense destinations such as shopping malls and transit stations.

Carsharing-related research as the product-service systems, which define a service blueprint for carsharing in Korea, was conducted [11]. The research presents that the design of a new car-sharing service model is applicable to South Korea because such a service will foster sustainable development for reducing traffic problems and air pollution. The car-sharing service model is related to a public transport system for increasing mobility. Therefore, car-sharing stations need to be implemented at transport interchanges and/or areas of low access to public transportation.

B. *Simulation*

A simulation approach is a process to design and conduct experiments for the purpose of understanding system behavior or evaluating various strategies for operation of the system. The results of simulation can be regarded as a good solution to implement a new system. There are various types of simulation. The representative type of simulation is discrete-event simulation, representing the operation of a system as a chronological sequence of events. Each event occurs at an instant in time and marks a change of state in the system. Basically, the idea of this simulation is based on the notion that the clock jumps to the next event as the simulation proceeds. The simulation can move the current time of the simulation through events and their timing instead of distinct time intervals. Thus, instead of checking every second that is time consuming, the simulation would go straight to the next scheduled event [12].

The simulation methodology can be applied to test the relocation techniques, namely shortest time and inventory balancing [5]. The first one - shortest time relocation moves a car from a neighboring station in the shortest possible time. However, the second one - inventory balancing relocation moves a car to a station with a shortage of cars from another station with an oversupply of cars. The forecasting model to predict the net flow of vehicles was suggested, using neural networks and support vector machines [6]. Consequently, the results of the simulation experiment demonstrate that all of the aforementioned techniques have the potential to improve carsharing services. The simulation approach in a research situation that researchers cannot collect real data will greatly assist a carsharing company in prioritizing their policies before offering its service.

III. Operation Model of Carsharing Service

A. *Trip Type*

If a driver makes a reservation for a carsharing car, he/she should decide trip type: one-way or round-trip. Many researchers performed a study on the trip type of carsharing service in carsharing systems in many countries [1]. One-way type is flexible in using a carsharing service. However, the price of the type might be expensive when it is compared with round-trip. On the contrary, since the round-trip type enables to efficiently operate the service, they can offer a cheap price of the round-trip to customers.

B. *Driving Duration*

The decision on the utilization period for the car is important in the process of making a reservation on the carsharing service. Two options are available on a driving time: fixed duration and open duration. This is a common situation in a transportation reservation process such as flight services. Whenever a user reserves a flight seat, he/she needs to conclude departure hour/date and return hour/date or can select the open option on return hour/date. Consequently, the carsharing service can provide such options for convenience of users. However, while the flight service successfully can run the options due to long time gaps between departure date and return data, the carsharing service might struggle the operation.

C. *Relocation*

One-way services require a relocation policy for stable service management because one-way services might produce unbalance of car distribution. This is common in the operation of one-way services. If users prefer to drive a car from a specific starting point to a destination, the starting point cannot have sufficient number of cars. The consequence of this situation causes the failure of stable service offering. Thus, this paper considers two options of relocation: homing relocation and nearest station relocation. First, homing relocation means that a car in a destination is returned to an original starting point. The first option is similar to a reset button of computers by returning a car in a midnight. Second, the nearest station relocation deals with a flexible strategy of relocation. If the number of cars in a station is more than the original number of cars in the station, the additional cars over the original number are moved to a nearest station that starves due to insufficient number of cars. Although in principle cars that are complete from a service need to be returned to an original station, the cost might inconsiderable in the operation. Thus, this paper intends to analyze the trade-off between the homing relocation and the nearest station relocation. The criteria of comparison are a reservation failure rate and car utilization rate. If a service option is efficient, the option will have good levels of in two criteria.

D. Destination

This paper can explain the operation model of carsharing model with the reservation of a flight service because the processes are similar. The operation in the destination factor of the carsharing service might be totally different from flight services. Even though the destination should be decided before the departure in flight services, the carsharing service can provide open destination to users. This factor is similar to the openness of driving duration. Since the relocation process can balance carsharing cars to each station, the flexible services can be presented to users. Thus, two options in deciding a destination station can be presented to implement carsharing services. First, the complete destination means that a user should select a destination station before using the service. Second, the flexible destination provides a service that a user does not have to decide a destination station prior to utilization of the service. The flexible destination service might be expensive because the service provides a lot of benefits to users. Table I summarizes the operation model of carsharing services.

TABLE I. THE OPERATION MODEL OF CARSHARING SERVICES

Factors	Operation Options
Trip type	One-way vs. Round-trip
Driving duration	Fixed duration vs. Open duration
Relocation	Homing relocation vs. Nearest station relocation
Destination	Complete destination vs. Flexible destination

IV. SIMULATION MODEL

In this paper, a simulation tool that implements a reservation algorithm to evaluate the performance of service models is proposed to offer an efficient system of carsharing service. Therefore, this research collects real reservation data of a Korean carsharing service. Two criteria (reservation failure rate and car utilization rate) are suggested to evaluate the performance of carsharing service models. First, car utilization rate is critical for a carsharing company because the service should be profitable, optimizing the operation of cars. Second, however, reservation failure rate is important to customers because it is an indicator to measure customer satisfaction. Thus, a service model that is benefits for companies as well as customers will be drawn in the simulation tool. The process enables carsharing managers to evaluate the services and relocation techniques. The specified return time service should be cheaper in comparison with the open-ended reservation service, due to the predictability of its ending time. Thus, the next reservation is ready to be done immediately. On the contrary, the flexibility of open ended reservation service would make the ending time unpredictable. Therefore, the car cannot be reserved before the car is returned.

This paper proposes a new type of carsharing service of undeclared destination service. The concept can be defined that the customer does not need to declare the destination station in reservation. Thus, this service must be round-trip or one-way at the end. These services could be considered as new carsharing services due to the flexibility of the reservation offered to customers. However, the services have several difficulties in implementing the services because the customers do not decide when and which station they will return the car. This will make a reservation be uncertain, affecting next reservations at the same time.

A. Input

The information on the total number of cars should be presented in this simulation. The interface of the simulation tool shows the status of the car during simulation (parked if a car is parked in the station, booked if a car is booked by a customer and on the road if a car is booked and used by the customer). In addition, the total number of stations is set to be 10 which is assumed to be enough for the first step of development in the carsharing service. The stations are designed to be located in high movement spots of target customers. Information on the travel distances and time between each station must be considered. Day operation that means the number of days that the simulation is implemented is set to be 5 workdays from Monday to Friday in this simulation. Furthermore, the operation time is set from 01.00 to 24.00. More details about input parameters are shown in Table II.

TABLE II. INPUT PARAMETERS OF SIMULATION

Input Parameters	Values
Total operated cars	100 cars
Total stations	10 stations
Operation time	01 AM – 12 AM (23 hours)
Day operation	5 days
Reservation per day	Start from 5 increase until 2000

id_reservation	id_customer	id_service	numb_car	start_time	end_time	from_location	to_location	id_day	call_time	id_service_detail
1	13192	15		04:39:48	06:39:48	140	140	533527	01:04:47	33
2	11619	15		09:59:58	11:59:58	140	140	533527	01:22:56	33
3	13239	15		18:26:45	20:26:45	140	140	533527	18:06:19	33
4	12517	15		11:55:59	13:55:59	140	140	533527	04:49:59	33
5	12941	15		14:57:51	16:57:51	140	140	533527	05:40:41	33
6	11837	15		19:58:31	21:58:31	140	140	533527	16:37:09	33
7	12652	15		19:52:37	21:52:37	140	140	533527	09:47:18	33
8	12727	15		07:59:51	09:59:51	140	140	533527	05:34:34	33
9	12256	15		15:59:37	17:59:37	140	140	533527	11:59:05	33
10	13306	15		13:56:57	15:56:57	140	140	533527	03:55:55	33
11	11551	15		19:25:45	21:25:45	140	140	533527	03:18:25	33
12	13249	15		19:58:32	21:58:32	140	140	533527	15:27:20	33
13	12638	15		18:38:40	20:38:40	140	140	533527	05:16:13	33
14	12350	15		02:41:31	04:41:31	140	140	533527	01:28:30	33
15	12959	15		08:59:54	10:59:54	140	140	533527	06:54:53	33
16	11592	15		18:55:34	20:55:34	140	140	533527	02:44:32	33
17	12140	15		11:51:50	13:51:50	140	140	533527	09:45:20	33
18	12406	15		17:45:24	19:45:24	140	140	533527	15:33:07	33
19	12882	15		17:50:59	19:50:59	140	140	533527	04:50:58	33
20	12121	15		14:52:32	16:52:32	140	140	533527	09:40:25	33

Figure 1. Artificial reservation data table for simulation.

The artificial reservation table in this study consists of several columns (transaction number, member identification number, service identification number, vehicle identification number, beginning reservation, end of reservation, from station, to station, date of reservation and calling time), which can be seen in Fig. 1.

B. Output

1) Car utilization rate

The car utilization rate is calculated with the percentage of total actual driving hours of rented cars over total possible driving hours of cars per day. The unit of evaluation is a day because cars are rented from other car rental companies, and a rental cost is generally calculated per day. In addition, in this discrete-event simulation, the data are generated and simulated each day. Since a carsharing company normally wants to optimize the number of rented cars, the company needs to ensure that all cars can be rented to increase profits. Thus, the formula for calculating the utilization ratio in this simulation tool is as follows.

Car Utilization Ratio = (vehicle-hours of cars used)/ (available vehicle-hours of the entire fleet)

2) Reservation failure rate

The car failure rate is information on the ratio of accepted reservations over the total number of reservations. Accepted reservations mean that the carsharing reservation system will check whether the customer can get an available car or not on the reservation call. If they get an available car, and there is an empty space at a destination station, the reservation is accepted and otherwise, the reservation is rejected. Since the system does not suggest a customer to delay his/her reservation to get the other car, the customer is expected to find another reservation which has no conflict with others. This reservation acceptance ratio is important to customers because it can provide a service option to maximize customer satisfaction. The formula for calculating the car acceptance ratio in this simulation tool is as follows:

Reservation Failure rate = (number failed reservations per day) / (total reservations per day)

V. Results

The results of simulation can be utilized to derive the operation policy of carsharing services.

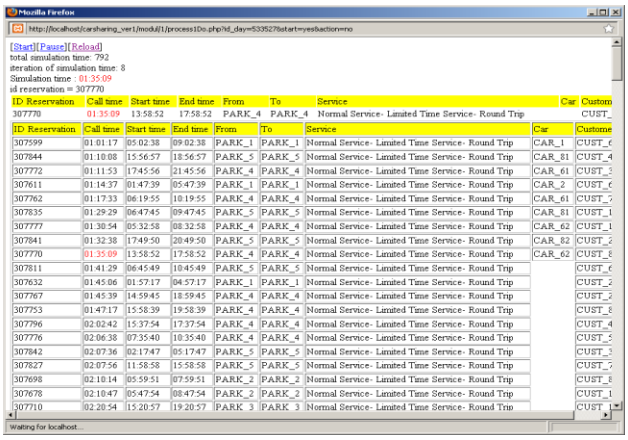

Figure 2. An interface of running the simulation program.

Fig. 2 shows a snapshot of running the simulation program. Since the program provides the information on car utilization rate and user reservation failure rate, the generated data fields should include calling time for reservation, starting time, ending time, ID of occupied car and customer ID. Each service model is simulated with the proposed simulation model and the artificial data.

Two evaluation criteria of the average car acceptance ratio and average car utilization ratio are used to evaluate the performance of service models as shown in Table III.

The results from the simulation indicate that the open-ended reservation provides a higher utilization ratio than specified return time service. However, different results are obtained from the acceptance ratio viewpoint. While the open-ended service will gain more customers, the acceptance ratio will be decreased, increasing the profit of a company. The result can be seen from the returning time service viewpoint that evaluates the type of service by two criteria.

TABLE III. Results of Simulation

Factors	Operation Options	Utilization Ratio of car (%)	AcceptanceRatio reservation (%)
Trip type	One-way	39.8	48.2
	Round-trip	37.3	68.4
Driving duration	Fixed duration	44.6	71.3
	Open duration	57.4	49.5
Relocation	Homing relocation	40.1	61.2
	Nearest station relocation	42.3	57.3
Destination	Complete destination	36.5	63.2
	Flexible destination	41.7	43.4

The one-way service provides the highest utilization ratio compared with other services. However, round-trip services have the highest percentage from the acceptance ratio viewpoint. If a company implements just a round-trip service, the total number of customer reservations will be low, and the opportunity for customers to get an available car will be high, causing a high acceptance ratio. In particular, a one-way destination makes the distribution of cars disproportional between each station, enabling to prevent customers from getting available cars (from a car-shortage station). While various services increase the profits of a company and attract a greater number of customers, the acceptance ratio of them will be decrease.

VI. Conclusions

This paper aims at developing a simulation tool to compare operation models in specific conditions of customer patterns. For this, this paper identifies various services, one-way and round-trip, fixed duration and open duration, homing relocation and nearest station relocation, and declared destination and flexible destination. In particular, an artificial reservation table has been developed in a simulation tool, which is designed to be similar to real reservation data of carsharing services. Two criteria (acceptance ratio and utilization ratio) have been presented to compare the options in four operation models. Moreover, this paper analyzes a comparison between various service models based on acceptance ratio and utilization ratio viewpoint. The results of the simulation indicate that the service model in carsharing is most sensitive to the relocation technique.

The limitation of this paper is as follows. First, the proposed approach just uses a few relocation techniques, and the service model focuses on the general transportation situation of customers in Seoul. Second, additional relocation techniques such as predictive relocation, trip splitting and trip joining are expected to be "add-ons" in this simulation tool. Various inputs can be added, not only in terms of the travelling path and hours for customer analysis, but also by grouping characteristics of customers in order to improve the service at a specific cluster of customers. Time period such as classification into weekend, weekday, peak time, and non-peak time to offer a service must also be considered. Existing public transportation modes should also be considered as an additional input of the simulation because they might affect the results.

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