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Chunmei Wang

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Dockless bicycle sharing simulation based on Arena

Wang Chunmei

College of Information Engineering, Nanjing University of Finance and Economics, Nanjing 210023, China
lncs@springer.com

Abstract. Shared bicycle sites vehicle imbalance is very common. When users arrive at a site to rent or return a bicycle, they often encounter the problem of "no bicycle to borrow" and "no land to return". Existing research, in response to the problem of unbalanced site demand, most scholars predict the demand for bicycle sites. In this study, the use of public bicycles at the site is analyzed from the perspective of simulation. The Arena simulation software is used as a tool to build a shared bicycle operation model, and three shared bicycle sites are established to simulate the user's arrival, riding, and bicycle use. Based on the simulation results, the unbalanced sites are determined. For unbalanced sites, use OptQuest to find the best decision-making plan. By changing the initial volume of bicycles at the site, reduce the number of users who can't be rented, the excess number of bicycles at the site, and the number of users waiting in the queue.
Keywords: shared bicycle simulation; initial bicycle volume; Arena

1 Introduction

As a new type of business sharing economy, sharing bicycles has effectively improved the "last mile" problem of urban transportation, and brought convenience to people in China. However, it has also developed a series of problem. In real life, we often encounter the problem of "no bicycle to borrow" and "no land to return". Especially in the morning and evening peak hours, the vehicle is tense, users often can't find bicycles, and the vehicles are parked more messy. At the same time, the blind sharing of bicycles by enterprises has resulted in an imbalance of supply and demand in the market, resulting in waste of resources and ultimately affecting the city appearance of the city [1]. Therefore, according to the actual situation, reasonable placement of bicycles for bicycle sites is an urgent problem to be solved.

At present, foreign researchers' research on the sharing of bicycle rebalancing mainly focus on the VRP (Vehicle Routing Problem) problem. There are not many researches on the initial bicycles volume of the sites, but some scholars have studied the demand forecast of the bicycles at the site. For example, KaltenbrunnerA[2] used the ARMA model to predict the number of bicycles at Barcelona stations based on data sampled from the operator's website. Robert Regue [3] predicted the number of bicycles at the site and analyzed the inventory quantity of the site to determine whether the initial inventory level of a given station is sufficient for future demand. Dong Zhang [4] established a mixed integer programming model. The model considers inventory level prediction, user arrival prediction, and proposes a new heuristic algorithm to solve the model. In China, Zeng et al. [5] built a multi-objective optimization integer programming model based on the actual needs, and obtained the number of parking facilities at the planning point. Dai Li [6] constructed a model for the problem of the number allocation of shared bicycle parking areas, and adopted the bacterial colony optimization algorithm to solve the problem of the number distribution of urban shared bicycle parking areas. Zeng Zeyu [7] used the actual data to establish a multi-objective decision-making comprehensive evaluation model using TOPSIS algorithm, and gave a reasonable number of shared bicycle campus placement points.

Some researchers have turned to establish simulation models to propose rebalance strategies.In order to minimize the re-scheduling cost of shared bicycle operators, Leonardo Caggiani [8] proposed a micro simulation model of the dynamic bicycle redistribution process, but lacked actual data. Yang-Kuei Lin [9] and Huang Zhengyi [10] proposed a simulation model to solve the vehicle rescheduling in the bicycle sharing system. In their model, for rescheduling the bicycle, the optimal number of vehicles and the number of shipments were studied. Sun Yizhen et al [11] used AnyLogic software to build a shared bicycle flow simulation model and gave a reasonable scheduling scheme.

In order to further study the initial volume of bicycles, in this paper, the use of public bicycles at the site is analyzed from the perspective of simulation.The actual data is analyzed and combined with the management simulation software Arena to simulate the operation of the bicycle. Using Arena simulation, you can visually see the flow of the vehicle and the number of users waiting to rent in the queue at the unbalanced site. In the model, three shared bicycle sites are established, and the results of the experimental operation are used to determine whether the vehicles at the site reached equilibrium. For unbalanced sites, use the package OptQuest that comes with Arena to find the best decision-making solution to optimize the problem. By changing the initial volume of bicycles at the site, the number of users who can't be rent, the excess number of bicycles at the site, and the number of people waiting in the queue for renting are reduced, thereby improving user satisfaction and utilization of bicycles.

The simulation software used in this paper is Arena. Arena is the world's leading discrete event simulation software. It has a strong modeling level and can be used for visual simulation of actual activities. It is widely used in service systems, manufacturing systems, logistics and transportation systems, etc. [12] . Arena and OptQuest have been widely used in practice to simulate a variety of real systems. However, few academic publications in business and economics use this analog technique.

2 The establishment of the model and the design of the parameters

2.1 Data processing

Select bicycle cycling data from 5:00pm to 6:30 pm on a certain day from the 2016 US Bicycle Rental System. The data collected is mainly the initial number of bicycles at the site, the number of free spaces, and the arrival rate of each site. First, use the input analyzer to fit the input distribution, fit the data to a probability distribution, and then build a model for simulation analysis. In the simulation experiment, three shared bicycle sites, S1, S2, and S3, are simulated. The arrival ratios of the users arriving at the site are S1 to EXPO (5.30), S2 to EXPO (1.96), and S3 to EXPO (1.84). The initial number of bicycles, the number of free parking spaces at the S1 site are 12,15, the S2 site are 17, 2 and the S3 site are 4,19 respectively. At the same time, when users arrive at the site, the proportion of users rent a bicycle is 50%. When user rent a bicycle, 80% of the people are willing to wait if there is no bicycle to rent.

2.2 Flow chart

Take the site S1 as an example, the flow chart of the simulation is shown in Figure 1:

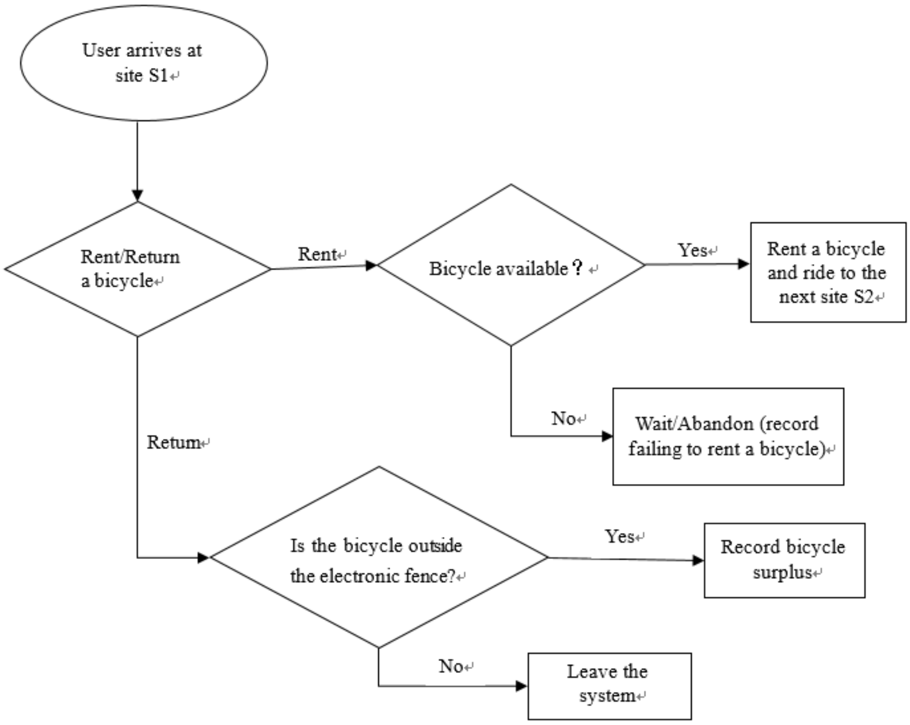

Figure 1. shared bicycle simulation flow chart

Because of the unreasonable placement of bicycles at the site, the uncertainty of demand, there will be a situation of waiting for a bicycle rental and returning the bicycle. Therefore, in the model, in order to better describe the reality, seting up a bicycle rental, return queue, which is also a factor for optimizing the experimental results.

The user arrives at the site S1 and chooses to rent or return the bicycle. Suppose the user wants to rent a bicycle, if there is a bicycle available at the site, the user rents the bicycle and rides to the next site S2; if there is no bicycle available at the site, the user chooses to rent the bicycle while waiting for the bicycle to be available or give up the bicycle. If the user gives up the bicycle, record failing to rent a bicycle. Suppose the user wants to return a bicycle, and after the user returns the bicycle, it is determined whether the bicycle is excessive. In actual life, the method of determining the excess bicycle is beyond the bound range. If it exceeds the range bounded by the electronic fence, the bicycle is recorded as surplus.

2.3 Logical model

The basic building blocks of the Arena model are called modules, which can be used to define simulation processes and data. First, create a Create module to simulate the user's arrival at the site, the demand is generated; Second,create a Station module that represents the site S1; Then,create the first Decide module and judge whether it is renting or returning a bicycle. The bicycle rental or returning bicycle is diverted according to the percentage of 5:5, and user enters the bicycle rental system and return system respectively.

If user enters the rental system, create a second Decide module and determine if there is a bicycle available for renting at the site. If there is a bicycle at the site and no one is waiting for the rental queue, rent a bicycle, and create a Seize module and an Alter module (indicate the number of bicycles is reduced by one, the number of bicycles that can be parked plus one), and then the user rides to the next site S2(destination) , enters the sub-model system; if the site has no bicycle to rent, create a third Decide module, and set 80% of people willing to wait. Create a Hold module, it means that the user who wants to wait and enters the Rent_wait queue. If the user does not want to wait, create a Record module, record the user failing to rent a bicycle.

If user enters the return system, first, return the bicycle and occupy an empty parking space, then create a Release module and an Alter module (indicate the number of bicycles at the site plus one and the number of parkable bicycles is reduced one). After the return of the bicycle, create a fourth Decide module. According to the number of bicycles that can be placed in the system,determine if there are any excess bicycles, if any, record bicycle surplus and finally leave the system. The main logical model is shown in Figure 2:

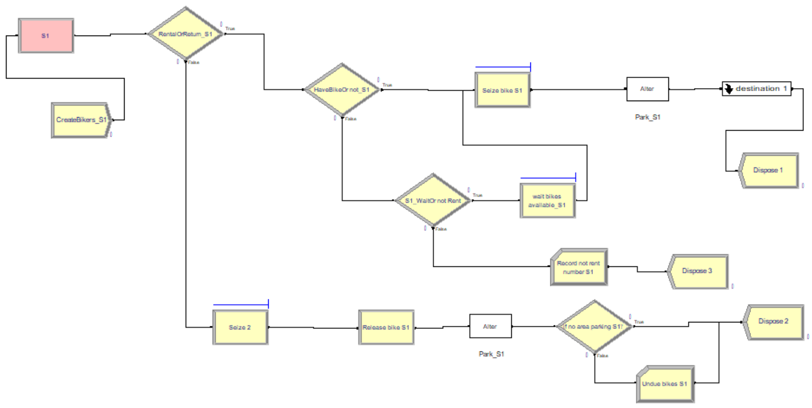

Figure 2. main logical model

3 Experiment

3.1 Running results

The model simulation duration is 90, the unit is minutes, and the number of repetitions is 5. Analyze the experimental results, as shown in Table 1.

Table 1. Experimental result

Site	S1	S2	S3
Rent.Queue	0	0.3660	0.8612
Rent_wait.Queue	0	1.9562	10.4044
Number of user not rent	0	1.6000	5
Return.Queue	0.0047	2.4497	11.5904
Excess bicycles	0	4	0

It can be seen from the running results of the simulation that the bicycles at the S1 site are more evenly distributed. Users can rent a bicycle without waiting, and park the bicycle in the designated area. At the S2 and S3 sites, there is a phenomenon of vehicle imbalance.

3.2 OptQuest optimization

Arena has a software package called OptQuest, purchased from OptTek Systems Inc., which uses heuristic algorithms such as tabu search and scatter search to move subtly in the input control variable space to find the best solution[13]. In the next work, the optimization problem is described first, and then it is searched for the value of the control variable that minimizes the predefined target.

The goal of experiment optimization is to solve the S2, S3 site imbalance problem.We set the OptQuest parameter to solve the above problem. First select the control variable, select Bikes_Si, Park_Si (i = 2, 3), indicate the number of initial bicycles and the number of free parking spaces at site S2, S3. And constrain its upper and lower bounds, according to the actual situation, set as follows: $0 \leq \text{Bikes\_Si} \leq 30, 0 \leq \text{Park\_Si} \leq 30 (i = 2, 3)$. Reselect the output variable: Record not rent number S2, Record not rent number S3, Excess bicycles S2,Excess bicycles S3, thus establish the minimum target:Record not rent number S2 + Record not rent number S3 + Excess bicycles S2 + Excess bicycles S3.

Table 2. Optquest optimized results

Site	S1	S2	S3
Rent.Queue	0	0.1321	0.1900
Rent_wait.Queue	0	0.0500	0.6100
Number of user not rent	0	0	0
Return.Queue	0.0047	0.4500	0.3500
Excess bicycles	0	0	0

After the experiment, the minimum target is 0, and the best solution is found. The details are as follows: 4 bicycles are placed at the S2 site and the number of area locations for parking 23 bicycles is vacated. 27 bicycles are placed at the S3 site, and the number of area locations for parking 16 bicycles is vacated. The results of the optimization are shown in Table 2.

4 Conclusions and further research

In this simulation model, three shared bicycle sites are established, and the actual operation is simulated by setting actual data parameters. The experimental results show that the S2 and S3 sites show bicycle imbalance. In order to solve this problem, the OptQuest software is used to find the optimal solution. By changing the initial volume of bicycles at the S2 and S3 sites, the number of users who can't be rented, the excess number of bicycles at the site are reduced to 0. As well as reduce the waiting number of queues,which is waiting for renting and returning bicycles, the problem of unbalanced S2 and S3 bicycle sites has been improved.

Existing research, in response to the problem of unbalanced site demand, most scholars predict the demand for bicycle sites. Nevertheless, In this study, the use of public bicycles at the site is analyzed from the perspective of simulation. Use the Arena simulation to build the model and determine the optimal volume of bicycles for the sites. Arena is the world's leading discrete event simulation software, however, few academic publications use this simulation tool. Research in this paper use the simulation tool mentioned above, based on the traditional dock public bicycle rental system. According to the actual operation of the domestic shared dockless bicycle, make changes and optimization.

The shortcomings of the model is that the real-time use of the shared bicycle is still not enough research. During the experiment, we assume the proportion of renting a bicycle and the proportion of unwillingness to wait. In the future, we can do further research in the following two aspects:

(1) Deepen the investigation of the real-time use of bicycles at the sites, and expand the three sites to a larger system to make the model more suitable for actual operation.

(2) Under the condition that the optimal initial delivery volume of each site is known, a multi-objective optimal scheduling model and algorithm are established to complete the static scheduling of multiple sites.

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