Advanced Materials Research Vols. 317-319 (2011) pp 2133-2137
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doi:10.4028/www.scientific.net/AMR.317-319.2133

Simulation of the Parking Behaviors in a Shopping Mall of Dalian

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Keywords: parking behaviors, simulation, parking space, illegal parking.

Abstract. The best is to read these instructions and follow the outline of this text. This paper models and simulates the parking behaviors in a main commercial area in Peace Plaza, Dalian City. By analyzing the simulation results, we propose a feasible plan to solve the problem that some customers cannot find a parking space and there are too many illegal parking behaviors in this area. The simulation shows that it can effectively reduce the number of cars that can't find a parking space or illegally park by the road.

Introduction

Now many shopping malls are facing the problem of insufficient parking space. In this way, the analysis of parking behaviors in this district will be very important. We can dynamically simulate the cars that get to the shopping mall and simulate the behaviors of them based of some kind of probability distribution. By modeling and simulating the parking behaviors, we can find the problems for the parking lots in the shopping mall and give some suggestions to solve it.

Dalian lies in the east coast of China. As the fast development of economy, a new shopping mall appears in downtown area. There are a lot of banks, shops and restaurants in this area, hence a lot of parking space is needed. However, the shopping mall is facing some serious parking problems recently. A lot of customers have to park their cars by the street because they can't find a parking space, which blocks the traffic and causes more serious problems. Some customers have to leave as soon as they get go the shopping mall because they don't want to park their car illegally by the street or they can't even find a place by the street. There have been two parking lots in this area, with 180 and 100 slots respectively. When a customer comes to this area, firstly he will try to find a nearest parking space in these two parking lots, and he also has a probability to illegally park on the street if it is the nearest parking place for him. If he finds both of the parking lots are full, he may choose to illegally park on the street or just leave. However, the street can only park 50 cars at most, even if it is illegal. The customer will have to leave if he can't find any parking space, which will lead to a potential loss of business transaction. To analyze the parking behaviors in this shopping mall, we will model it and then simulate the parking behaviors. Based on the simulation result, we will give a suggestion to solve the parking problem for the shopping mall.

Model Description

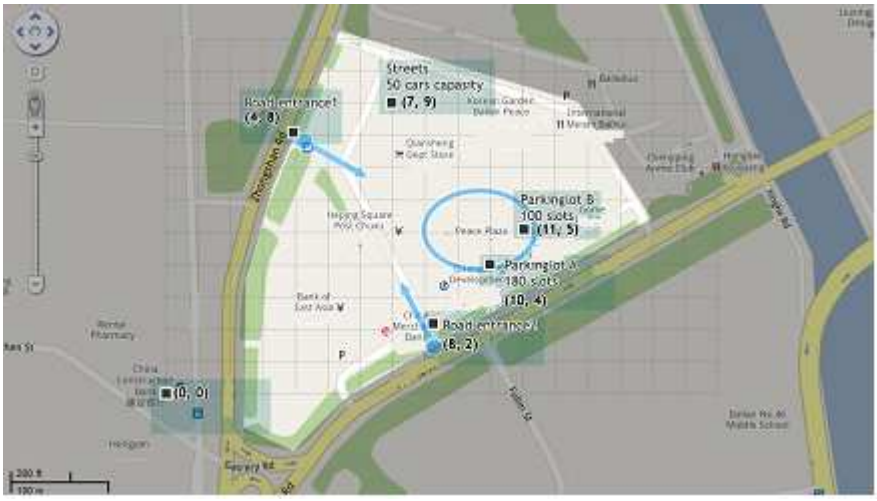

Figure1 - Map of the shopping hall in Dalian
(map from Google Map)

The picture above is the map for this shopping mall. First we build a coordinate for it. We choose a point at the southwest corner of the shopping mall as the origin of the coordinate. We use a line from due west to due east as the X axis and a line from due south to due north as the Y axis. From the map we can see the shopping mall is surrounded by two main roads. There are two road entrance to the shopping mall, and their coordinates are (4, 8) and (8, 2). There are two parking lots within the shopping mall: parking lot A and parking lot B, with 180 and 100 slots respectively. The streets can also park 50 cars at most, but it is illegal and will cause some traffic problems for the shopping mall. When a customer gets into the shopping mall from the road entrance, first they will try to find a nearest parking space, very few of them will park directly by the street. For simplicity, we just compare the straight-line distance between the road entrances and the parking lots. If both of the parking lots are full, some of the customers will just leave, however, some others will risk the danger of being fined to park it by the street. When even the street is also full of cars, the customer will have to leave. Parking by the street or leaving are situations that we don't want to see.

Our Solution

We figure out that the primary reasons of the problem are:

1. Pressure of the two parking lot is too high, need more parking slots;
2. The two parking lot is far from the road entrance A, which more cars drives.

We came up some solutions, all of them have one new parking lot C added, but have different location. Because of the design of the shopping mall, room for another parking lot is limited, so only two can be considered:

Solution A

The new parking lot C with 200 slots will be built on location (7, 3), the new parking lot sits near the existing ones and near the entrance B. We hope this can reduce the pressure of each parking lot.

Solution B

Similar to solution A, but the parking lot C will be built near the road entrance A at (6, 7). We want more cars from entrance A to use the new parking lot, thus the pressure of the other two parking lots will be reduced.

The Simulation Program

Flowchart of parking behavior of customers is shown below:

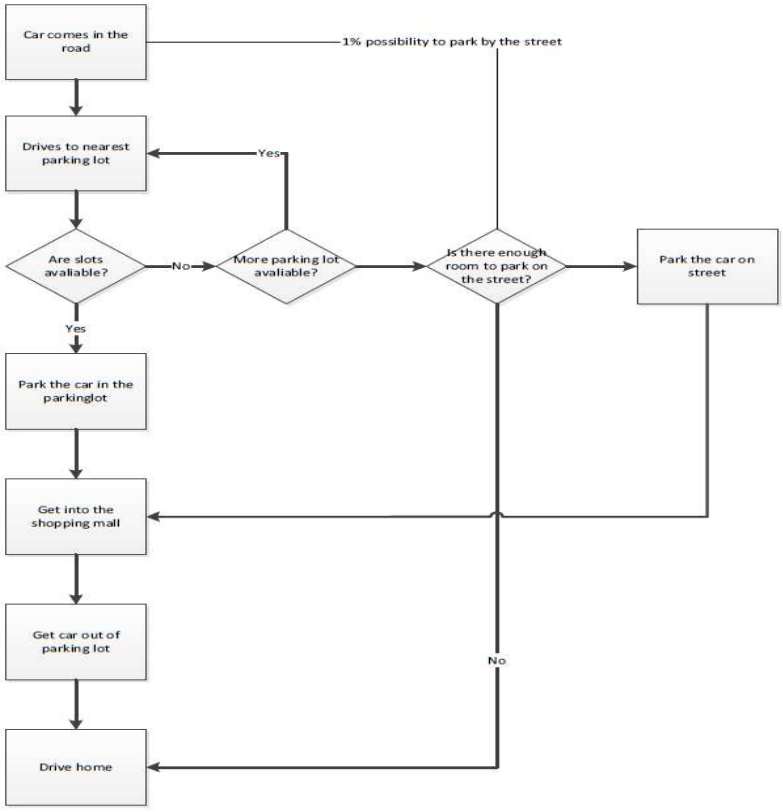

Figure2 - Flowchart of parking behavior

The following assumptions are made for this model:

(1)The model represents a parking process from 8 a.m. to 9 p.m.

(2)It has been proved that the interval time between two cars driving into the shopping mall is negative exponential distributed. [Headway Distribution Models and Their Application on Two-lane Highway in Mountainous Areas]

(3)The parking time of a car in the parking slots follows negative exponential distribution with a mean time of 90 minutes.

(4)After driving into the shopping mall, the driver will firstly go to the nearest parking slot, if there is no parking space left in any parking slot, he has a probability of 70% to park it by the street and 30% to leave the shopping mall.

(5)When a car drives in, there's 1% possibility of the driver to directly park the car on street illegally.

(6)On average 150 cars get into the shopping mall from entrance A an hour, while 100 cars are from entrance B an hour.

Simulation

The three graphs below shows the simulation result of the original situation and our two schemes.

Table 1

	Original	Solution 1	Solution 2
Average available parking slots	1.8	67.6	90.7
Average street car number	47.8	2.1	4.0
Customers lost due to lake of parking slots	1704	0	0

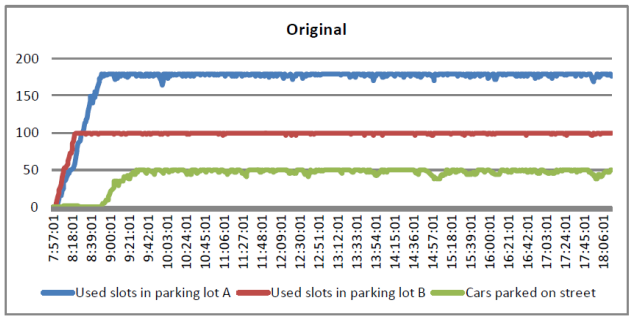

Figure 3

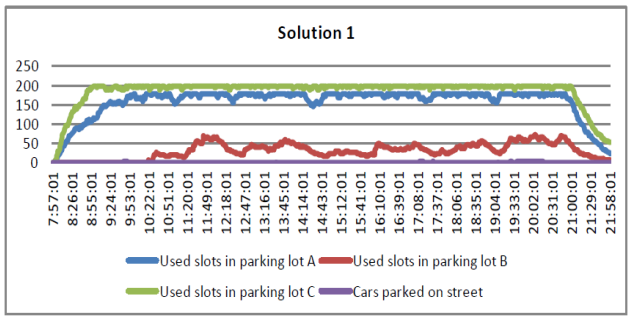

Figure 4

In the simulation of current parking lot situation, the shopping mall faces great customer lost – 1700 customers a day -- since many of them cannot find a place to park their car. The average number of available parking slots is 0, moreover, many cars have to be parked along the streets, which may block the traffic around.

Figure 3 shows each parking lot usage in the 10 hours of a day, each lot remains a high usage throughout the whole day.

From the simulation result we can easily found that we need to increase the parking slots to satisfy the needs, and in the result of the two approaches, we can see the difference.

Figure 4 shows the result of our first solution to improve the parking situation. After another parking lot has been added at point (7, 3), which is near the road B. However, as set in model, about 1% driver will still choose to park on the street. The newly added parking lot reduces the pressure of parking lot A and B, since it's near the road entrance A, which has 1.5 times more traffic than B on average, more cars will park in the new parking lot, this makes the parking lot C remains high usage.

During the simulation, the system has 73 parking slots available on average, this satisfied the parking needs, so no customer lost in this solution.

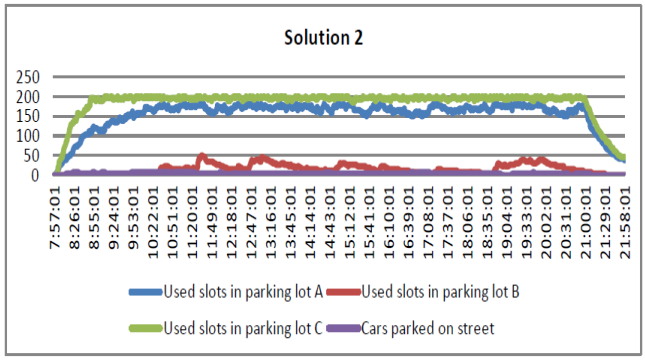

Figure 5

	Solution 1 1st run	Solution 1 2nd run	Solution 2 1st run	Solution 2 2nd run
Average available parking slots	72.8	67.6	90.7	88.6
Average street car number	1.0	2.1	4.0	3.7
Customers lost due to lake of parking slots	0	0	0	0

Table 2

In the second solution, the new parking lot C (6, 7) is closer to the road entrance A. From figure 5, we can see the fluctuate rate of parking lot B is smaller than the first solution, but the difference is small. To validate whether the second solution is better than A, we repeated the two simulation several times, and figure 6 and 7 shows the second run result.

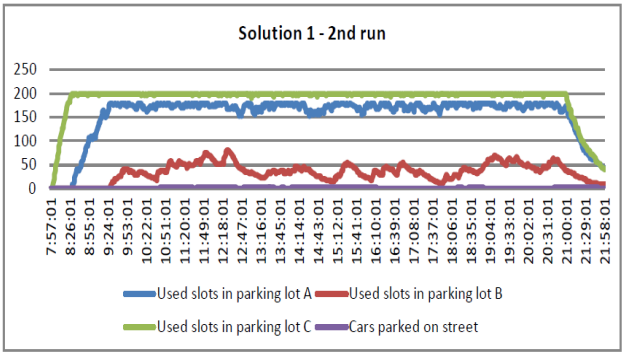

Figure 6

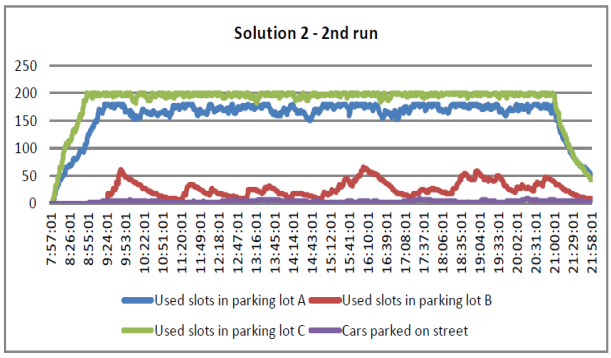

Figure 7

Although the two solutions have similar result, the second one has slightly more average available parking slots according to table 1. The reason the two solution has similar parking behavior is no matter which road the car is in when entering the shopping mall, the nearest parking lot is always C, then A, B. We cannot find a place to balance the three parking lots, since to achieve this, we need to make the sorted order of the distance to A, B and C different when entering from different roads, but the place not exists due to the design of the shopping mall.

Conclusion And Recommendations

The simulation shows that the current parking situation cannot meet the parking needs, also may introduce customer lost. Building another parking lot may improve the situation, but no solution we provided is the best.

Due to the design of the shopping mall, the better solution is not practical. So based on the previous simulation, our recommendation is the second one, because it provides more available slots than A.

Acknowledgements

The subject is sponsored by the National Natural Science Foundation of P.R China (No.60973139, 60903181, 61003039, 61003236), Scientific and Technological Support Project (Industry) of Jiangsu Province (No.BE2010197, BE2010198), Special Fund for the Development of Modern Service Industry of Jiangsu Province, the Natural Science Foundation for Higher Education Institutions of Jiangsu Province (10KJB520013,10KJB520014), Academical Scientific Research Industrialization Promoting Project (JH10-14), Fund of Jiangsu Provincial Key Laboratory for Computer Information Processing Technology (KJS1022), Postdoctoral Foundation (20090451241), Science and Technology Innovation Fund for Higher Education Institutions of Jiangsu Province (CX09B-153Z, CX10B-197Z, CX10B-200Z), Ph. D Fund of Ministry of Education (20103223120007), the Six Kinds of Top Talent of Jiangsu Province (2008118), talents project of Nanjing University of Posts and Telecommunications(NY210077), and the Open Research Fund from the Key Laboratory for Computer Network and Information Integration (Southeast University), Ministry of Education, China(K93-9-2010-13).

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