(27) VISUALIZATION ON TRAFFIC INFLUENCE OF PARKING FLOW LINE WITH & WITHOUT UNDERGROUND INNER-ACCESS

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It is obvious that parking a car is very difficult in cities, especially in urban downtown. Car parking flow line will influence the traffic on municipal roads in addition to it always being very crowded near the entrance of underground garages. In this paper, the authors propose a virtual reality (VR) simulation method to test car parking in underground space for a project in China. Addtionally, we compare two cases, i.e., one with and one without underground inner-access among different parcels for parking. The results show that the traffic situation of the case with underground inner-access is much better than the case without underground inner-access. Meanwhile, we find that the VR simulation method seems to be more intuitional and immersive than traditional methods.

Key Words: *virtual reality (VR), car parking, underground inner-access*

1. INTRODUCTION

It is obvious that parking is very difficult in cities, especially in downtown in megacities. It is known that substantial underground parking lots built in urban key areas have brought many problems, such as congestion near the entrance of underground parking lots, which in turn has a strong impact on the traffic flow of adjacent municipal roads, etc. As a result, it is essential to plan the layout of parking lots in detail, especially the location of the exit & entrance and the parking flow line. Sometimes underground inner-access for parking among different parcels is planned in underground complex. When and how should the planners design this inner-access? How much benefit can the inner-access bring to traffic situations? This paper will present an analysis method on car parking flow line with underground inner-access based on visual reality (VR) technology.

2. LITERATURE REVIEW

For parking process, based on General Purpose Simulation System (GPSS), Hamajima et al. [1)] presented a general model which can be created in a short time, and in which parking parameters, like entering time, parking time, flowrate on the roads, etc. could be adjusted freely. Zhang [2)] studied traffic organization of large underground garages and proposed the importance of inner-access between different parcels. Tan et al. [3)] calculated queue length and time of one super large underground garages based on the Queuing Theory. However, the model created by Hamajima seems to be relatively simple and may not be applicable for massive underground garages. Moreover, Zhang didn't calculate how much benefit the inner-access can bring for traffic situations and the research done by Tan may not make sense to laypeople. If the importance of the inner-access can be quantified and the queuing length is simulated through some methods, it may be extraordinarily helpful to the government and land owners.

3. OBJECTIVE

Traditional analysis methods just present fundamental data on traffic influence, while VR methods can bring intuitional and immersive scenes and be able to convince the government as well as land owners. In most situations, different land parcels belong to different land owners, who never realize the importance of inner-access among different parking lots. Therefore, they are not willing to invest a lot of

money in the construction of the inner-access parking lots. This paper will show how important the inner-access among land parcels is for parking. The cases with and without inner-access are quite different in terms of traffic situations. This is because the inner-access plays an important role for traffic when the surrounding municipal road space is not sufficient. In other words, vehicles can transfer from one parcel to another through the inner-access during rush hour, thus making the vehicle flowrate above ground less dense. The results of this paper may give an assertive evidence that the inner-access should be planned and constructed under certain conditions in order to increase land owners' motivation for constructing them.

4. METHOD

This paper takes a key area in downtown of Tongren City, China as an example. The area is about 9.4 hectares which is divide into parcels A & B & C as shown in **Fig. 1**. The east is Jinjiang Avenue, the south is The First Commercial Street, the west is Dongtai Avenue, and the north is Gongqing Road. This research is based on related detailed planning[4),5)] of the area. Some problems or technical difficulties concerning underground parking are proposed as follows:

(a) The underground vertical layout is complex. Terrain elevation of this area changes dramatically. As a result, the vertical layout is planned as mutiple stories based on terraced landform.

(b) Traffic organization is complex. Research areas are divided into 3 parts (A & B & C parcels). The berths number of each parcel is 801, 1370 and 2230 respectively. Based on Design Code for Garage JGJ100-98 [6)] of China, all the parcels are super massive garages. The adjacent road space can not meet the needs of parking flow line.

As a result, the original planning confirmed the traffic organization shown in **Fig. 2**. As a whole, the traffic flow line for parcel A and B is clockwise, while for parcel C it is counterclockwise. The information for exit & entrance is shown in **Table 1**. After analyzing the existing conditions of the research area, we define traffic flowrate along each parking line. UC-win/Road software is used for VR simulation and two cases are compared; one (Case 1) is without inner-access and the other (Case 2) is with inner-access. One can see that the key difference of the two cases is that for Case 2 parking berth number can be adjusted freely between two adjacent parcels if one is not sufficient, but it cannot be realized for Case 1. We have to express the difference with the adjustment of traffic flowrate and parking line.

As shown in **Fig. 2**, there are 5 directions from outside for vehicle flow line i.e. direction 1-5. Based on the detailed planning, parcel C is the most crowded area during weekday mornings, when the vehicle flowrate (entrance) is 270 & 10 & 1800 per hour and the vehicle flowrate (exit) for is 0 & 240 & 240 per hour for parcel A & B & C respectively. We define the hypothesis of equal division from the 5 directions. The comparison process for flowrate is presented in **Tables 2 - 5**. Case 1 is that all the vehicles go long the municipal roads and find the entrance of their destinations; Case 2 is that all the vehicles find the most close entrance which can connect their destinations through underground inner-access, based on spatial choice of car drivers' parking search behavior [7)]. The principle of flowrate adjustment can be called a method of the most shortest distance on the roads as shown in **Table 6**. Then we create the roads and models in UC-win/Road and import all the flowrate values. Here, we assume no thru-traffic is on Gongqing Road, which is the main road connecting underground garages based on the flow line. Simulation image is show in **Fig. 3**.

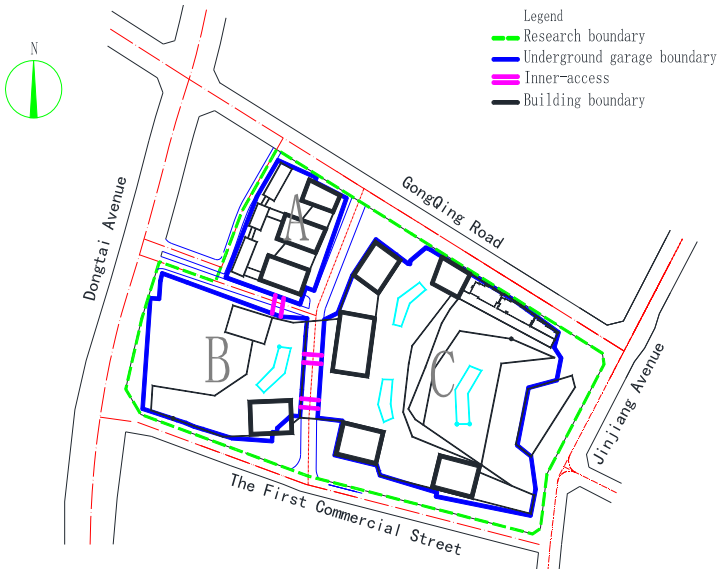

Fig.1 Research area

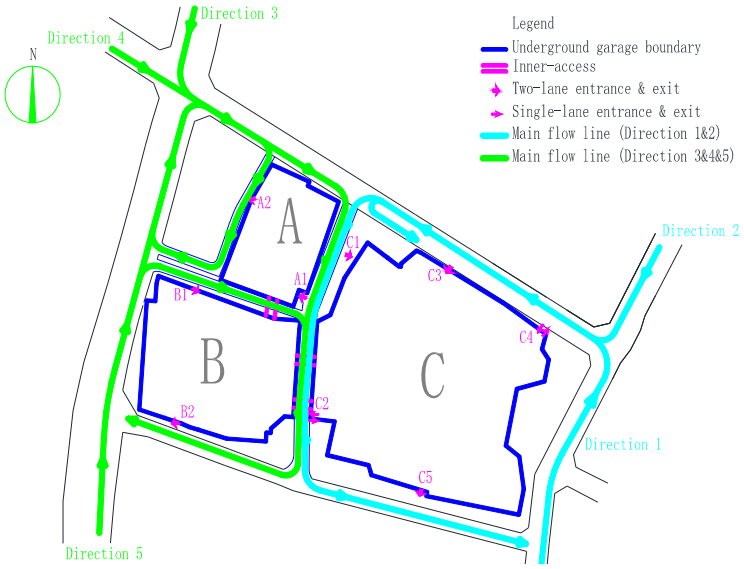

Fig.2 Traffic organization

Table 1 Exit & entrance information

		Entrance lane number	Exit lane number
A	A1	2	0
	A2	0	2
B	B1	2	0
	B2	0	2
C	C1	2	0
	C2	1	1
	C3	2	0
	C4	1	1
	C5	0	2

Table 2 Flowrate (entrance) definition for Case 1

		Direction					
	Destination	1	2	3	4	5	Sum
Case 1	A1	54	54	54	54	54	270
	B1	2	2	2	2	2	10
	C1	120	120	120	120	120	600
	C2	60	60	60	60	60	300
	C3	120	120	120	120	120	600
	C4	60	60	60	60	60	300
Sum		416	416	416	416	416	2080

Table 3 Flowrate (entrance) adjustment for Case 2

		Direction					
	Destination	1	2	3	4	5	Sum
Case 2	A1	*56*	*56*	*102*	*102*	*54*	*370*
	B1	*0*	*0*	2	2	*362*	*366*
	C1	120	120	*104*	*104*	*0*	*448*
	C2	60	60	*52*	*52*	*0*	*224*
	C3	120	120	*104*	*104*	*0*	*448*
	C4	60	60	*52*	*52*	*0*	*224*
Sum		416	416	416	416	416	2080

Table 4 Flowrate (exit) definition for Case 1

		Direction					
	Start	1	2	3	4	5	Sum
Case 1	A2	0	0	0	0	0	0
	B2	48	48	48	48	48	240
	C2	12	12	12	12	12	60
	C4	12	12	12	12	12	60
	C5	24	24	24	24	24	120
Sum		96	96	96	96	96	480

Table 5 Flowrate (exit) adjustment for Case 2

		Direction					
	Start	1	2	3	4	5	Sum
Case 2	A2	0	0	96	96	0	192
	B2	0	0	0	0	96	96
	C2	0	0	0	0	0	0
	C4	0	96	0	0	0	96
	C5	96	0	0	0	0	96
Sum		96	96	96	96	96	480

Table 6 Flowrate adjustment principle

Entrance		Exit	
Case 1	Case 2	Case 1	Case 2
1, 2→A1, C	1, 2→A1, C	A2, B2, C→1	C5→1
1, 2→B1	1, 2→A1	A2, B2, C→2	C4→2
3, 4→A1, B1	3, 4→A1, B1	A2, B2, C→3	A2→3
3, 4→C	3, 4→A1, C	A2, B2, C→4	A2→4
5→A1, B1	5→A1, B1	A2, B2, C→5	B2→5
5→C	5→B1		

5. RESULT AND DISCUSSION

We find that the crowded length on each road in Case 1 is longer than that in Case 2. We surveyed the west side of Gongqing Road for comparison as it is the most crowded area in Case 1. The crowded

length comparison is presented in **Fig. 4**. In Case 1, the road is basically saturated, whereas in Case 2, it is quite smooth. If we overlay thru-traffic that goes through research parcels, it will be hard to distinguish any significant differences, due to the narrow scope of case 2 which has been taken. We can deduce that the main reason for the difference is that all of vehicles from Dongtai Avenue (Direction 5) go through entrance B1 and arrive at their destinations. For instance, a salary man's office is in parcel C, and he goes to work from direction 5. Taking crowded situations of Case 1 into consideration, he would prefer to go through entrance 1 and the underground inner-access that connects parcel A and parcel C in order to arrive at his office timeously. Nevertheless, it is impossible for all the drivers from direction 5 to choose the inner-access as a means to reach their destinations, so Case 2 is the most viable option. As a result, in actuality it is somewhere between Case 1 and Case 2. And how much closer to Case 2 it is, will be dependent on the drivers' experience whether or not they decide to make use of the underground inner-access as a means of getting to their destinations. Moreover, parking path choice is a random behavior essentially [8], so the flowrate adjustment principle also adopts the equal division method to simplify original complicated problems.

Fig.3 Simulation image

6. CONCLUSION

We have come to the conclusion that traffic situation of Case 2 is much better than that of Case 1. Reason being is that underground inner-access plays an important role when dealing with parking. As for the pilot area, the congestion length on the roads in Case 2 is much shorter than that in Case 1. Nevertheless, the shorter length of different areas with different traffic conditions may vary. Meanwhile, based on VR simulation the whole parking process and the theoretical scale of vehicles that choose to make use of the inner-access to arrive at their destinations are understandable. However, there still are some assumptions that should be validated further, and the authors will carry out related research in future work.

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Case 1

Case 2

Fig.4 Comparison for 2 cases

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