Research on Emergency Evacuation Time under Different Road Network Form

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Abstract. This paper studies the emergency evacuation time of vehicles in three different forms of road traffic networks, and finds out which traffic network is more suitable for emergency evacuation of road traffic network. Based on the method of emergency evacuation path optimization of road congestion degree, this paper simulates the emergency evacuation time of a certain number of vehicles in three different road network forms by MATLAB simulation. The results show that the total evacuation time of the 2000 vehicles in the ring radial road traffic network is the shortest, followed by a square grid road traffic network and freestyle road traffic network. Compared with the square grid road traffic network and the freestyle road traffic network, the total evacuation time of the ring radial road traffic network respectively is reduced by 7.7% and 45.7%. It can provide some reference for the future planning and construction of the road network around the large public parking lot. The innovation of this paper examines the emergency evacuation time of three different road traffic networks.

1. Introduction

At present, many cities have built large-scale sports venues in China. Once the tournament is held, these public places will be usually larger vehicle aggregation. If there are some unexpected events, the number of vehicles in the road traffic network around the public places will increase dramatically, and the structural reliability of the road network will be reduced, so that the road network vehicle capacity can not meet the needs of the vehicle for emergency evacuation, which will give people a great threat to the safety of life. So the study of vehicle emergency evacuation time is of great significance under different road network forms for the disaster around the road network planning and construction.

At present, scholars have done a lot of researches on emergency evacuation at home and abroad: Li Qingquan et al. proposed an emergency evacuation path optimization method based on road congestion, which alleviates the congestion of the vehicle during emergency evacuation and reduces the total time of vehicle emergency evacuation[1]; Wang Dan et al. built the optimal path model of the vehicle emergency evacuation, the genetic and ant colony hybrid algorithm was used to solve the model[2]; Ma Yi et al. studied the shortest evacuation time flow in the evacuation case and studied the conservative evacuation time flow in the worst case of evacuation[3]. On the basis of the minimum cost model of intersection delay and traffic capacity, Gao Mingxia et al. constructed the emergency evacuation route of the vehicle, and adopted the minimum cost road algorithm to solve[4]; On the basis of the road congestion, Ning Xuanxi studied the impact of traffic flow on the emergency evacuation time[5]; Hamza reasonably arranged the vehicle to quickly evacuate to a safe place, in the case of the maximum traffic allowed by the road network[6]; Hamacher studied the problem of emergency evacuation of maximum flow, fastest flow and so on[7]; Based on the guidance technology of geographic information system, Brachman studied the evacuation of the road network, then constructed the corresponding fastest emergency evacuation model[8].

This paper takes three different forms of urban road network as the research object. Under the same number of evacuation vehicles, the same total length of the road network and the same number of emergency evacuation safety points, this paper studied the emergency evacuation time of vehicles in three different forms of road traffic networks, based on optimization of vehicle emergency evacuation...
2. Urban road network form expression

2.1 The Square Grid Road Network

Xi’an city road traffic network is the square grid network that is Jiugong pattern. Xi’an city road traffic network is abstracted as Fig. 1 in this paper. The lines of the square grid are linear, the total length of Xi’an city road traffic network is 12a. It sets points C, E, F, H for the four safety exit, point O is the emergency evacuation center.

E.g: \( OA = OB = OD = OG = AE = AF = a \), \( DE = DC = BC = BH = GH = GF = a \).

![Figure 1. The square grid road map.](image1)

2.2 The Ring Radial Road Network

Chengdu urban road network is the ring radial road network, the ring radial road network is shown in Fig. 2. The ring radial road network is a radioactive road that is connected with the circular road, the total length of Chengdu urban road network is 12a. The points A, C, E, F are the four safety exit, this paper sets point O for the emergency evacuation center, e.g.:

\( OA = OB = OC = OD = OE = OF = r \), \( DE = DC = BC = BA = \frac{1}{4} \pi r \), \( EF = FA = \frac{1}{2} \pi r \).

The total length of road network meets the relationship:

\[ 6r + 2\pi r = 12a \]

\[ (1) \]

![Figure 2. The abstraction diagram of circular radial road network.](image2)
2.3 The Freestyle Road Network

Chongqing urban road network is the freestyle road network, this paper abstracts the freestyle road network as Fig. 3. The shape of the freestyle road network road is irregular; the total length of the freestyle road network road is $12a$. The same as above, it sets four points for the four safety exit; there is an emergency evacuation center in this paper, e.g.:

$\overline{OA} = \overline{OB} = a$, $\overline{OC} = 1.5a$, $\overline{BD} = 2a$, $\overline{BC} = 3a$, $\overline{CE} = a$, $\overline{CF} = 2.5a$.

![Figure 3. The abstraction diagram of freestyle road network.](image)

3. The Test

3.1 The Vehicle Emergency Evacuation Plan

The vehicle shortest path travel program is that the vehicle chooses the shortest path to travel. In the emergency evacuation, the transport path of each vehicle tends to choose the shortest path in order to transport the vehicle from a disaster point to a safe place as soon as possible. Based on this principle, the vehicle emergency evacuation path allocation will use the former k shortest path algorithm[9]. But in the actual transport process, a large number of vehicles will converge to a shorter path if the vehicle takes the shortest path travel program; the path will be easy to produce congestion, which will result in reducing vehicle transport efficiency. Therefore, in order to improve the evacuation efficiency of road network, this paper chooses the shortest path algorithm[1]. The emergency evacuation time of the vehicle in three different road traffic networks is optimal, which makes the test results persuasive.

3.2 The Test Data

In this paper, three different forms of road transport network are regarded as research areas, and assume that center O has a large stadium in three different forms of road transport network. Due to a fire or a situation in a large event, it requires evacuation of the vehicle. The total length of the road network in this paper is $12a$, where $a = 800m$. According to the connection with roads, this paper establishes the topology network, as shown in Fig. 1, 2 and 3. The vehicle road capacity in this paper refers to "road traffic capacity theory"[10]. The vehicle data is the maximum capacity in Wuhan zhuankou Gymnasium. The test data in this paper are shown in Table 1.

<table>
<thead>
<tr>
<th>Number of evacuated vehicles / vehicles</th>
<th>Driving speed / (m/s)</th>
<th>Total length of road network (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>12.5</td>
<td>9600</td>
</tr>
</tbody>
</table>

3.3 Analysis of Test Results

In this paper, the evacuation time of 2000 vehicles in three different networks is simulated by MATLAB simulation. The results are shown in Table 2 and Fig. 4.
Table 2. The total time of emergency evacuation of the different road networks.

<table>
<thead>
<tr>
<th>The Road Network Form</th>
<th>Emergency Evacuation Time / s</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Square Grid Road Network</td>
<td>845</td>
</tr>
<tr>
<td>The Ring Radial Road Network</td>
<td>780</td>
</tr>
<tr>
<td>The Freestyle Road Network</td>
<td>1437</td>
</tr>
</tbody>
</table>

Figure 4. The vehicle’s emergency evacuated time.

The important indicator of road network emergency evacuation efficiency is the vehicle emergency evacuation time. From Table 2, Fig. 4, the information can be seen.

In the square grid road network, the ring radial road network, the freestyle road network, the vehicle emergency evacuation time is not the same. The vehicle emergency evacuation time in the freestyle road network is the longest; the expected evacuation time curve is more stable, because the free road traffic network in the road network structure is simple. The emergency evacuation process of the vehicle just can select the less path, the path of the vehicle in the road network is easy to gather congestion, which results in vehicle emergency evacuation efficiency being low. The total time of vehicle emergency evacuation in the square network road network and the ring radial road traffic network is significantly lower than that in the free road traffic network, because the structure of the square grid road traffic network, the ring radial road network is more complex than its the freestyle road traffic network; In the vehicle emergency evacuation process, the road diversion can reduce the congestion, and improve the road network vehicle emergency evacuation efficiency. Compared with the square grid road traffic network, the total time of vehicle emergency evacuation in the ring radial road network is reduced by 7.7%. It can be seen that the emergency evacuated efficiency of the vehicle in the ring radial road network is the highest.

4. Conclusion

This paper studies the emergency evacuation time of the vehicles in three kinds of road traffic networks, such as the ring radial road network, the square grid road traffic network and the freestyle road traffic network. It is shown by comparative analysis: In a single form of road traffic network, the ring radial road network has the shortest emergency evacuation time. It is important that the large-scale stadium parking lot around the road planning and construction has a certain guiding role in the future.
5. References


