Research on optimization of traffic management and control measures for expressway emergency based on VISSIM simulation

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Abstract. With the continuous enhancement of China's economic strength, the scale and quantity of expressway construction are constantly improving, and the expressway network has basically covered the whole country. With the rapid increase of the number of vehicles, the traffic pressure is also increasing, which poses a more serious challenge to keep the expressway unblocked. First, the increasing traffic pressure is very likely to lead to the occurrence of various emergencies. Second, the completely closed expressway and non-central city promote the emergence of an independent environment, which makes the expressway once an emergency, will have a very negative impact on the effective use of the expressway. Third, every single accident on the expressway will lead to serious traffic jam. At the same time, if the emergency rescue on the expressway is not properly implemented, it will not only bring all kinds of negative obstacles to people's lives, but also seriously affect people's property safety and social order stability. Therefore, the construction and improvement of the expressway emergency and related emergency rescue system has gradually become the focus of people's attention. Traffic management and control under incident conditions is an important link in the emergency rescue system, so this paper conducts research on traffic management and control measures under emergency conditions. Expressway design phase, normally takes into account the traffic management and control measures, such as the location of the median opening, the location of the emergency rescue centre, and the traffic organization mode. However, in-depth research should be carried out to ensure its rationality. This paper takes as an example of an expressway in our country, based on VISSIM simulation technology, quantitative analysis was carried out on the design phase of the traffic management and control measures, provide the basis for the optimization of traffic management and control measures. The evaluation method proposed in this paper is universal, and other expressways can also use this method to evaluate the effectiveness of traffic management and control measures in the design stage.
1. Introduction
There are all kinds of traffic accidents on expressways. Traffic accidents may occupy some lanes of expressways and reduce the capacity and service level of roads. Merely increasing the road supply or suppressing the traffic demand cannot solve the problem well. Rational use of emergency traffic organization measures is one of the effective methods to solve the traffic jam.

VISSIM is a micro driving behavior simulation modeling tool, which is used to model and analyze the traffic operation under various traffic conditions. It is an effective tool for evaluating traffic engineering design and road planning. At present, VISSIM is mainly a microscopic traffic simulation system in time and behavior. The parameter setting of relevant roads in this system is a favorable tool for expressway simulation and emergency traffic diversion program simulation.

Lee d. Han (2005) established the road network simulation model with VISSIM, and effectively carried out emergency traffic evacuation through the analysis of simulation results. Zhang H et al. (2008) analyzed and simulated the traffic condition under the abnormal events of expressway. The traffic state after the accident was analyzed, the simulation analysis of lane closure was carried out, and the corresponding measures were taken according to the difference of upstream traffic volume and the duration of traffic event. Li Y (2008) established the evaluation index system and standard of traffic service level of expressway construction section, adopted the multi index comprehensive evaluation method to evaluate the traffic service level of construction section, applied the VISSIM software to simulate the traffic operation state of typical two-way four lane construction section, and evaluated the simulation results. In order to study the impact of expressway traffic accidents on traffic, Chen H et al.(2015) established traffic accident models on the basic sections and sections of the expressway through VISSIM simulation software, and analyzed the changing rules of vehicle delay and average queue length of the accident sections with time under different input traffic volumes and proportions of big cars. In that paper, the effective capacity of expressway in accident condition in China is studied. Taking Shihuang expressway as an example, Zhang S (2016) established the expressway network and traffic accident model through VISSIM software, and analyzed the variation rules of vehicle delay and average queue length along the accident section with different traffic volume, different proportion of large vehicles and different accident duration. Based on this, the emergency traffic organization measures such as ramp control, traffic diversion, speed limiting measures and utilization of opposite lanes are proposed, and VISSIM software is used to verify the effect of the four traffic organization methods. Based on the basic capacity, the actual capacity and the quantitative relationship between them, Liang X (2018) used VISSIM simulation model to determine the reduction coefficient of each influencing factor, so as to estimate the effective capacity of expressway under different traffic accident conditions.

Taking an expressway in China as an example, this paper uses VISSIM simulation to evaluate and optimize the emergency traffic management and control measures proposed in the design stage, so as to provide a strong guarantee for the safe operation of the expressway after it is completed and opened to traffic.

2. Basic information of expressway
This paper takes an expressway in China as an example to carry out the research. The expressway is 48km long, with four lanes in both directions. The width of roadbed is 22.5m, the width of single lane is 3.75m, and the width of right hard shoulder is 3m. The designed driving speed is 100km/h. Through 4 islands, 5 Bridges (Bridge 2 is steel beam suspension bridge). It is planned to set up the expressway emergency rescue centre at locations A, B and C, as shown in the figure 1.
3. Traffic management and control measures

According to the design file, when there is an emergency on the expressway, the following traffic management and control measures should be taken:

- 15min after the emergency, the rescue vehicle starts from the nearest rescue centre (two directions) to accident point. When passing through the nearest median opening upstream of the accident point, some rescue workers get off the rescue vehicle and open the median opening, and command the stranded vehicles upstream of median opening to evacuate from the expressway, and other rescue workers continue to go to the accident point to deal with the accident.

- 10min after the accident, the variable information board of each section along the expressway was opened to release the accident information and prompt the vehicles to evacuate the expressway from the nearest interchange exit, and vehicles were no longer allowed to enter at both ends of the expressway.

- For vehicles unable to evacuate through the interchange exit at the upstream of the accident, they can turn around from the nearest median opening at the upstream of the accident to the opposite lane under the command of the rescue workers, and then search for the nearest interchange exit to evacuate expressway.

- When the vehicles turn around form the median opening, if there are still vehicles in the opposite lane that have not been evacuated, the traffic shall be channelized, and the inner lane shall be reserved for the vehicles in the direction of the accident to turn around; if all the vehicles in the opposite lane have been evacuated when the median opening is opened, the opposite two lanes can be used to turn around.

Whether the above traffic management and control measures are reasonable or not, this paper uses VISSIM simulation to conduct quantitative analysis, providing quantitative data for the optimization of traffic management and control measures.

4. Simulation model establishment and simulation results analysis

4.1. Simulation model establishment

When building the simulation model, taking the design file as the base drawing and the existing technical parameters as the basis to build the same road as the design scheme, as shown in the figure 2. Combined with the characteristics of the Island Bridge combination of the expressway, the expressway rescue centre is set at A, B and C, which is far away from the three rescue centres as the emergency occurrence point. Therefore, the middle point of the two adjacent rescue centres, that is, the position...
shown in P1 and P2 in figure 1, is selected as the accident point, and the above traffic management and control measures are simulated and analyzed.

Figure 2. Simulation model in VISSIM

4.2. Simulation assumptions
According to the work experience, the traffic management and control measures proposed in the design stage are detailed, the simulation assumptions are as follows:

- In order to simulate the most unfavorable situation, it is assumed that the accident needs to close two lanes in the same direction, and the whole expressway needs to be closed in two directions after the accident occurs, that is, vehicles in A and C areas are forbidden to enter the expressway, and other vehicles along the expressway are also forbidden to enter, and they will be released after the accident is completely handled.
- Since the traffic volume in direction C to A is greater than that in direction A to C, it is assumed that the accident occurs in direction C to A.
- The speed of the rescue vehicle is 80km/h, and it reaches the accident point through the right hard shoulder.
- It takes 15min from the time of the accident occurs to the time the vehicle leaves the rescue point.
- The length of the median opening is 40m, and the speed of vehicles passing through the median opening is 20km/h. Only one lane is allowed to transition from the opening to the opposite lane.
- It will take 5min to open the median opening.

4.3. Simulation results analysis
Based on the above assumptions and traffic management and control measures, when the accident occurs at the middle point P1 of AB road section, the simulation screenshots are as follows.

Figure 3. Vehicle queuing in case of emergency
The accident occurred at 1800s after the simulation began, and the variable information board opened along the expressway at 2400s. No new vehicles entered at both ends of the expressway and along the expressway, and the upstream vehicles of the accident began to drive out along the interchange exit of the expressway. At 2700s, the rescue vehicle drove out from the rescue centres A and B. At 3253s, when passing through the nearest median opening upstream of the accident point, some rescue workers got off the rescue vehicle to open the median opening, and the rest rescue workers continued to rush to the accident point.

It will take 5min to open the median opening, then the median opening will be opened at 3553s, and the vehicle will start to evacuate, the vehicle evacuation will be completed at 4188s.

At 3333s, the rescue vehicle from direction B arrived at the scene of the accident, and at 3384s, the rescue vehicle from direction A arrived at the scene of the accident.

Vehicle dissipation time=vehicle evacuation time-full blocking time
=4188s-1800s=2388s=39.8min After the accident, the time for the rescue vehicle from B to the accident point
=3333s-1800s=1533s=25.6min After the accident, the time for the rescue vehicle from A to the accident point
=3384s-1800s=1584s=26.4min

The simulation method of P2 accident point is similar to that of P1 accident point, so it will not be discussed in this paper.

According to the design file, bridge 2 is a steel beam suspension bridge. Once the main cable of the suspension bridge is in fire, it can be burnt out within 30min, leading to the instability of the whole bridge. Therefore, the simulation analysis is specially carried out for the location of bridge 2 main cable, and the time when the rescue vehicle arrives at the accident site from the nearest rescue point B is about 2.51min (excluding the time of receiving the alarm and preparation). That is to say, it can reach the scene of the accident 17.51min after the accident, less than 30min, so the fire accident at the main cable can be controlled.

5. Discuss and Conclusion

According to a statistics result of French Civil Defense Department (2000), the survival rate of the seriously wounded with the same injury condition is 80% in 30min, 40% in 60min and less than 10%
in 90min. Therefore, in the process of traffic accident emergency rescue, we should shorten the rescue time for the injured to get timely and effective rescue, improve the survival rate of the injured, which is also the key to reduce the accident mortality.

When the rescue vehicle arrives at the accident scene, the injured can obtain the necessary emergency rescue. Therefore, the survival rate refers to the probability of the injured survival until the rescue arrives. Time division of rescue vehicles arriving at the scene of the accident is shown in figure 6.

Figure 6. Rescue process of traffic accident

According to the simulation results and the problems found in the simulation, and based on the principle of improving the rescue efficiency, the existing traffic management and control measures are refined and optimized:

- Accident and vehicle evacuation information was released through the variable information board in the first time after the accident. In view of the situation that the bridge is unable to open due to the fire, it is suggested that additional manpower should set up temporary traffic signs along the expressway to carry out traffic evacuation.

- After the occurrence of the accident, it is judged whether the expressway is closed in both directions according to the severity of the accident. When two lanes need to be closed due to the impact of the accident, the vehicles upstream of the accident point shall immediately find the nearest interchange exit to evacuate the expressway after being informed of the accident. Some vehicles have passed the interchange exit, and need to wait for the median opening to be opened, under the command of the rescue workers, they should turn around from the median opening to the opposite lane, then look for the nearest exit to evacuate from the expressway. If there are still some vehicles passing through the median opening upstream of the accident point, drivers should abandon the vehicle to escape from the accident point under the command of the rescue workers according to the severity of the accident or wait for resuming the traffic after the accident is handled.

- Vehicles that need to turn around at the median opening, especially large vehicles, should follow the direction of the rescue workers. Because it is more difficult for large vehicles to turn around than small vehicles, they should turn from the outer lane to the opposite inner lane. The median opening must be equipped with enough manpower to command the traffic, so as to prevent the occurrence of secondary accidents.

- In order to make it convenient for large vehicles to turn around and evacuate from the median opening, the length of the median opening should be lengthened if possible; in order to improve the opening speed of the median opening, the mobile guardrail with convenient opening and roller should be selected, and the plug-in guardrail should not be selected.

- In case of turning around and evacuating through the median opening, if there are still vehicles in the opposite lane in the direction of the accident or there are vehicles passing normally, the traffic shall be channelized, and the inner lane shall be reserved for turning around use of the vehicles in the
direction of the accident; if all the vehicles in the opposite lane have been evacuated when the median opening is opened, the two opposite lanes can be used to turn around.

- Under normal operation conditions, lane management should be strengthened to ensure that large vehicles pass by the outside.
- In order to facilitate traffic management and control under incident conditions, the variable information board recommends encryption if possible.
- The passing speed of vehicles at the opening of the median separation belt shall be strictly controlled, which shall not exceed 20km/h.
- In order to ensure the traffic safety of turning vehicles, it is suggested that single lane transition should be carried out for the median opening.

In this paper, the simulation is carried out under the ideal condition that the rescue vehicle is not interfered by other factors. In the actual rescue, it may be interfered by traffic jams and other situations, resulting in the delay of rescue time. This paper only proposes a quantitative method of traffic management and control measures under incident conditions. The simulation results can give the designers and managers a quantitative intuitive feeling. The designers can design the length of median opening according to the simulation results. The managers can improve the efficiency of each rescue link according to the quantitative time, so as to improve the survival rate of the injured, improve the evacuation ability, and reduce the death and traffic congestion caused by the accident. In addition, the implementation of traffic organization under the condition of incident is relatively complex, the time and cost of field exercise are high, and the flexibility is poor. VISSIM simulation can adjust traffic organization scheme flexibly with low cost and infinite times, which is an effective analysis tool. That is, when there are different traffic control schemes, VISSIM simulation can be used for quantitative comparison, and finally the optimal scheme can be selected.

Acknowledgement
This study is supported by:
The National Key Research and Development Program of China (2017YFB0403504).
The project: Research on key technologies of coupling simulation of multiple traffic modes in traffic station, No.2019-0118.
The Central Public-Interest Scientific Institution Basal Research Fund (2017-9087).
The Jiangsu Transportation Science and Technology Project (2018Y40).

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