Research on Abnormal Event Classification of Expressway Tunnel based on Security Control

Jiangbi Hu¹, Zechoao Zhang¹, Qingyun Cao¹, Shangwen Qu¹ and Ronghua Wang¹*

¹Faculty of architecture, civil and transportation engineering, Beijing University of Technology, Beijing, 100124, China

*Corresponding author’s e-mail: wangrh@bjut.edu.cn

Abstract: Based on the perspective of tunnel traffic safety operation and control and the human, vehicle, road, and environment system in tunnel operation process, adopting event tree analysis method according to the different influencing factors, generation mechanism and performance characteristics of tunnel abnormal events, this research propose abnormal event classification tree diagram. According to the current abnormal event management and control mechanism in China, the administration departments and disposal facilities associated with different types of abnormal events in expressway tunnel operation are sorted out, which can provide decision-making support for the rapid treatment of abnormal events and realize intelligent control of tunnel.

1. Introduction
Accurate judgment of tunnel abnormal event type is the core technology and basic work of tunnel abnormal event control and emergency response capacity construction [1-4]. The establishment and improvement of a systematic and comprehensive tunnel abnormal event classification system plays a crucial role in the selection of abnormal event treatment scheme, allocation of resources, determination of rescue opportunity and other aspects, and is also an important step towards intelligent "one-click response" of tunnel.

In terms of classification types, Wang S.F. et al. classified traffic events affecting the normal operation of expressway tunnels into seven categories, including severe weather, traffic accidents, fire accidents, dangerous accidents, planned events, emergency events and other events [5]. Shen Y.J. et al. classified 121 road tunnel traffic accidents in China into rear-end accidents, collision accidents, vehicle ramming into tunnel wall accidents, fire accidents, vehicle rollover accidents and other accidents [6]. As to classification methods, based on the definition of the event, Wang Y. et al. extracted the characteristic attributes of the event from the definition of the event and classified the event using the characteristic attributes of the event [7]. Based on the evolution of emergencies, Zhang Y.Q. constructed an emergency case database from two perspectives: event classification system structure and event evolution law [8].

At present, there are some problems in the classification of abnormal events in expressway tunnel, such as unclear event classification, fuzzy boundary, or cross classification. There is still a large space for optimization and research necessity in the systematization and comprehensiveness of the classification system of abnormal events in expressway tunnel. In this paper, the mechanism of abnormal events generated by tunnel operation is analyzed based on the level of traffic system, and the event tree analysis method commonly used in risk analysis is adopted to analyze the event factors, event types, event treatment departments and facilities involved in the identification, judgment, and treatment of
abnormal events in expressway tunnel. It is necessary to establish a systematic, clear, and practical classification system of abnormal events in tunnels, which is of great significance to the safety, efficient operation, and intelligent control of expressway tunnels.

2. Classification characteristics of tunnel abnormal event

2.1 Influencing factors and mechanism of abnormal tunnel events

The traffic operation system of expressway tunnel is composed of multiple factors such as human, vehicle, road, and environment. The incoordination and non-integration of any factor and link in the operation system will form potential safety hazards and even cause serious accidents. The correlation of each influencing factor is shown in Figure 1. When different factors or different individuals of the same factor do not coordinate or even conflict with each other in the operation process, abnormal events will occur in the expressway tunnel.

![Figure 1. Influencing factors of abnormal tunnel events](image)

The human factors in the tunnel can lead to casualties and traffic accidents if not managed well. Since the clearance in the tunnel is limited, once there are people in the tunnel, they will be very close to the driveway, which will easily lead to conflicts between people and passing vehicles, resulting in traffic accidents.

In abnormal events caused by vehicle factors, vehicle is an important component of tunnel traffic operation. Conflicts between single vehicles, vehicles and tunnels will be caused by uncoordinated operation between vehicles, large speed difference between vehicles, abnormal behavior of vehicles: changing the driving state of other vehicles, increased driving workload of drivers, vehicle faults and so on.

The abnormal events caused by tunnel factors are mainly structural damage, loss of function and obstacles of tunnel pavement, which directly lead to the vehicle running abnormally in tunnel.

Tunnel environmental factors have a certain influence on the occurrence of abnormal events, but environmental factors, personnel, vehicles, and tunnel factors will not produce abnormal events without incompatible operation or conflict. Therefore, environmental factors will not be considered separately in the classification process of tunnel abnormal events.

2.2 Analysis of tunnel abnormal event characteristics

In terms of the conflict between people and vehicles, it has been stipulated in The Road Traffic Safety Law of the People's Republic of China that the people who violate the tunnel are classified as abnormal personnel events [9], and the objects of control are the people who enter the expressway illegally. Abnormal event features are identified and judged by the characteristics of personnel.

In the conflict between vehicles and vehicles, abnormal event features are represented by vehicle features, and the object of abnormal events in operation control is the vehicle driven by the driver. During the process of driving in the tunnel, vehicles violate relevant regulations and increase the safety risk of other vehicles in the tunnel, including over speed driving, low speed driving, parking in lane, reversing driving, astern running, frequent lane changes, crossing the line driving abnormal traffic behavior events; If a vehicle has an accident in a tunnel, it may cause harm to people and property, etc. Once the event occurs, it is very easy to cause more serious secondary accidents if not timely treated, including multiple vehicles rear-end collision, scraping collision and single vehicle rollover, cartwheel, fire and other single-vehicle accidents, and events that affect the safe operation of other vehicles in the
tunnel.

There are two aspects of conflict between vehicles and tunnels. The objects of abnormal events are vehicles, including collisions between vehicles and tunnels when vehicles hit the tunnel wall or the access road. The object of abnormal events control is the tunnel pavement, including the events that affect the normal running of vehicles in the tunnel, such as the discharge of tunnel pavement.

Through the analysis of the characteristics of abnormal events in expressway tunnels, 16 types of abnormal events in tunnels are obtained, as shown in Table 1.

| Serial number | Event                | Serial number | Event                         |
|---------------|----------------------|---------------|-------------------------------|
| 1             | Speeding             | 9             | Roll                         |
| 2             | Low speed driving    | 10            | Fire                          |
| 3             | Parking in lane      | 11            | Rear-end collision            |
| 4             | Reverse driving      | 12            | Scraped                       |
| 5             | Astern running       | 13            | Bump wall                     |
| 6             | Frequent lane changes| 14            | Collision repair way          |
| 7             | Crossing the line    | 15            | Abandoned object              |
| 8             | Cartwheel            | 16            | Pedestrian                    |

3. Establishment of tunnel abnormal event classification system

3.1 Event tree analysis

Event Tree Analysis (ETA) starts from the initial state of the event and analyzes the results of various sequences that may be caused by the initial event in a certain order, thus qualitatively or quantitatively evaluating the characteristics of the system [10]. When abnormal events occur in expressway tunnels, abnormal events are treated according to the order of abnormal event characteristics and event handling mode. The evolution law of occurrence and development follows the basic principle of event tree analysis.

3.2 Tunnel abnormal event classification system

Tunnel abnormal events are judged by influencing factors and event characteristics. Therefore, according to the basic logic of event tree analysis, tunnel abnormal event tree is studied and compiled from two perspectives of influencing factors and event characteristics, and then tunnel abnormal events are classified. The influencing factors of the event include human factors, tunnel factors and vehicle factors. The characteristics of the event include abnormal traffic behavior, single vehicle accident, collision accident, tunnel road surface and personnel. Combined with the 16 types of abnormal events of expressway tunnel sorted out above, the classification tree of abnormal events of expressway tunnel is obtained as shown in Figure 2.
Figure 2. Classification tree of abnormal events in expressway tunnel

By using event tree analysis method, 16 types of abnormal tunnel events are divided into six categories from the influencing factors and event characteristics of abnormal tunnel events: abnormal vehicle traffic behavior events, single-vehicle accidents, vehicle-vehicle collision accidents, vehicle-tunnel collision accidents, tunnel pavement events and human events.

4. Management and control of tunnel abnormal events by category

Different types of abnormal events in expressway tunnels require different personnel, facilities and management units for event control and treatment. Abnormal events occurring in expressway tunnels are generally handled in coordination by tunnel management units and relevant departments according to the event type, severity, and department functions [11]. In terms of control and treatment of abnormal events in expressway tunnel and related facilities, the Specifications for Design of Highway Tunnels, Section 2, Traffic Engineering and Affiliated Facilities, stipulates the setting requirement [12] and functions of various facilities [13][14]. Combined with the influencing factors and event characteristics of abnormal events in the expressway tunnel, the classified management and control of abnormal events in the tunnel can be obtained as shown in Table 2.
Table 2. Classification control of abnormal events in expressway tunnel

| Event             | Type         | Feature                        | Unit                                      | Facility                                                                 |
|-------------------|--------------|--------------------------------|-------------------------------------------|--------------------------------------------------------------------------|
| Speeding          | Single vehicle | Abnormal traffic behavior      | Traffic police, road administrator        | Traffic monitoring facilities, emergency calling facilities               |
| Low speed driving | Single vehicle | Abnormal traffic behavior      | Traffic police, road administrator        | Traffic monitoring facilities, emergency calling facilities               |
| Parking in lane   |               |                                | Traffic monitoring facilities, emergency calling facilities |                                                                         |
| Reverse driving   |               |                                | Traffic monitoring facilities, emergency calling facilities |                                                                         |
| Astern running    |               |                                | Traffic monitoring facilities, emergency calling facilities |                                                                         |
| Frequent lane changes |       |                                | Traffic monitoring facilities, emergency calling facilities |                                                                         |
| Crossing the line |               |                                | Traffic monitoring facilities, emergency calling facilities |                                                                         |
| Cartwheel         |               | Single-vehicle accident        | Traffic police, fire, road administration, medical treatment | Traffic monitoring facilities, ventilation facilities, lighting facilities, fire protection facilities, emergency calling facilities |
| Roll              |               | Collision accident             | Traffic police, fire, road administration, medical treatment | Traffic monitoring facilities, ventilation facilities, lighting facilities, fire protection facilities, emergency calling facilities |
| Fire              |               | Collision accident             | Traffic police, fire, road administration, medical treatment | Traffic monitoring facilities, ventilation facilities, lighting facilities, fire protection facilities, emergency calling facilities |
| Rear-end collision| Vehicles and Vehicles | Collision accident | Traffic police, fire, road administration, medical treatment | Traffic monitoring facilities, ventilation facilities, lighting facilities, fire protection facilities, emergency calling facilities |
| Scraped           | Vehicles and Tunnels | Collision accident | Traffic police, fire, road administration, medical treatment | Traffic monitoring facilities, ventilation facilities, lighting facilities, fire protection facilities, emergency calling facilities |
| Bump wall         | Vehicles and Tunnels | Collision accident | Traffic police, fire, road administration, medical treatment | Traffic monitoring facilities, ventilation facilities, lighting facilities, fire protection facilities, emergency calling facilities |
| Collision repair way |       | Collision accident             | Traffic police, fire, road administration, medical treatment | Traffic monitoring facilities, ventilation facilities, lighting facilities, fire protection facilities, emergency calling facilities |
| Abandoned object  | Tunnel pavement | Tunnel accident               | Traffic police, road administrator        | Traffic monitoring facilities, emergency calling facilities               |
| Pedestrian        | Personnel     | Personnel                     | Traffic police, road administrator        | Traffic monitoring facilities, emergency calling facilities               |

5. Conclusion

Based on the tunnel operation system, the influencing factors and event characteristics of abnormal events in the expressway tunnel are analyzed. By using the event tree analysis method, the abnormal events in the tunnel are divided into six categories: vehicle traffic abnormal behavior event, single-vehicle accident, vehicle-vehicle collision accident, vehicle-tunnel collision accident, tunnel pavement event and personnel event. According to the logic of occurrence, characteristic judgment, and accurate identification of abnormal events in tunnel, the tree chart of abnormal events classification in expressway tunnel is drawn, and the classification of abnormal events in tunnel is realized systematically. Finally, according to the different types of abnormal tunnel events sorted out, the units and facilities involved in the treatment of abnormal events of different types of expressway tunnel are given, which provides theoretical and methodological basis for the realization of "one-click response" security control technology of abnormal tunnel events.

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