Factor Analysis of Traffic Safety in Urban Roads Based on FTA-LEC

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Abstract. In order to reduce the number and the loss of urban road traffic accidents in our country, improve the safety of road traffic, a statistical analysis of the research report on major road traffic accidents in 2016 was conducted. The risk factors affecting urban road traffic in China were analyzed by using FTA to find the basic hidden events. Secondly, the risk value of the identified hidden danger events were calculated and classified into four levels I, II, III and IV through the LEC evaluation method. Finally, the graded results of risk factors are verified through a case of specific accidents in Beijing. The results show that: the case verified the scientificalness and effectiveness of hazard classification and provided guidance for urban road traffic management.

1. Introduction
The number of fatalities in traffic accidents has remaining high and the mortality rate ranks fourth in China. In 2016, the number of traffic accidents in China reached nearly 300,000, and the toll was about 40,824 which increased 4,646 compared with 2015. According to the World Health Organization, the number of deaths from road accidents in low and middle-income countries accounted for 90% of the deaths caused by accidents in 2002. It is expected that, the average mortality rate in high-income countries will fall by about 27.30% by 2020, and that will rise to 80-83% on average in low and middle-income countries. In all fatalities in our country, traffic accidents account for the largest proportion, as shown in Figure 1.

Figure 1 Distribution of various types of accidents in 2016
Regarding the issue of road traffic, experts have made some achievements. Ren Ying and Peng Hongxing\cite{1} believed that road traffic accidents in China are mainly caused by human factors, especially the drivers of motor vehicles; Zhang Lixia\cite{2} showed that the three factors such as drunk driving, fatigue driving and over-speed driving have the greatest impact on road traffic accidents; Zheng Anwen\cite{3} believed that some road defects will affect the driver’s behavior. At the same time, foreign scholars Sabey and Taylor \cite{4} insisted that accidents caused by driver's personal factors accounted for 95\% of the total number of accidents; Guangnan Zhang\cite{5} showed the peccanay driving caused by driver will seriously affect road safety; Rachel Talbot and Azra Habibovic believed\cite{6} the traffic accidents occurred due to the slowing down or changing direction when the drivers were distractive or unruly. At present, many experts have studied the causes of traffic accidents. However, there is still a lack of systematic analysis and hierarchical management of the safety hazards that caused accidents. Therefore, the analysis and study of the causes of road safety hazards and the risk levels of hidden dangers have a significant effect on promoting social development.

2. The establishment of information flow model
Psychology believes that \cite{7}, “information collection → information input → information processing → information output → Occurrence” constitutes the human body's information processing system. The accident is caused by the out of control of security risks in one of the links. Based on the analysis of the process of information processing, the theory draws an information flow model for the process of traffic information \cite{8, 9}.

The actor will perceive and realize the traffic information while he discovers it. Then judging the information weather it is new. If yes, continue to make behavior judgments to generate actions and update the latest information to the personal information database; if the information has been contacted, we can make the appropriate behavior directly based on the information base. In addition, there are information exchange with personal information databases in the process of information perception: making judgments and generating actions.

3. Analysis of Road Safety Hidden Trouble

3.1 Security Hidden Trouble Analysis Methods
The identification of hidden dangers in road traffic safety is an urgent task for current traffic management which will seriously affect the effectiveness of security management. The literature review \cite{10} and the questionnaire \cite{11} shows that the identification methods of safety hazards in urban roads can be divided into two types: field survey analysis and theoretical analysis. The specific classification is shown in Table 1.

| Method                          | Details                                                                 |
|---------------------------------|-------------------------------------------------------------------------|
| Data access method              | Systematically analyze the security risks through consulting the literature at home and abroad |
| Laws and regulations comparison method | Contrast with national laws and regulations to find out the safety hazards of pedestrians crossing the street. |
| Fault Tree Analysis             | From the top event, we analyze the security risks at each level, step by step, and gradually go to the basic events. |
| Questionnaire                   | Questionnaires are used to conduct questionnaires for pedestrians at representative intersections to determine the actual safety hazards. |
| Field observation               | Experts in safety management observe and analyze the site based on their existing experience and knowledge to identify potential safety hazards. |

3.2 FTA-LEC analysis of safety hazards
3.2.1 FTA Model Construction
The FTA mainly describes the logical relationship between events and uses deductive analysis to explore possible causes of the top event until the most basic sub-event. Through the study of the investigation reports on major traffic accidents in 2016, summarized the basic hidden dangers of road traffic safety accidents (Table 4) based on the causes of the accidents, and triggered traffic accidents were regarded as the top events. The modeling of fault tree, based on unsafe acts in road traffic, unsafe status of motor vehicles and others, and management defects, is shown in Figure 2.

![Fault Tree Model](image)

Figure 2 Security risk accident fault tree

From the fault tree, it can be seen that all the diagrams are "or gates", that is to say, the occurrence of any one of the basic events in the diagram will cause an accident. Therefore, the failure rate of this system is quite large. According to Figure 3, the Boolean algebra expression of the fault tree can be expressed as:

\[ T = G_1 + G_2 + G_3 = \sum_{i=1}^{35} X_i \]

According to the expression, there are 35 minimum cut sets in the system, which means that each basic event is a minimum cut set, so the system is prone to accidents.

3.2.2 Classification of Safety Hazards
In order to manage the hidden dangers of pedestrian safety preferably, the author plans to classify and control the hidden dangers of safety according to the magnitude of the risk of potential safety hazards. At present, there are many methods for calculating the magnitude of security risks, such as pre-hazard analysis (PHA), risk and operability study (HAZOP), risk matrix method, LEC evaluation method and so on. Among them, the LEC evaluation method is more in line with the actual situation thanks to take the exposure frequency of pedestrians to dangerous environments into consideration. Therefore, using LEC evaluation method to analyze and calculate the magnitude of hidden safety hazards.

The method involves three kinds of indicator values: the probability of an accident (L), the exposure frequency of a person to a hazardous environment (E) and the possible consequences of an accident (C). Setting different scores for different levels of factors (as shown in Table 2), and then use the value of three scores (D) to indicate the risk of hidden dangers:

\[ D = L \times E \times C \]

| L Value | Possibility        | E Value | Frequency  | C Value | Consequence   |
|---------|--------------------|---------|------------|---------|---------------|
| 10      | Totally predictable| 10      | Continuous | 100     | More than 10  |

Table 2 Score setting table of L, E, C various factors
Combined with actual conditions, road traffic safety hazards can be classified into four levels of safety hazards (Table 3) by comprehensive analysis of road traffic safety hazards and their consequences. Basic data were obtained through questionnaires and interviews conducted by relevant experts. The questionnaires were distributed in an amount of 100 copies and 94 were recovered. The questionnaire recovery rate was 94%. Then use the LEC method to calculate the specific scores of various safety hazards in road traffic and carry out the risk rating (Table 4).

**Table 3 Security risk classification**

| Risk level | Risk name              | Degree of danger | Color | Risk value (X) |  |
|------------|------------------------|------------------|-------|----------------|---|
| I          | Significant risk       | Extremely dangerous | Red   | $X \geq 320$   |  |
| II         | Larger risk            | Highly dangerous  | Orange| $160 \leq X \lt 320$ |  |
| III        | General risk           | Significant danger | Yellow| $70 \leq X \lt 160$ |  |
| IV         | Low risk               | General danger    | Red green| $X \leq 70$    |  |

**Table 4 Road traffic safety risk values and risk levels**

| Number | Basic event name                          | Risk value | Risk level | Number | Basic event name                          | Risk value | Risk level |
|--------|------------------------------------------|------------|------------|--------|------------------------------------------|------------|------------|
| $X_1$  | Driving illegal vehicles                  | 135        | III        | $X_{19}$ | Road traffic signs are not clear           | 129        | III        |
| $X_2$  | Drunk driving                             | 900        | I          | $X_{20}$ | Roadside water well cover is not tight     | 9          | IV         |
| $X_3$  | Driving without a license                 | 21         | IV         | $X_{21}$ | No warning sign was placed in time when emergency stop | 410        | I          |
| $X_4$  | Fatigue driving                           | 720        | I          | $X_{22}$ | Motor vehicle brake failure                | 400        | I          |
| $X_5$  | Driving vehicles are inconsistent with quasi-drivers | 18        | IV         | $X_{23}$ | Tire burst                                | 143        | III        |
| $X_6$  | Driving safety hazard vehicle             | 270        | II         | $X_{24}$ | The battery car was installed without authorization | 264        | II         |
| $X_7$  | Illegal driving                           | 280        | II         | $X_{25}$ | Missing signal at the intersection         | 126        | III        |
| $X_8$  | Over speeding                             | 300        | II         | $X_{26}$ | Around the island and the crosswalk        | 36         | IV         |
| $X_9$  | Pedestrian safety awareness is weak       | 26         | IV         | $X_{27}$ | Vehicle illegally transported contraband   | 240        | II         |
| $X_{10}$| Pedestrians do not obey traffic rules     | 30         | IV         | $X_{28}$ | Shared bike parking chaos                  | 90         | III        |
| $X_{11}$| Pedestrians walking                       | 126        | III        | $X_{29}$ | The road was not                           | 420        | I          |
4. Example analysis

3.2.3 Analysis of results

From the above table, it can be seen there is a large gap of the risk values among each security risk. According to this, security risk factors can be classified four levels: X2, X4, X21, X22, X29, and X35 are I-level security risks; X6, X7, X8, X15, X24, X27 are II-level safety hazards; X1, X11, X12, X14, X19, X23, X25, X28, X31, X34 are III-level safety hazards; X4, X5, X6, X10, X13, X16, X20, X26, X30, X31, and X32 are IV-level security risks.

Basic hidden dangers: drunk driving (X2), fatigue driving (X4), warning sign not placed in time after emergency stop (X21), motor vehicle brake failure (X22), road not cleaned in time after rain or snow weather (X29), and battery car Retrograde (X35) are Class I safety hazard incident with a high risk value, indicating that they are the top priority in preventing traffic accidents. Secondly, driving safety hazard vehicles (X6), illegal driving (X7), speeding (X8), freewheeling of shared bicycles (X15), unauthorized installation of parasols (X24), and illegal transport of contraband (X27) are also important factors that causes traffic accidents. They are important for strengthening the control in these areas.

From the perspective of human unsafe behavior, drunk driving (X2), fatigue driving (X4), driving safety hazard vehicles (X6), illegal driving (X7) and over-speed driving (X8) are the most important safety hazards in traffic accidents. For these hidden dangers, safety education and training for drivers should be strengthened to increase road safety awareness.

Stand on the state of machinery and equipment, the hidden factors such as warning sign (X21), motor vehicle brake failure (X22), battery-powered parachute (X24), vehicle illegal transport (X27), road not cleaned in time after rain or snow weather (X29) are other important factors that causes traffic accidents. If warning signs are not placed in time after the emergency stop, especially on high-speed roads, the rear vehicle may not find the existence of the faulty vehicle in time and lead to tragic accidents. Many battery car drivers install umbrellas to shield the ultraviolet rays without authorization in summer which obstruct the view of the rear vehicles and put themselves and others in a dangerous environment, especially in overtaking. For such hidden incidents, the relevant departments need to strengthen the implementation of the relevant regulations, prompt drivers to improve the safety performance of driving vehicles to reduce the possibility of accidents.

From a management point of view, roadside stalls occupying the carriageway (X31), private cars occupying the bus stop (X34) and the battery car retrograde (X35) are also important factors that cause accidents, education and management in this area should be strengthened to create a safer traffic environment.
On February 18, 2016, a unit driver drove a Beijing jeep on his way home from work caused a traffic accident, which collided with an oncoming tricycle and caused a boy on the tricycle die on the spot, driver suffered broken legs, three-wheeled motorbike damage serious, and the jeep’s face damaged.

After investigating and analyzing, the direct causes of this accident were: three-wheeled motorbike drivers driving without a license (X₃), illegal driving (X₅), over-speed driving (X₈), and retrograde (X₃₅); indirect causes: the snow on the road surface did not melt, the road surface was slippery (X₂₉), and the traffic sign was not clear (X₁₉). The most common causes of accidents among these factors are illegal driving (X₅), speeding (X₈), slippery road (X₂₉) and retrograde (X₃₅).

According to the table 4, the risk classification of each security risk factor is that: X₂₉ (the road was not cleaned in time after rain and snow weather) and X₃₅ (vehicle retrograde) are classified as I-level hidden factors, X₅ (driving illegally) and X₈ (Speeding) is II-level security risk factor. In addition, X₁₉ (unclear driving sign) and X₃ (undocumented driving) are III-level and IV-level hidden factors, which are basically in line with actual case conditions.

5. Conclusion
(1) Using FTA fault tree analysis to find hidden dangers in urban road traffic safety, and dividing security risks into three aspects: human unsafe behavior in road traffic, motor vehicle insecurity, and management defects. Human factors are the major security risks affecting traffic accidents.
(2) According to the qualitative analysis, it can be seen from the minimum cutting set that every basic hidden event may lead to a traffic accident. Therefore, the incidence of urban road traffic accidents is at a high level.
(3) Using LEC evaluation method to calculate the risk value of each security risk, so as to determine the risk level of each hidden risk factor and find the key point of road traffic management.
(4) Using the specific case to verify the risk classification of the security risks classified by the LEC method in the paper. The results show that the risk classification is basically in line with the actual situation, which verifies the scientificness and effectiveness of the hidden risk classification, and provides guidance for the traffic control.

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