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A Review of Research on Highway Driving Safety in Adverse Weather Conditions

Zhiyuan Shen

School of Traffic & Transportation, Chongqing Jiaotong University, Chongqing 400074, China

Abstract

Traffic safety accidents have gradually become a problem in the world in recent years. Compared with traffic accidents that occur in normal situations, the frequency of accidents on expressways under adverse weather conditions is higher, the harm is greater, and the losses are more serious. . In order to reduce the occurrence of expressway traffic accidents under adverse weather conditions, this paper sorts out the research methods, safety evaluation and prevention technology of expressway driving safety problems under adverse weather conditions at home and abroad, and discusses the research insufficiency and development. trend. The comprehensive analysis shows that: in terms of research methods, the driving simulation system that simulates adverse weather conditions can more accurately and simply obtain the data required for the experiment; in terms of safety evaluation, it is mainly based on the perspective of driver behavior characteristics to conduct driving safety under adverse weather conditions. Analysis; Accident prevention should be combined with human-vehicle-road coordination technology to optimize the design of traffic safety assurance.

Keywords

Bad Weather; Highways; Safety Studies.

1. Introduction

My country has a large land area. In recent years, the mileage of expressways in my country has been increasing, but the development of safety construction of expressways has been relatively slow, which has also led to increasingly prominent traffic safety problems on expressways. Most highways are built in mountainous areas and deep valleys, so the terrain and road conditions are more complicated. Under adverse weather conditions, the driver's judgment, reaction and operation will be greatly affected. This results in more accidents on highways in adverse weather conditions.

Bad weather usually refers to bad weather, usually rain, snow, high temperature, fog, sand and dust, road icing, etc. In bad weather conditions, it takes a long time to deal with incidents and recover after a traffic accident. Casualties will be more severe. Bad weather is an objective factor, and its influence on the driving safety of drivers is mainly in terms of traffic conditions, vehicle conditions and driver status.

This paper studies the safety of expressway driving under adverse weather conditions, analyzes the main factors affecting driving safety under adverse weather conditions, compares the safety problems of expressway driving under adverse weather conditions by different research methods, and proposes expressway driving safety problems under adverse weather conditions. Preventive measures for driving safety, give full play to the role of existing traffic safety application technology, equipment and facilities, and ensure the traffic safety of highways in mountainous areas.

2. Analysis on the Characteristics of Highway Driving under Adverse Weather Conditions

2.1 Road Alignment Feature

The linear characteristics of the expressway are mainly based on the combination of local topographic conditions, the height of the terrain and the tortuous terrain, which lays the foundation for the horizontal and vertical alignment to a certain extent. Expressways generally have the following characteristics in advance design.

(1) Plane linear features

In the expressway, except for some specific bridges and tunnels, most of the other plane alignments are constructed according to the terrain and the principle of adapting to the terrain. This also leads to the characteristics of large plane corners and plane curves and small plane radii in some places. In some places, the corners even reach 70°~80°, and some plane curves can reach 1000~1500m[1]. Due to the irregular terrain conditions, the balance of the plane alignment of the expressway is also poor.

(2) Longitudinal linear features

Some highways in mountainous areas often have continuous long-slope sections, and these sections can even reach 10-15km. These sections are a serious challenge for both drivers and vehicles. Moreover, the longitudinal gradients of these road sections are relatively large, with an average gradient of more than 3%.

2.2 Speed Variation Characteristics

The frequency of change of vehicle speed on the highway is relatively high, and the variation range of vehicle speed is usually large. Due to the characteristics of high highway alignment, when the vehicle is driving on the road, it suddenly encounters a downhill and sharp turn, and there is usually a speed difference of more than 30km/h[2]. At the same time, the traffic composition has a great influence on the running speed. Taking into account the dynamic characteristics of the vehicle and the loading characteristics of large trucks. In addition, large trucks will greatly affect the speed of other vehicles.

2.3 Climate Characteristics

Bad weather often refers to rain, snow, high temperature, fog, dust, road icing, etc., also called bad weather. News media often report on accidents that caused mass deaths and injuries due to heavy fog, ice and snow, etc., which is shocking. According to statistics, 50% of traffic accidents on highways in my country occur in adverse weather conditions, and 71% of major traffic accidents and 65% of direct economic losses occur in adverse weather conditions. The impact of bad weather on traffic safety: First, it reduces the adhesion between the vehicle and the road. For example, in rainy and snowy weather, the thin ice formed by the cooling is less likely to be discovered by the driver, which also causes the driver to not pay enough attention, resulting in traffic accidents. Accidents; the second is to reduce the visibility, such as foggy weather, the visibility is greatly reduced, and the road ahead cannot be clearly seen; the third is to change the stress state of the car; the fourth is to adversely affect the driver's psychology.

2.4 Coupling Analysis of Multiple Unfavorable Factors

Mountain expressways are affected by various unfavorable factors such as small radius curve sections, long downhill slopes, tunnel groups, fog and ice. Small radius curve sections may be coupled with long downslopes, tunnel groups may be coupled with long downhill sections, and heavy fog and icy weather may occur at the same time.

Therefore, when the vehicle travels on these road sections, it may face the risk of brake failure caused by long downhill slopes, the repeated occurrence of "black hole effect" and "white hole effect" caused by tunnel groups, and the occurrence of small radius curve sections[3]. The risk of sideslip, the low visibility caused by heavy fog, and the low adhesion coefficient caused by icing, so the traffic accident

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caused by this road section is the result of the coupling effect of many factors. Driving risk, only preventing and controlling a certain factor cannot comprehensively solve its driving risk.

3. Research Methods

The research methods for highway driving safety problems in adverse weather are similar to the research methods under conventional roads. They are mainly based on data collection, and different evaluation and analysis methods are determined according to the collected data. There are usually three types: the first is to directly perform statistical analysis on historical data; the second is to conduct actual vehicle driving experiments; the third is to use driving simulation experiments.

3.1 Historical Data Statistics

The statistical method of historical data is the most basic method to study traffic safety problems. It selects the historical data that needs to be used from a large amount of historical data, combines relevant mathematical methods, and finally solves the corresponding method of the research problem. At present, this method is mainly applicable to the study of the law of occurrence of accidents and the factors affecting the occurrence of accidents.

For the law of accident occurrence, it mainly analyzes three aspects, namely, the prediction of accident hazards, the spatiotemporal distribution characteristics of accidents, and the analysis of accident morphology. The hidden danger prediction of accidents belongs to the pre-accident analysis, and the spatiotemporal distribution characteristics of the accident and the morphological analysis of the accident belong to the post-accident analysis, but these three are all to minimize the probability of traffic accidents. The analysis of the influencing factors of accidents is mainly based on the statistical analysis of historical data to build the model. In practice, roadside conditions, road alignment, vehicle speed, weather and other factors all have a certain impact on traffic safety issues. In addition, in recent years, in addition to the analysis of vehicle conditions and road conditions, in-depth analysis of driver behavior has also begun, such as whether the driver is distracted, fatigued, speeding, etc. The combination of these factors constitutes the occurrence of traffic accidents[4].

Because the occurrence of accidents is the result of the joint action of many complex factors, it is difficult to count the influence of various factors when the accident occurs only by using the historical data statistical method. In addition, due to the difficulty of collecting accident data and the incomplete influencing factors, it may lead to certain problems in data analysis, resulting in inaccurate results of analysis problems. It is necessary to further improve this method before the problem can be further improved. Accurate research analysis.

3.2 Actual Vehicle Driving Experiment

The actual vehicle driving experiment is mainly divided into two methods, one is the natural driving experiment method, and the other is the real vehicle experiment method. The natural driving experiment method refers to the use of specific data acquisition equipment to measure and record the actual driving conditions of the driver under ordinary circumstances; the real vehicle experiment method refers to the driver performing certain driving tasks in a real driving environment. Vehicles are equipped with eye trackers, cameras, radars, psychological recording equipment and other equipment to record the physiological and psychological characteristics of drivers during driving. The main difference between these two methods is that the first one is to record the driving data of the vehicle and the driver's behavior; the second method is to directly record the driver and record the relevant physiological and psychological characteristics. However, since both are driving on real roads, there are many uncontrollable environmental factors, and there are certain dangers, and the experimental data that can be collected is less, and the cost and risk are relatively high.

This experimental method is usually used to study some accident-prone sections under adverse climatic conditions. The purpose of the research is mainly in three aspects: one is to evaluate the safety of the road; the other is to influence the driving factors under adverse weather conditions; the third is to study the relationship between the driver and the driving safety[5]. These data are usually studies of the driver's physiological conditions, visual characteristics, and psychological conditions. Heart rate and visual characteristics are data that reflect the driver's emotional changes, pressure changes and other data during driving. The occurrence of accidents is usually related to the driver's behavior, and the driver's behavior is closely related to the driving characteristics. The driving characteristics of vehicles under adverse weather conditions are of great significance in driving safety.

3.3 Driving Simulation Experiment Method

The driving simulation experiment method mainly simulates some characteristic indicators of the driver under specific conditions through some driving simulators, such as the physiological characteristics, psychological characteristics, and driving characteristics obtained in the above-mentioned actual vehicle driving experiments. Compared with the actual vehicle driving experiment, the simulation experiment can obtain the required experimental data in a safer, simpler and faster way. Especially in recent years, simulated driving experiments have gradually become the most practical method in the field of traffic safety research at home and abroad.

Compared with the actual vehicle driving experiment, the simulated vehicle driving experiment is safer and can be simply designed according to the specific conditions required by the experimenter. The total number of experimenters can conduct multiple experiments in the same environment, or in different environments. Repeat the experiment below. The data obtained in this way is richer and more accurate.

In general, driving simulation experiments will play an increasingly important role in the field of traffic safety in the future, and how to better the actual driving situation is also an area that needs continuous improvement in the future.

4. Speed Control Technology of Expressway under Adverse Weather Conditions

4.1 General Road Section Speed Limit Value Formulation Method

According to the "Guidelines for Safety Evaluation of Highway Projects" (JTC/T B05-2004), according to the relationship between the horizontal and vertical indicators of the route and the predicted vehicle speed, the speed prediction model divides the route into four basic road sections, namely straight sections, longitudinal sections, and flat sections. Curved road section, curved slope combined road section[6].

Straight road section: the radius of the flat curve is ≥1000m, and the longitudinal slope is less than 3%;

Longitudinal slope section: the radius of the flat curve is ≥1000m, and the longitudinal slope is more than 3%;

Flat curve section: radius <1000m, longitudinal slope <3%;

Curved slope section: the radius of the flat curve is less than 1000m, and the longitudinal slope is more than 3%;

The corresponding relationship between design speed and initial operating speed is given in "Guidelines for Safety Evaluation of Highway Projects" (JTC/T B05-2004), see Table 1.

Table 1. Corresponding relationship between design speed and initial running speed

Design speed		60	80	100	120
Initial running speed(V0)	Large car	50	65	70	75
	Small car	80	95	110	120

When the mileage of a general road section is long, the calculation results of the running speed in the same general road section may also fluctuate greatly. The speed distribution map regards the road section with roughly the same running speed measurement value and relatively stable changes (up and down fluctuations not exceeding 10km/h) as a speed limit section, and divides the general road section into several speed limits with roughly the same running speed measurement results. Section, each speed limit section has its own speed limit value.

Assuming that each speed limit section contains multiple operating speed measurement sections, there are n characteristic point operating speed measurement values, denoted as Vi, and the average running speed of the speed limit section is obtained as the speed limit reference value of the speed limit section.

$$\bar{V} = \frac{\sum_{i=1}^{n} V_i}{\mathrm{n}}$$

In expressway speed management, the speed limits of 80km/h, 90km/h, 100km/h, 110km/h and 120km/h are common speed limit values, denoted as V, and these common speed limit values are subtracted from the speed limit reference value Take the absolute value, and set the V with the smallest absolute value as the final speed limit value Vmin of this speed limit section. Because is only the average value of the running speed, it is recommended that $\bar{V} \leq V_{min}$.

$$|\bar{V} - V_{min}| = |\bar{V} - V|$$

4.2 Method for Formulating Speed Limit Values for Special Road Sections

Drivers generally take deceleration and braking measures when entering a small radius curve section, the slip rate increases, and the lateral adhesion coefficient decreases, which is prone to side-slip accidents. From the perspective of lateral force coefficient, when the lateral force coefficient on the vehicle is greater than 0.15, the vehicle is in an unstable state[7]. The lateral force is calculated as follows:

$$u = \frac{X}{G} = \frac{v^2}{gR} - i_h$$

Let u<0.15 get:

$$v < \sqrt{(0.15 + i_h)gR}$$

The unit of velocity v in the formula is m/s.

Considering the concept of "tolerant design" and "fault tolerance", the road is not considered when setting the speed limit value.

The surface is super high, so the above formula becomes:

$$v < \sqrt{0.15gR}$$

4.3 Dynamic Speed Control Technology under Adverse Weather Conditions

The driving safety of general road sections under adverse weather conditions is mainly threatened by reduced visibility and reduced road friction coefficient. Therefore, this paper is mainly divided into the calculation of the speed limit value under the condition of poor visibility and the small road friction coefficient.

Under the condition of low visibility, considering the most unfavorable situation, the speed limit value is calculated based on the restriction that the driver can brake and stop in time when there is a stationary obstacle in front. At this time, the visibility in foggy weather is the parking sight distance of the vehicle[8]. The calculation model of vehicle parking sight distance is as follows:

The parking sight distance S includes three parts: the driving distance S1, the braking distance S2 and the safety distance S3 within the reaction time.

$$S = S_1 + S_2 + S_3$$
$$S_1 = V(t_1 + t_2)$$
$$S_2 = V^2/254(f \pm i)$$

In the formula: t-the total reaction time consists of two parts, the driver’s reaction time t and the braking system’s lag time t, generally.

Take the total reaction time as 2.5 seconds;

f-the adhesion coefficient between the wheel and the road surface;

i-the longitudinal gradient value of the road section (the general longitudinal gradient value of the expressway is 0.03~0.05);

S3-generally 5m~10m, take the safety distance as 5m.

The final expression for the parking sight distance S is as follows:

$$S = \frac{2.5V}{3.6} + \frac{V^3}{254(f \pm i)} + S_3$$

5. Safety Evaluation under Adverse Climatic Conditions

In terms of traffic safety evaluation research, compared with the United Kingdom, the United States and other countries, my country has developed relatively late. It only began to develop gradually in the 1980s, and currently there is a large gap with these countries. In view of the fact that there are very few highway driving safety evaluations under adverse weather conditions, in this regard, traffic safety evaluation indicators and evaluation methods are still the two main research directions.

There are two kinds of traffic safety evaluation indexes, one is qualitative index and the other is quantitative index. Qualitative indicators refer to non-linear indicators such as traffic signs, roadside facilities, landscape, and weather on the road during driving. Therefore, in the evaluation of traffic safety, these qualitative indicators must be quantified, and the method of quantification is usually the Delphi method. Quantitative indicators refer to indicators that can be directly recorded by using data during driving, such as driving speed, road alignment, sight distance and other indicators. Traffic safety evaluation usually needs to integrate these two indicators, so as to convert the complex driving state into data that can be calculated, and then analyze and evaluate these data to obtain the final result.

There are many types of existing traffic safety evaluation methods, including neural network-based evaluation methods, grey relational methods, and fuzzy comprehensive evaluation methods. Through the summarization and research of these methods, it is found that these methods are evaluated in three aspects: one is the analysis of accident causes; the other is the analysis of historical data; the third is the analysis of driver behavior. So far, most of the safety evaluation analysis is mainly to analyze the driver, because the driver's factor is the most complicated factor among all the factors, and it is also a hot spot and mainstream of the traffic safety evaluation analysis. However, there are few evaluation and analysis of adverse climatic conditions, so this aspect needs more in-depth research in the future.

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6. Driving Safety Precautions under Adverse Weather Conditions

With the continuous deepening of the research on traffic safety, certain theoretical achievements have been achieved, and the security technology has gradually deepened and comprehensive. The following two aspects will be discussed from the risk monitoring of security measures.

6.1 Security Measures

Safety assurance measures are of great significance in driving safety and can greatly reduce the occurrence of traffic accidents.

The first thing to analyze is the setting of safety facilities. The establishment of traffic safety facilities is mainly to remind drivers that common traffic facilities include speed bumps, traffic signs, and avoidance lanes[9]. However, if the location of these traffic safety facilities is unreasonable, it will also have the opposite effect. In response to these problems, many studies have also proposed relevant solutions. For example, in some studies related to anthropology, the design of traffic signs based on the driver's sight distance is proposed. Although the design of the speed bump will reduce the comfort of the driver and passengers, it has a significant effect on reducing the speed of the vehicle. In addition, with the development of smart transportation, some scholars have begun to study the detection and identification of traffic safety measures.

Then there is traffic safety management, which is mainly to reduce the bad driving habits of drivers, such as overloading, overweight, fatigue driving, etc. However, as far as the current situation is concerned, the practice in this area is still insufficient, and it can only stay in the document, and cannot actually fall into practice. Finally, in terms of traffic safety education, drivers can learn relevant regulations and safe driving behaviors through regular safety education and training for drivers[10].

6.2 Risk Monitoring Technology

The low safety of high-speed kilometers is mainly due to the geographical environment and adverse climatic conditions. In view of the particularity of adverse climatic conditions, potential risk monitoring and early warning of vehicles and roads during driving are required.

In terms of risk monitoring, real-time monitoring of road conditions under adverse climatic conditions is the main purpose. In developed countries abroad, there will be special departments to monitor the road conditions in bad weather conditions in real time. When bad weather occurs, real-time forecasts will be made and these bad weather will be rated accordingly, so as to remind drivers of speed limit and The specific conditions of the weather can achieve the purpose of driving safety under adverse weather conditions[11]. However, in my country's highways, there are only signs to pay attention to rain and snow, and these signs are easily ignored by drivers. The related monitoring technology abroad should also be studied in depth and real-time in my country.

The other is the driving assistance system. This system mainly monitors the real-time road environment through various sensors and satellite systems, and reminds the driver to take relevant measures in time.

7. Summary and Outlook

Based on the research and analysis of domestic and foreign literature, the following conclusions and prospects are put forward:

(1) In terms of research methods, the three methods mentioned have their own advantages and disadvantages, which need to be selected and used according to the actual situation. But in general, the simulated driving experiment method is safer and simpler, and more researchers use this method. This method needs to be further improved in the future to improve the experience of the experimenter and more realistic scenarios.

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(2) In terms of safety evaluation, although some research results have been made on driving characteristics and driver characteristics, the research on the mechanism of accidents is still insufficient.

(3) The construction of a safety guarantee system under adverse weather conditions is the premise of the study of safety guarantee technology. Monitoring technology and driving assistance system need to be further studied in combination with human-vehicle-road coordination technology.

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