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A case study on the causal of electric two-wheelers traffic accidents in Yangzhou, China

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ABSTRACT

In recent years, electric two-wheelers are a very popular means of transportation in China and are loved by the people. And, because driving electric two-wheelers does not require a driver's license or insurance, electric two-wheelers have become the preferred mode of transportation for the people in China. However, while electric two-wheelers bring convenience to people, they also bring hidden dangers to traffic safety. Nearly 200,000 traffic accidents occur in China every year, of which electric two-wheelers account for 60%. In addition, the trend of traffic accidents is increasing year by year, which is seriously threatening the safety of people's lives and property. It is urgent to prevent the traffic accidents of electric two-wheelers and maintain the personal safety of citizens. Therefore, this study aims to determine which factors contribute to traffic accidents of electric two-wheelers and to explore the importance of their influence on traffic accidents. The sample data for this study will be collected from the people of Yangzhou City, Jiangsu Province, China by distributing questionnaires. The data from the completed questionnaires will also be analyzed using SPSS analysis tool.

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1. INTRODUCTION

The electric two-wheeler was introduced to China in 1997. It is a kind of electric transportation. With the continuous expansion of urban scale, people's travel distance has been increasing. With its advantages of speed, convenience and low cost, electric two-wheelers have become the preferred mode of transportation for residents traveling within a certain distance. The number of electric two-wheelers has been increasing rapidly since 2012. After more than ten years of development, the number of electric two-wheelers has surpassed that of motor vehicles in many cities in China. It has become the most dominant mode of transportation on urban roads. In the survey of residents' travel mode in many places, electric two-wheelers have surpassed other kinds of transportation and become the most important transportation mode for urban residents, which has profoundly changed the structure of urban residents' travel mode in China.

The structure of this paper unfolds as follows: section 2 provides an overview of the background, while section 3 outlines the proposed literature review. Moving forward, section 4 explains into the research methodology, and section 5 discusses the results. Following this, section 6 outlines the proposed implementation. The paper concludes with a summary and insights into future work in section 7 and section 8, respectively.

2. BACKGROUND

China's road traffic environment is complex. As electric two-wheelers are light, small and flexible in steering, they present characteristics such as wobbliness, discrete and poor violation of regulations during driving [1]-[4], often causing conflicts with motor vehicle traffic. This reflects the non-reciprocity and non-integration, and seriously affects the normal traffic flow [5]. The rise of electric two-wheelers in China has significantly impacted urban traffic safety. In 2016, these vehicles were involved in 36.7% of traffic injuries in Beijing and 40% in Chongqing. Annually, electric two-wheelers account for 60% of China's 200,000 traffic accidents, with their share of non-motorized casualties doubling from 67,500 in 2009 to 331,900 in 2019. Despite their convenience, the lack of road design adaptation and safety education exacerbates their risk, posing a critical challenge to urban traffic management. Existing research predominantly focuses on automobiles, leaving a gap in understanding the specific accident factors for electric two-wheelers. This gap impedes the development of effective traffic safety measures and interventions. Addressing these issues is crucial for formulating traffic management policies and safety designs to mitigate the growing risks associated with electric two-wheelers.

3. LITERATURE REVIEW

3.1. Electric two-wheelers

Electric two-wheelers in China predominantly include electric bicycles and electric motorcycles, differentiated by their speed and weight. Electric bicycles, weighing under 40 kg and traveling up to 20 km/h, contrast with electric motorcycles, which are heavier than 40 kg and can reach speeds of up to 50 km/h. Research [6]-[8] reveals that electric bicycle users are predominantly aged 20-40, with balanced gender distribution and lower-middle income levels. This demographic primarily uses electric bicycles for commuting, replacing traditional transport modes such as buses and bicycles. The average travel distance for electric bicycles is within 10 km, with a travel time of 20-30 minutes, reflecting a 50% increase in distance and longer travel times compared to traditional bicycles.

3.2. Analysis of road traffic accidents

The road traffic system includes four factors: driver, road, vehicle, and environment. In the process of traffic operation, these four factors interact and influence each other, and if one of them has a problem, it may lead to traffic accidents. Researchers in various countries have conducted detailed analyses of the factors influencing traffic accidents in terms of drivers, roads, vehicles, and environments. Studies in the literature and traffic accident statistics show that some demographic and socioeconomic background variables of drivers, such as age [9], gender [10], marital status [11], income [12], and education level [13], have a significant impact on the occurrence of road traffic accidents. Although traffic accident statistics show that traffic accidents caused by vehicles account for a small proportion of the total number of accidents. However, related research shows that the type of vehicle [14], vehicle condition [15], vehicle performance [16], vehicle distance [16] and other vehicle factors on the impact of traffic accidents can not be ignored. The road is the carrier of vehicle operation, and is also the main external information that drivers obtain. Although statistics show that the number of traffic accidents directly caused by road factors is small. However, road factors generally have an impact on the occurrence of traffic accidents through the driver or in combination with environmental factors. Related studies show that road factors such as road class [17], road morphology [18], safety facilities [19], and road surface materials [20] have a significant impact on traffic accidents. Related research shows that environmental factors such as time of day [21], weather [22], climate [23], and light visibility [24]. Can influence traffic accidents to some extent influence on traffic accidents to some extent.

3.3. Risky driving behavior patterns

Human factors, especially risky behavior, are the primary contributors to traffic accidents. Since human behavior is influenced by subjective motivations, analyzing driving patterns is essential. Researchers often use questionnaires to study these behaviors [25]. Reason's driving behavior scale categorizes risky behaviors into "errors" (unintentional mistakes), "violations" (deliberate rule breaches), and "negligence" (inattention or fatigue). The driving behavior questionnaire (DBQ) surveys motorists to identify these risky behaviors, and various adaptations of the DBQ have been developed to suit different study populations. Westerman and Haigney [26], Blockey and Hartley [27] utilized the DBQ to examine risky driving behaviors in different environments, with Blockey focusing on Australia. Lajunen *et al.* [28] tested the DBQ across the UK, Netherlands, and Finland, finding it applicable in the latter two countries, though its UK-centric design may limit its global applicability. Nazari *et al.* [29] found significant differences in Iranian drivers' behaviors compared to those in the UK, highlighting limitations in the DBQ's adaptability to developing countries. Xie and Parker [30] identified distinct risky driving behaviors in China, such as errors and aggressive violations, and noted the impact of cultural differences, suggesting that the DBQ may not fully capture Chinese driving patterns.

There are also studies on different types of vehicles. Sullman *et al.* [31] used the DBQ to explore the risk behaviors of truck drivers in New Zealand to understand the relationship between risky driving behaviors and accidents. Elliot *et al.* [32] used the DBQ as a basis to design the motorcycle risky riding behavior questionnaire (MRBQ). After analysis, they concluded that motorcyclists' risky driving behaviors could be categorized into: traffic errors, control errors, speed violations, aggressive behaviors, and use of safety guards. Li *et al.* [33] conducted a study of motorcyclists' driving behaviors across chongqing city and defined four categories of driving behaviors: impulsive behaviors, speeding and violation behaviors, error behaviors, and alert safety behaviors. Feenstra *et al.* [34] studied the bicycle riding behavior of 1749 Dutch youths and found that bicycle risk behaviors could be categorized into three latitudes: errors, general violations, and extreme violations.

Based on [35]; drivers with a propensity for risky driving behavior usually also have a high risk of accidents. Rimmö and Åberg [35] argue that the occurrence of accidents can be considered as the end of a chain consisting of many times. In psychological terms, driver characteristics influence mediating variables such as driving attitudes, which in turn influence driver behavior. The outcome of driver behavior ultimately influences the occurrence of an accident. The occurrence of an accident can be seen as a consequence of the execution of the behavior. Therefore, the study of driver behavior can clarify the causes of accidents. To date, researchers have developed a number of models to analyze driver behavior, the most widely used of which is based on the theory of reasoned action (TRA), which was co-proposed by Hill *et al.* in 1977 [36]. The theory was proposed to explain how goals or plans guide behavior and to indicate which factors motivate people to change their initial intentions or prevent them from acting on them [37]. TRA analyzes the process of behavior formation using three stages: attitude, norm, behavioral intention, and behavior.

In order to overcome the shortcomings of TRA and make it applicable to analyze more behaviors, Ajzen proposed a modified model based on the theory of rational behavior, the theory of planned behavior (TPB) [38]. TPB argues that the process of forming driving behavior can be 3 stages: (1) behavioral attitudes, subjective norms and intuitive behavioral control; (2) driver behavioral tendencies; and (3) behavior occurrence. Elander *et al.* [39] argued that the "person" in driving is influenced by a series of factors that eventually manifest themselves in a comprehensive pattern of driving behavior [40], safety attitudes and other factors [25], [41], [42]. Meanwhile, Rimmö and Åberg [35] argued that drivers' personal traits influence mediating variables such as driving attitudes, which in turn influence driver behavior, while forming a complete model of risky driving behavior research.

3.4. Related works

Tang *et al.* [43] have done extensive research on the influence of the psychological factors of electric bicycle riders on electric bicycle traffic accidents. By means of questionnaire survey, they collected more than 2,000 data of electric bicycle riders from Shanghai, China, and analyzed these data using the TPB framework. TPB is a social psychological model, which is widely used to study the intention of driving related behavior. They divided the psychological factors of electric bicycle riders into seven categories (descriptive norms, ethics, perceived risk, self-identity, legal norms, conformity tendency and past behavior). Research shows that most electric bicycle riders believe that violating traffic rules is immoral. However, herd mentality has a great impact on electric bicycle riders. Most riders believe that Chinese electric bicycle riders are easy to violate traffic rules, which is very common. This makes it easier for most riders to break traffic rules. They believe that the study has two limitations. First, in this study, the potential injury risk of traffic rule violation may be different, and psychological factors may affect the intention of each traffic rule violation differently. Second, the data source of this study is the electric bicycle riders who are still using electric bicycles, and the data of riders who no longer use electric bicycles due to traffic accidents are not collected. Tang *et al.* [43] reviewed the research on the influencing factors of electric bicycle traffic accidents, and showed that the existing research had never studied the psychological factors of electric bicycle riders. Therefore, this is regarded as a gap in this kind of research.

Ma *et al.* [44] have done extensive research on the risk riding behavior of urban electric bicycles. They mainly used two methods in the data collection of dangerous riding behavior of electric bicycles, namely questionnaire survey method and video collection method. They collected data from 1,487 Chinese electric bicycle riders and 3,659 Swiss electric bicycle riders by questionnaire. They used the method of video collection to collect the behavior data of 18,000 Chinese electric bicycle riders and 90,000 American electric bicycle riders. Structural equation models (SEMs) and binary probability unit (BP) models are used to analyze these data. Research shows that weather, temperature and road infrastructure are closely related to electric bicycle riding behavior. Most electric bicycle riders can't stand a red light for more than 49 seconds. Moreover, electric bicycle riders are more likely to run red lights in hot and rainy days. Ma *et al.* [44] reviewed relevant studies and showed that the study of adventure riding behavior is of great significance to reduce the occurrence of electric bicycle traffic accidents and ensure the safety of life and property of traffic participants. Due to the difficulties in obtaining relevant data and the limitations of research ideas, this study has many deficiencies, and the analysis results have a certain deviation. And because there are few relevant research results, quantitative research should be carried out to study the riding rules under special weather conditions. Zhou *et al.* [45] examined the influence of hazardous driving behaviors among E-bike operators on driving safety. Utilizing a questionnaire survey conducted among Guilin citizens in China, they scrutinized safety knowledge and safety attitudes as two key factors. Their analysis suggests a higher propensity for aggressive behavior among male drivers compared to female drivers. Additionally, their research indicates that older individuals exhibit fewer irregularities in driving compared to younger counterparts. However, it's noteworthy that the dataset for this study is limited to Jilin City and may not accurately reflect the broader situation across China [46].

4. PROPOSED RESEARCH METHOD

4.1. Research framework

In road traffic accidents, the human risk behavior factor has been the main cause of accidents, and in this chain of events, how to reveal the role of the human "risky driving behavior" ring is the most effective and valuable. "Risky driving behavior" refers to behavior that deviates from the expected normal and reasonable driving behavior. Electric two-wheeler drivers have little awareness of traffic safety, lack traffic knowledge and professional driving skills training, and have insufficient foresight of the traffic environment and hazards, so risky driving behaviors such as running red lights, traveling against traffic, and speeding are more frequent. As learned from previous literature reviews, recent studies of motor vehicles, motorcycles, and bicycles by researchers have found that safety attitudes, risk perception, and driving confidence are three important factors that influence risky driving behavior. Therefore, this paper plans to consider whether these factors also influence e-bikes and what the relationship of influence is. So the framework is established as shown in Figure 1.

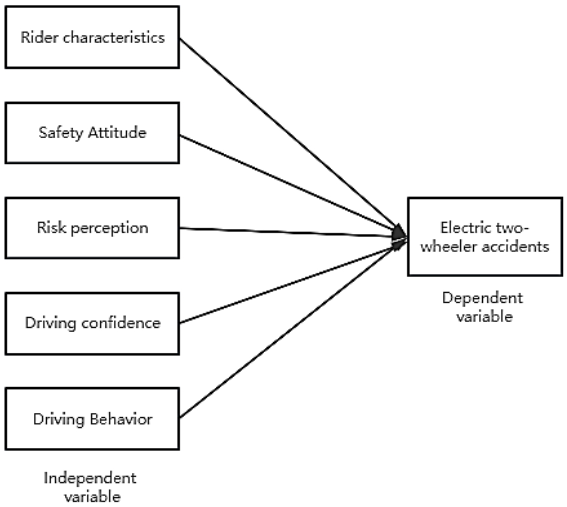

Figure 1. Proposed research framework for electric two-wheeler accident

4.2. Questionnaires

This research developed a tailored questionnaire to assess risky driving behaviors among electric two-wheeler riders, focusing on four key constructs: risk perception, driving confidence, safety attitude, and risky driving behavior. A new scale was designed to reflect the unique characteristics of electric two-wheelers, incorporating driving confidence, evaluated through eight questions on technical and judgment skills; risk perception, assessed via dimensions of emotional apprehension and cognitive risk assessment; safety attitudes, which included 14 items on personal responsibility, traffic rules, and herd mentality; and risky driving behavior, measured through four types of risky actions: violations, negligence, aggression, and lead-seeking. Additionally, the questionnaire records accident experience and gathers demographic and socioeconomic information. This comprehensive framework provides a robust tool for analyzing driving behaviors and attitudes, ultimately enhancing traffic safety for electric two-wheelers.

5. RESULTS AND DISCUSSION

5.1. Data analysis

This study adapted the motor vehicle risk riding behavior scale for electric two-wheelers, developing a 58-question scale relevant to the Chinese context. Analyzing data from 200 valid online responses revealed key insights: Risk perception is represented by three factors "danger level", "worry level", and "chance assessment". Riding confidence consists of "technical ability" and "judgment ability". Safety attitude includes "attitude toward traffic rules", "safety responsibility", and notably, "herd mentality". Risky riding behavior features four factors: "negligence and mistakes", "violation", "bravery", and "getting ahead", with the last reflecting actual riding behaviors better than traditional speeding metrics. These findings provide a targeted framework for addressing risky behaviors in electric two-wheeler usage.

5.2. Discussion

Factor analysis gives the relationships and strengths between the factors and the original variables, followed by an analysis of the variability of basic information about different electric two-wheeler drivers on each factor. This research conducted a one-way ANOVA on the three constructs of risk perception, riding confidence, and safety attitude, as well as on the variability of factor scores for risky riding behavior. The results of the one-way ANOVA for electric two-wheeler drivers of different genders showed significant differences in the effects of gender on the risk perception ($F=10.09$, $p<0.01$) and riding confidence ($F=3.95$, $p<0.05$) constructs. Female drivers had significantly higher risk perception scores than males, while male drivers were significantly more confident in riding than females.

Male drivers showed more frequent aggressive riding behavior ($F=3.84$, $p<0.05$) and acquisition of lead ($F=10.47$, $p<0.01$) than females, while negligence and errors occurred more frequently in female drivers than in males. Also the results showed that male and female electric two-wheeler drivers did not realize significant differences in riding violations ($F=0.34$, $p>0.05$). There was no significant effect of age on the safety attitude construct and a significant difference in the effect on risk perception ($F=5.25$, $p<0.01$) and riding confidence ($F=8.06$, $p<0.001$). The results of the multiple comparisons showed that the middle-aged group of electric two-wheeler drivers had significantly higher risk perception scores ($p=0.012$) and significantly lower riding confidence scores ($p=0.007$) than the youth group ($p=0.000$) and the elderly group ($p=0.007$). It was further shown that the frequency of violations among the electric two-wheeler drivers in the older group was significantly higher than the youth group ($P=0.000$) and the middle-aged group ($P=0.000$), while the frequency of obtaining the lead among the electric two-wheeler drivers in the youth group was significantly higher than the middle-aged group ($P=0.001$) and the older group ($P=0.044$). As age increases drivers' priority-seeking behavior decreases and intentional violations increase, so special attention should be paid to their differences in age in the analysis of risk behavior.

The effect of different levels of education on risk perception was not significant, and there were significant differences in the effects on the riding confidence ($F=3.47$, $p<0.05$) and safety attitude ($F=5.84$, $p<0.01$) constructs. The results of multiple comparisons showed that the riding confidence of electric two-wheelers increased with increasing education, and safety attitude became more positive with increasing education. On each factor of risky riding behavior, there was a significant difference in the effect of different education levels on the factors of violation ($F=6.03$, $p<0.01$), aggression ($F=3.85$, $p<0.05$) and getting ahead ($F=15.47$, $p<0.01$). Highly educated motorized two-wheeler drivers had a higher frequency of violation and gaining lead behaviors, while lowly educated motorized two-wheeler drivers had a higher frequency of aggressive risky riding behaviors. In this paper, electric two-wheelers were divided into pedal and motorcycle types, and the results of one-way ANOVA showed in Table 1 that risk perception ($F=7.03$, $p<0.01$) and aggressive behavior were significantly different in riding models ($F=4.75$, $p<0.05$), with pedal-type electric two-wheeler drivers having higher risk perception scores and motorcycle types having more aggressive behavior, which could be due to the fact that motorcycle-type electric two-wheelers It is possible that this is because motorcycle type electric two-wheelers are larger and more difficult to drive, and drivers with strong risk perception tend to choose pedal type electric vehicles, while drivers with aggressive behavior tend to choose motorcycle type electric two-wheelers.

The effect of frequency of use on the risk perception ($F=5.47$, $p<0.01$) and safety attitude ($F=5.75$, $p<0.01$) constructs was significantly different, with drivers who used the vehicle more frequently having lower perceptions of risk and more positive attitudes toward safety. There was also a significant difference in the effect of frequency of use on the violation ($F=15.18$, $p<0.01$), negligence and error behavior ($F=4.31$, $p<0.05$), and getting ahead behavior ($F=3.84$, $p<0.05$) factors. The results of the multiple comparisons in Table 2 showed that drivers who drove more than 6 times per week had a higher frequency of violations and acquisition of leading behavior, while drivers who drove less than 2 times had a higher frequency of negligent and blundering behavior.

Table 1. Comparison of the differences in scores of each conformational factor relative to vehicle type

	Foot-operated	Motorcycle type	F
Risk perception	3.84	3.67	7.03*
Riding confidence	2.58	2.66	1.09
Attitude towards traffic safety	3.81	3.85	0.89
Violation	1.93	1.88	0.36
Negligence and error	2.23	2.22	0.63
Aggressive behavior	1.9	2.07	4.75*
Getting ahead	2.35	2.39	0.13

Table 2. Comparison of the differences in scores of each conformational factor relative to frequency of use

	1-2	3-5	6-7	F
Risk perception	3.9	3.67	3.7	5.47**
Riding confidence	2.69	2.71	2.56	2.46
Attitude towards traffic safety	3.73	3.84	3.91	5.75**
Violation	1.76	1.77	2.08	15.18**
Negligence and error	2.95	2.73	2.66	4.31*
Aggressive behavior	1.98	1.97	2.1	2.32
Getting ahead	1.85	1.96	2.03	3.84*

ANOVA analysis of factor scores reveals key insights into driving behavior: female drivers demonstrate higher risk perception but lower confidence and fewer violations than males, who show greater confidence and more frequent violations. Increased riding experience correlates with more rule violations, particularly among older drivers, while younger drivers engage more in leading behaviors. Higher education levels are linked to greater riding confidence and aggressive safety attitudes, resulting in more violations. Motor vehicle experience does not significantly affect risk perception or safety attitudes, though it increases lead-seeking behaviors. Frequent drivers exhibit lower risk perception and more positive safety attitudes but higher violation rates, whereas infrequent drivers display more negligent behaviors. These findings highlight the intricate relationships between demographics, experience, and driving behavior, emphasizing the need for targeted safety interventions.

6. PROPOSED RECOMMENDATION

To enhance traffic safety for electric two-wheelers, the research recommends implementing regulatory measures such as licensing and license plates, boosting legal education to raise awareness, providing emotional support to riders, and deploying traffic police at busy intersections during peak times. It also identifies gender-specific and experience-related differences in risk perception and behavior: female riders generally perceive higher risk but have lower confidence, while males tend to exhibit more violations and aggression. Experienced and older riders often commit more violations, whereas younger and frequent riders are more prone to risky behaviors. These findings underscore the need for targeted safety interventions tailored to different rider profiles to improve overall safety.

7. CONCLUSION

This research utilized a social media-based questionnaire to analyze factors influencing traffic accidents involving electric two-wheelers in China, analyzing 200 valid responses through a customized risky driving behavior scale. Key findings revealed distinct categories for risk perception, driving confidence, safety attitudes, and risky behaviors. These insights enhance the understanding of electric two-wheeler rider behaviors and attitudes, guiding more effective safety interventions. Future research should examine additional correlations and develop a decision support system for traffic managers. Limitations include reliance on self-reported data, potential psychosocial biases, and a lack of consideration for external environmental factors affecting driving behavior and accident risk.

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