sustainability

Article

Analysis of Risky Driving Behavior of Urban Electric Bicycle Drivers for Improving Safety

Dan Zhou [1,*], Mengying Chang [1], Guobin Gu [1], Xin Sun [1], Huizhi Xu [2], Wenhan Wang [1] and Tao Wang [1]

[1] School of Architecture and Transportation Engineering, Guilin University of Electronic Technology, Guilin 541004, China; cmy15878398672@163.com (M.C.); 15251707205@163.com (G.G.); sunx_lynn@163.com (X.S.); wenhan@guet.edu.cn (W.W.); wangtao_seu@163.com (T.W.)
[2] School of Traffic and Transportation, Northeast Forestry University, Harbin 150040, China; stedu@126.com
* Correspondence: zhoudan_5460@126.com; Tel.: +86-0773-230-3726

Abstract: In this work, to clarify the impact of electric bicycle drivers' risky driving behavior on driving safety, we used multiple regression analysis methods combined with a questionnaire survey of residents of the city of Guilin, China. We studied the impact of the two dimensions of safety knowledge and safety attitude on risky driving behavior, and identified the differences in the impact of these two dimensions from the perspective of personal characteristics. Through modeling analysis, we found that "responsible attitude" and "group behavior attitude" explain 62.4% of the variation in aggressive behavior; 48.5% of the variation in negligent behavior is caused by "age", "safety knowledge" and "responsible attitude"; and 52% of the variation in violations is caused by "age", "violation attitude" and "group behavior attitude". The results show that "group behavior attitude" affects the occurrence of aggression; that safety knowledge has a significant negative impact on unintentional negligence but has no significant effect on deliberate violations and aggression; and that the difference in risky driving behavior is mainly manifested in "age", "gender", "violation" and "accident experience".

Keywords: traffic safety; electric bicycles; risky driving behavior; multiple regression analysis

check for updates

Citation: Zhou, D.; Chang, M.; Gu, G.; Sun, X.; Xu, H.; Wang, W.; Wang, T. Analysis of Risky Driving Behavior of Urban Electric Bicycle Drivers for Improving Safety. *Sustainability* **2022**, *14*, 1243. https://doi.org/10.3390/su14031243

Academic Editors: Efthimios Bothos, Panagiotis Georgakis, Babis Magoutas and Michiel de Bok

Received: 28 December 2021
Accepted: 20 January 2022
Published: 22 January 2022

1. Introduction

In recent years, negative impacts of urban traffic congestion, air pollution and traffic accidents have caused new problems in the lives of residents [1]. Electric bicycles, as an effective alternative to fuel vehicles, have attracted the attention of all sectors of society from the perspective of environmental protection and energy. Electric bicycles have lower economic costs than cars. The energy-saving and low-carbon characteristics of electric bicycles meet time requirements and the needs of environmental protection. Electric bicycles meet the needs of consumers with an increased travel radius in the process of urbanization. With the continuous improvement of product quality and technological innovation, electric bicycles will be more widely used as a green, energy-saving means of transportation.

China's express industry and take-out food delivery services are developing rapidly; therefore, the demand for electric bicycles is high. The output of China's electric bicycles from 2015 to 2020 is shown in Figure 1. The rapid growth of electric bicycles and the limited management of their use have resulted in great challenges to urban management and road safety [2]. According to the statistical data obtained from the Guilin Traffic Police Department, from 2011 to 2018, there were a total of 2999 traffic accidents caused by electric bicycles, including 341 accidents that resulted in death, 2294 accidents that caused injury and 364 accidents that caused property loss.

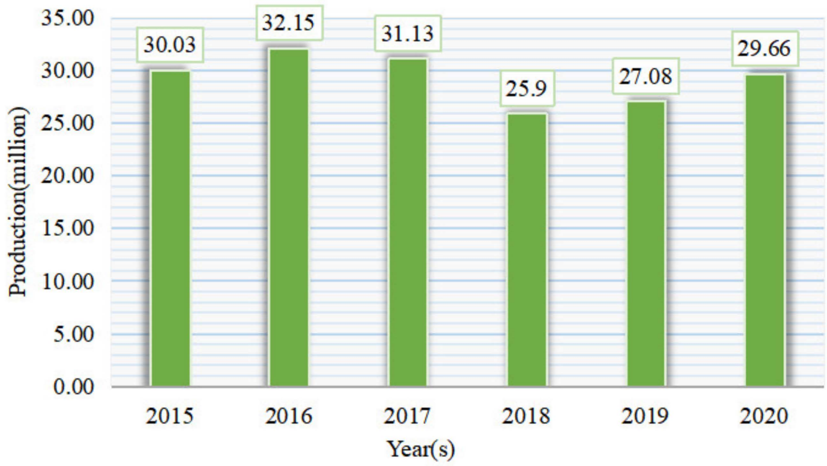

Figure 1. China's electric bicycle production in 2015–2020.

Among the casualties of China's road traffic accidents in 2019, the number of deaths and injuries caused by electric bicycles reached 8639 and 44,677, respectively. The number of casualties accounts for nearly 70% of non-motor vehicle casualties, which means that on average, one electric bicycle rider died and five electric bicycle drivers were injured in road accidents every hour. In the literature on China, among the electric bicycle accidents that resulted in death, 19.1% of accidents occurred because riders failed to follow traffic regulations, 18.6% of accidents were caused by riders violating traffic signals, 15.6% by riders illegally occupying roads and 11.1% by riders riding the wrong way. In total, approximately two-thirds of accidents were caused by disobeying traffic rules. From the analysis of road traffic accidents, people's behaviors were key factors in traffic accidents [3], and approximately 95% of the accidents were related to the risky driving behavior of drivers [4]. Therefore, it is relevant to study the "risky driving behavior" of drivers.

2. Research Status

2.1. Research Status of Risky Driving Behavior of Drivers

In the past, Reason et al. [5] first constructed a Driving Behavior Questionnaire for risky driving behaviors of motor vehicle drivers, which provided a reference for subsequent studies on related behaviors. Electric bicycles have become popular in the past decade and have been studied by many scholars. Yao [6] argued that with the increase in the number of electric bicycles, the safety of electric bicycles drivers is of increasing concern. It was found that risky driving behavior is the main factor that causes electric bicycle traffic accidents. Safety attitudes and risk perception significantly influence risky driving behaviors. Tao [7] explored the physiological factors, including age, gender and personality traits, that influence risky driving behavior. For example, a psychotropic personality is likely to cause emotional illegal driving behaviors, such as speeding and aggressive driving. Wang et al. [3] also developed a scale based on previous research that studied the structure of risky driving behavior of electric bicycles. Based on the electric bicycle risky driving behavior scale proposed by Wang, Yang [8] designed his own driving behavior questionnaire for electric bicycle drivers, taking into account the actual situation and the characteristics of electric bicycle riding behavior in China, and conducted a reliability test on the questionnaire, which can be used as a valid tool to assess electric bicycle riding behavior. Based on this, researchers have conducted additional studies. Măirean et al. [9] constructed a scale for measuring dangerous driving behavior from the scale measurements of T-loc (traffic locus of control). A correlation between mortality significance (MS) and dangerous driving and a correlation interaction between external control traffic location (T-loc) and dangerous driving were found.

In recent years, researchers used intervention technology to identify and intervene in the risky driving behavior of drivers through technical means, such as electronic radars and driving records [10]. In addition, the MKD method, SPSS, satellite positioning [11] and the literary measurement method [12] were also used for risky driving behavioral research. For more advanced research methods in psychology and transportation research, GAO [13] used a mixed choice model to quantitatively measure the effects of psychological inertia. The results provide conclusive evidence for psychological inertia in mode-shifting behavior through a new approach and provide a methodological and empirical study to measure the quantitative impact of psychological inertia. Prospect theory describes and predicts the behavior of people who behave inconsistently with traditional expectancy value theory and expected utility theory during risk-facing decisions. GAO [14] developed a model of travel behavior based on cumulative prospect theory and multi-attribute decision theory to help readers understand the mechanisms of travel behavior in essence, rather than using arbitrary conclusions from economics.

2.2. Influencing Factors of Risky Driving Behavior

2.2.1. Physiological and Psychological Factors

In a large number of studies, the influencing factors of risky driving behavior are mainly divided into two categories, physiological and psychological, which offered new research directions for risky driving behavior. Vision problems, obstructive sleep apnea syndrome and other physiological diseases had a significant impact on driving ability and the perception of danger, which affected driving behavior [15]. The research was conducted by dividing the psychological factors into two major categories: endogenous psychological factors, such as personality and cognitive emotions; and exogenous psychological factors, including stress and job burnout, stress pessimism and long-term oppression encountered in daily life and work. These factors also affected risky driving behavior [16].

2.2.2. Factors of Personal Characteristics

Male drivers were more likely to have negligent traffic accidents than female drivers, while drivers with motor vehicle driving licenses were less likely to have accidents than drivers without licenses [17]. The study of Ma et al. [18] showed that both gender and driving experience were related to traffic accidents, confirming this finding. Young drivers were more likely to have risky driving behaviors due to their immaturity and limited driving experience [19].

2.2.3. Factors of Safety Attitude and Risk Perception

Sang [20] used safety attitudes and personality characteristics to study drivers' risky driving behavior tendencies, including extroversion, pleasantness and conscientiousness. Drivers were always exposed to more or fewer risks caused by external or internal environmental factors during driving. Therefore, it was particularly important to manage the safety of drivers' behavior. Wang et al. [21] suggested that the risky driving behavior of electric bicycle drivers was related to their attitudes about safety and risk perception; driving confidence can also indirectly affect driving behavior through safety attitudes and risk perception.

2.3. Summary of Current Research

The research on risky electric bicycle driving behavior is summarized in Table 1. Systematic and comprehensive research studies have been carried out in the field of risky driving behavior patterns and many research results have been achieved. Since e-bikes have only appeared on a large scale in the past decade, the research on the risky driving behavior of e-bikes is still in its initial stage. Some important research points on driving behavior patterns are less developed. There are some shortcomings in the research methods. Driving behavior patterns and their influencing factors have been systematically studied for different groups of drivers worldwide. Some studies have also been conducted in China. The studies are fragmented and focus on the analysis of risky driving behavior factors and structural equation modeling. It is necessary to conduct an in-depth study of the relationship between risky driving behavior and its influencing factors by combining risky driving behavior multiple regression analysis and analysis of variance.

Table 1. Research summary.

	Researcher (Year)	Research Content
Risky driving behavior	Reason, J. (1990)	First constructed a Driving Behavior Questionnaire for risky driving behaviors of motor vehicle drivers [5].
	Yao, L. (2012)	Risky driving behavior is a major contributing factor to e-bike traffic accidents [6].
	Tao, D. (2016)	Factors influencing risky driving behavior of electric bicycles [7].
	Yang, S. (2019)	Design and reliability testing of electric bicycle driving behavior questionnaire [8].
	Wang, T. (2019)	Electric Bicycle Driver Risk Driving Behavior Scale [3].
	Cornelia, M. (2021)	A scale to measure risky driving behavior is constructed by combining the scale measures of T-loc [9].
	Dan, J.Y. (2013)	Variability of individual characteristics in risky driving behavior [15].
	Wang, C.L. (2018)	The influencing factors of risky driving behavior are divided into two main categories: physical and psychological [16].
	Sang, H.Y. (2020)	Drivers' propensity to engage in risky driving behaviors by using safety attitudes and personality traits [21].

Combined with current research, it is found that risky driving behavior is influenced by personal characteristics, safety knowledge and safety attitudes, but scholars have not comprehensively studied the impact of these three factors on the driving behavior of electric bicycle drivers.

In this study, we focus on the design of the e-bike risky driving behavior scale based on the results of the driver questionnaire. We explore the degree of influence of the constructs of safety knowledge and safety attitudes on the driving behavior of e-bike drivers and analyze the differences in e-bike risky driving behavior based on driver information, so as to provide a reference basis for developing e-bike safety management methods, reduce e-bike accidents and improve e-bike traffic order.

3. Research Methods

3.1. Sample

By the end of 2021, the number of electric bicycles in the city of Guilin, China, had reached 12.8 million. In this article, the size of the study population is approximated to infinity. The sample size is calculated as follows:

$$n = \frac{z^2 p(1-p)}{e^2} \tag{1}$$

where n is the number of samples, e is the allowable range of sampling error, Z is the lookup table value of the standard normal distribution under the confidence level of 1-α, and p is the probability value of occurrence of parent events.

In the 95% confidence interval, the Z value is 1.96, and the control error is within $\pm$ 5%. p is set as the maximum absolute error estimate value 0.5 for calculation. The calculation result shows that the required number of survey samples is at least 385. The survey was conducted in five main urban areas of Guilin. Five hundred electric bicycle drivers were randomly selected to answer a questionnaire survey. As shown in Figure 2, 411 valid questionnaires were collected.

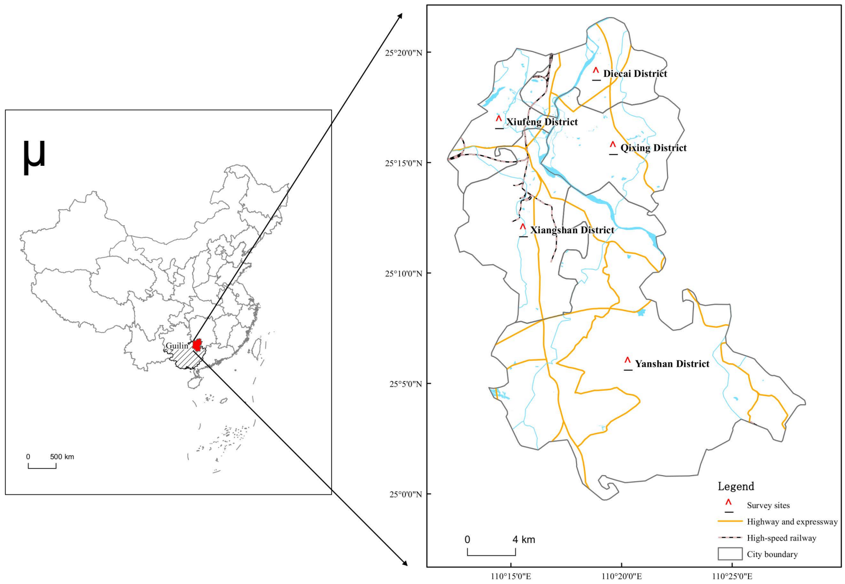

Figure 2. Survey area.

3.2. Research Tools

Combined with existing studies, the scale of risky driving behavior of electric bicycles in this study contains five parts: risky driving behavior, safety knowledge, risk perception, safety attitudes and basic information [22].

3.2.1. Personal Information Scale

The basic information is mainly composed of the following attributes: age, gender, level of education, has a driver's license or not, type of electric bicycle, driving experience, occupation, driving frequency, daily cycling distance, experienced traffic accident or not and type of accident and personal information. The information is shown in Table 2.

3.2.2. Driving Safety Knowledge Scale

We designed a total of eight questions by referring to the Regulations on the Application and Use of a Motor Vehicle Driving License issued by the Ministry of Public Security of China. The interviewees' knowledge was examined from two aspects: knowledge of legal symbols and the right of way, and knowledge of defensive and polite driving. The questions are single-choice problems. The interviewees chose the answer according to their knowledge base. A correct answer earned one point. The higher the score, the more knowledgeable the participant is about driving.

Analyzing the results of the safe driving knowledge questionnaire, we found that the correct rates of question two (the meaning of the turn sign) and question five (the main influence of rain on safe driving) were the highest, at 88.56% and 88.81%, respectively. The lowest correct answer rates were only 41.61% and 35.04% for question seven (the minimum age for people to ride electric bicycles) and question eight (the order of the right of way to turn). This shows that drivers have a certain degree of safe driving knowledge, but they still need to learn more. The correct answer rates of each question are summarized in Table 3.

Table 2. Personal information.

Attribute	Category	Number of Samples	Percentage	Attribute	Category	Number of Samples	Percentage
Gender	Male	223	54.26%	Driving age of the electric vehicle	1–3 years	200	48.66%
	Female	188	45.74%		4–7 years	151	36.74%
Age	<18	54	13.14%		>8 years	60	14.59%
	19–25	100	24.33%	Use frequency	1–5 times a week	169	41.12%
	26–45	201	48.91%		6–10 times a week	200	48.66%
	>46	56	13.62%		More than 11 times a week	42	10.22%
Level of education	Below junior high school	128	31.15%	Travel distance	Under 4 km	125	30.41%
	High school	139	33.82%		5–10 km	169	41.12%
	Above college	144	35.04%		More than 10 km	117	28.47%
Occupation	Students	100	24.33%	Been cited for a traffic violation	Yes	41	9.98%
	Employees	179	43.55%		No	370	90.02%
	Individual	39	9.49%	Had a traffic accident	Yes	21	5.11%
	Other	93	22.63%				
Motor vehicle driving license	Have	169	41.12%		No	390	94.89%
	Do not have	242	58.88%	Accident type	Uninjured accident	330	80.29%
Type of electric vehicle	Pedal type	107	26.03%		Minor injury accident	78	18.98%
	Motorcycle type	304	73.97%		Serious injury accident	3	0.73%

Table 3. Correctness rate of driving safety knowledge.

Question Number	Content	Correct Rate
1	Double yellow solid line (picture) meaning	76.89%
2	U-turn sign (picture) meaning	88.56%
3	What to do when you encounter a flashing yellow light	57.66%
4	How to overtake	55.23%
5	The impact of driving on rainy days	88.81%
6	Right of way concept	80.54%
7	The legal minimum age for drivers	41.61%
8	The sequence of the right of way turns	35.04%

Figure 3 is the statistical table of the correct answers of the interviewees. From the distribution results of the correct answers of all the interviewees, the lowest number of correct answers is zero (all wrong), and the highest number of correct answers is eight (all right). The majority of the correct answers of the interviewees are between four and seven. Sixteen people (3.9%) answered all the questions correctly.

3.2.3. Traffic Safety Attitude Scale

For our Traffic Safety Attitude Scale, according to the scale proposed by Ulleberg and Rundmo [23], a total of 11 questions were designed, composed of three categories: responsibility attitude, violation attitude and group behavior attitude. Likert's five-point scoring method was used to measure the rating, with the interviewees choosing results according to their usual cycling experience, where "1" means very dissatisfied, "2" means somewhat dissatisfied, "3" means uncertain, "4" means somewhat satisfied and "5" means very satisfied. The higher the score of attitudes toward violations, the more likely the interviewees are to break the rules; the higher the score of attitudes toward group behavior, the more likely they are to take risks; and the higher the score of attitudes toward responsibility, the more responsible the interviewees are.

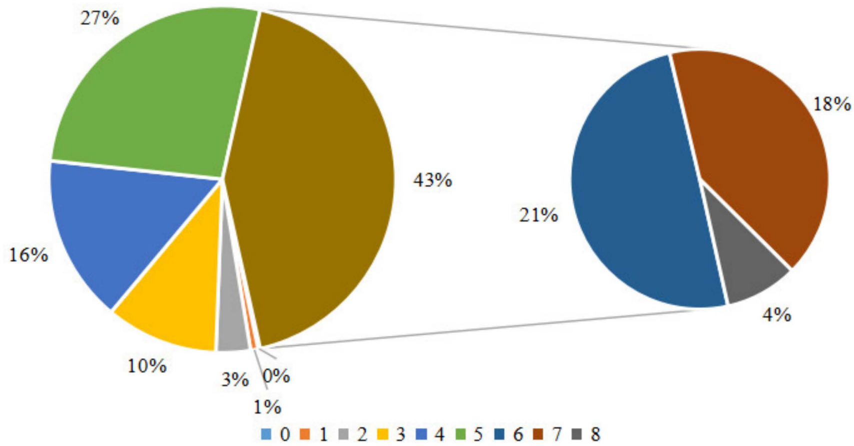

Figure 3. Statistical table of correct answers.

Table 4 is a detailed introduction of the mean value and deviation of the content of the test. Here, we try to understand driver attitudes toward safe driving. On the aspect of traffic responsibility, according to the mean value, the majority of interviewees' attitudes are between strongly agree and uncertain. The interviewees strongly disagree with question eight that breaking the rules avoids responsibility. In terms of risky driving, the interviewees are more willing to ride in groups, indicating that the interviewees are more inclined to ride at risk. In general, interviewees agree with the attitude toward traffic safety.

Table 4. Risk perception test statistics.

Question Item	Content	Mean	Standard Deviation
1	I am responsible for the safety of others	3.60	0.696
2	I will do my best to prevent accidents	2.01	1.236
3	I believe that every road traffic participant should be responsible for his or her actions	3.37	0.794
4	Traffic regulations are too complicated to be observed in practice	1.09	1.277
5	If an accident happens because of my fault, I will feel guilty	3.34	0.979
6	Sometimes it's okay to break traffic rules if I am in a hurry	1.74	1.255
7	I feel guilty after breaking the traffic rules	3.06	1.093
8	I think you can get away with breaking the rules with others	0.80	1.139
9	Follow the person next to me and I won't be blamed	1.83	1.275
10	I like to follow the crowd when I ride my bike	0.90	1.206
11	I think riding with other e-bikes is safer than riding alone	3.55	0.861

3.2.4. Risky Driving Behavior Scale

Taking the DBQ driving behavior questionnaire as the main template, we modified it concerning current documents [7] and included aggressive behavior to form our Risky Driving Behavior Scale. The scale is divided into three dimensions: aggressive behavior, negligent behavior and violation behavior. The scale uses Likert's five-point system to measure the frequency of each problem, where "1" means never, "2" means rarely, "3" means sometimes, "4" means often and "5" means always. The higher the score, the higher the frequency of the analyzed behavior.

Table 5 presents a detailed introduction of the mean and deviation of the content of the test questions. By analyzing the mean value in Table 5, the frequencies of certain dangerous driving behaviors are understood. By analyzing the average value, we can see that driving behaviors with lower frequency are violation behaviors from questions one to three, negligent behaviors are from question nine, aggressive behaviors are from questions twelve to fourteen and question sixteen and driving behaviors with higher frequency are negligent behaviors from questions six to seven.

Table 5. Frequency statistics of driving behavior.

Question Item	Content	Mean	Standard Deviation
1	Use mobile phone while driving	0.94	0.949
2	Ride the wrong way for convenience	0.88	0.934
3	Pass the intersection at a red light	0.71	0.920
4	Ride an electric bicycle on a motorway	1.04	1.005
5	Park beyond the parking line for non-motor vehicles	1.06	1.002
6	Fail to observe the movement of other vehicles when changing lanes or turning	2.01	1.352
7	When avoiding a vehicle, slow down and pass behind the vehicle	2.19	1.184
8	Forget to turn on headlights when driving at night	1.13	1.036
9	Don't pay attention to traffic lights when passing an intersection	0.93	0.949
10	Forget to turn on the turn signal when turning	1.49	1.174
11	Encounter a yellow light in front of the stop line at the intersection, speed up and pass	1.18	1.115
12	Deliberately get close to the vehicle in front, urging the vehicle in front to ride faster or give way quickly	0.64	0.906
13	Chase other vehicles	0.55	0.849
14	Desire to overtake as long as I'm behind others	0.70	0.945
15	Ride much faster than surrounding vehicles	1.12	0.963
16	When the vehicle in front is turning right, forcibly approach and cut off	0.71	0.974

3.3. Investigation and Statistical Processing

Cronbach's α reliability coefficient is the most frequently used reliability coefficient at present [24,25]. The formula is:

$$\alpha = \left(\frac{\kappa}{\kappa - 1}\right) \times \left(1 - \frac{\sum \sigma_i^2}{\sigma_i^2}\right) \quad (2)$$

where κ is the total number of questions on the scale, and σ_i^2 is the in-question variance for the score of question i.

The specific analysis of the reliability coefficient of the total scale is shown in Tables 6 and 7.

According to the results of the statistical analysis, each Cronbach's α value of the Safety Knowledge Scale, Traffic Safety Attitude Scale and Risky Driving Behavior Scale is greater than 0.5, which indicates that the reliability of the data is sufficient. Each KMO value is greater than 0.6, indicating that the validity of the data fully reflects the content to be investigated.

Table 6. Confidence scale.

α Value	Confidence
$\alpha > 0.9$	Fully Credible
$0.7 < \alpha \leq 0.9$	Very Credible
$0.5 < \alpha \leq 0.7$	Credible
$0.4 < \alpha \leq 0.5$	Slightly Credible
$0.3 < \alpha \leq 0.4$	Barely Credible
$\alpha \leq 0.3$	Not Credible

Table 7. Cronbach's α value and KMO value of each factor.

Factor	Cronbach's α Value	KMO Value
Driving safety knowledge	0.564	0.645
Traffic safety attitude	0.859	0.781
Risk perception	0.567	0.745
Risky driving behavior	0.893	0.929

3.4. Analytical Method

Multiple linear regression is a quantitative analysis method that describes the degree to which multiple variables are simultaneously associated with a continuous outcome. Multiple regression can provide an understanding and interpretation of each variable based on the coefficients when building the model. The expression of the results of the regression can be analyzed quantitatively, using specific data to reveal the degree of influence of safety knowledge, the construct of safety attitude on risky driving behavior and the variability of risky driving behavior of e-bike drivers with different characteristics. The ease of interpretation of multiple regression makes it difficult to replace in the fields of physics, economics and business.

Multiple regression analysis incorporates multiple useful predictive variables into the regression equation. Therefore, the residual error is reduced, and the explanatory ability of variables is increased. In this study, the stepwise regression analysis method is used. First, the maximum and minimum F values of the independent variables are set. Then, the method uses the above-mentioned forward selection method and the reverse elimination method. Finally, the F values of the independent variables between the set maximum and the minimum F value of the independent variable are kept [26].

In multiple regression analysis, multiple tests are carried out to ensure the stability and credibility of the results. Firstly, the variance inflation coefficient of the estimated values of the multiple regression model parameters is tested to determine whether there is a linear overlap between the independent variables. The Durbin–Watson method is used to test the autocorrelation between independent variables. After passing the hypothesis test, the F statistic is used to test whether the overall regression model is valid. Then, the revised coefficient of determination is used to determine the proportion of the overall explanatory independent variable that can explain the variation in the dependent variable. Finally, the explanatory power and significance of the main influencing factors are tested by a *t* test. The test methods are summarized in Table 8.

Table 8. Test criteria for multiple regression models.

Test Items	Inspection Content
Durbin–Watson test	Test whether the residual term has a first-order self-correlation problem DW value, is close to 2 Show that there is no significant self-correlation between residuals
VIF statistics	Parameter estimate variance expansion factor, to test whether there is a linear coincidence between the independent variables MAX VIF < 10 means wireless coincidence phenomenon
After adjustment R2 Coefficient of determination	Measure the explanatory power of the overall independent variable of the regression equation to the dependent variable
F statistics	Test whether the overall regression model is valid and whether the test result rejects all null hypotheses with a coefficient of 0
T statistics	Test whether the regression coefficient is 0; the test result rejects the null hypothesis for which the regression estimate β is 0

4. Resulting Analysis

According to the above method, safety knowledge, safety attitude (three factors) and age of interviewees [17] are identified as five independent variables. Aggression, negligence and violation in risky driving behavior are identified as dependent variables.

4.1. Modeling

In the regression model, risky driving behavior Y is the explanatory variable, where y_1 is aggressive behavior, y_2 is negligent behavior and y_3 is violation behavior. Five variables, namely, safety knowledge x_1, responsibility attitude x_2, violation attitude x_3, group behavior attitude x_4 and age of interviewees x_5, are taken as explanatory variables to analyze the influence degree of these five variables on aggression, negligence and violation. SPSS software is used to analyze the complex regression of risky driving behavior Y model built in this study, assuming the following relationship between Y and $x_1, x_2 \cdots x_5$:

$$Y = \beta_1 * x_1 + \beta_2 * x_2 + \beta_3 * x_3 + \beta_4 * x_4 + \beta_5 * x_5 + C \tag{3}$$

In Formula (3), C is the random disturbance term; β_1, β_2, β_3, β_4 and β_5 are regression coefficients, the absolute value of which represents the explanatory degree of this variable to Y; and the positive and negative situation represents the direction of influence of this variable on Y.

4.2. Aggressive Behavior

4.2.1. Multiple Regression Analysis of Aggression

With aggressive behavior as the dependent variable, we conducted stepwise regression analysis. The independent variables selected in the model are responsibility attitude x_2 and group behavior attitude x_4.

F = 78.745 and P = 0.000; that is, the regression equation is significant. The maximum VIF statistic is 1.070, indicating that there is no linear coincidence; the DW value of 1.735 indicates that there are no self-related problems within the acceptable range. R^2 = 0.624, indicating that responsibility attitude and group behavior attitude explain 62.4% of the variation in aggressive behavior.

$$y_1 = -0.123 * x_2 + 0.506 * x_4 + 1.363 \tag{4}$$

The specific results are shown in Table 9.

Table 9. Results of multiple regression analysis of aggression.

Dependent Variable	Elected to the Independent Variable	Coefficient	T Test		VIF Statistic	F Test		R-Squared	D-W Value
			T Value	*p* Value		F Value	*p* Value		
Aggression	Constant term	1.363	11.431	0.000	—				
	Responsible	−0.123	−3.508	0.000	1.070	78.745	0.000	0.624	1.735
	Group behavior attitude	0.506	10.668	0.000	1.058				

4.2.2. Analysis of Differences in Aggressive Behavior

In terms of social characteristics, the test results show that male drivers have a different performance from female drivers in aggressive behavior. Multiple comparisons show that the frequency of aggressive behavior of male drivers is significantly higher than that of female drivers. The relevant results are summarized in Table 10. The test results show that there is a significant difference between aggressive behaviors and violation behavior. Multiple comparisons show that the frequency of aggressive behavior of drivers who committed rule-breaking before is significantly higher than that of drivers who did not. The relevant results are summarized in Table 11.

Table 10. Test results of aggressive behavior—differences in social characteristics.

Variable		Mean Value	F Value	Saliency	Multiple Comparisons
Gender	①. Male	2.73	7.31	0.007	① > ②
	②. Female	2.29			
Age	①. Under the age of 16	2.39	0.597	0.44	—
	②. 17–25	2.36			
	③. 26–45	2.25			
	④. 46 years old or above	2.29			
Level of education	①. Junior high school or below	2.29	0.015	0.904	—
	②. Senior high school	2.18			
	③. College or above	2.39			
Motor vehicle driving license	①. Have	2.25	0.571	0.45	—
	②. Do not have	2.32			
Profession	①. Office clerk	4.21	0.022	0.881	—
	②. Student	4.29			
	③. Self-employed	4.31			
	④. Other	4.19			

4.3. Negligent Behavior

4.3.1. Multiple Regression Analysis of Negligent Behavior

With negligent behavior as the dependent variable, we conducted stepwise regression analysis, and three independent variables were selected for the resulting model, namely, safety knowledge x_1, responsibility attitude x_2 and age x_5.

Table 11. Test results of aggression—differences in driving experience.

Variable Factor		Mean Value	F Value	Significance	Multiple Comparisons
Vehicle type	①. Treadle type	2.33	0.188	0.665	—
	②. Motor scooter	2.28			
Driving age of the electric vehicle	①. 1–3 years	2.28	0.011	0.918	—
	②. 4–7 years	2.21			
	③. More than 8 years	2.75			
Driving frequency	①. 1–5 times per week	2.28	0.044	0.833	—
	②. 6–10 times per week	2.31			
	③. >11 times per week	2.11			
Driving distance	①. 4 km below	2.02	0.958	0.328	—
	②. 5–10 km	2.35			
	③. 11 km above	2.31			
Violations experience	①. Yes	2.51	3.818	0.048	① > ②
	②. No	2.10			
Accident experience	①. Yes	2.10	0.903	0.343	—
	②. No	2.30			
Injury type	①. Unhurt	2.30	0.296	0.587	—
	②. Slightly wounded	2.28			
	③. Severely wounded	2.67			

F = 21.218 and P = 0.000; that is, the regression equation is significant. The maximum VIF statistic is 1.102, indicating that there is no linear coincidence. The DW value of 1.542 indicates that there are no self-related problems within the acceptable range. R^2 = 0.485, indicating that 48.5% of the variation in negligent behavior is caused by age, safety knowledge and responsibility attitude variation.

$$y_2 = -0.108 * x_1 - 0.148 * x_2 - 0.229 * x_5 + 2.237 \tag{5}$$

The specific results are shown in Table 12.

Table 12. Regression analysis results of negligent behavior.

Dependent Variable	Elected Independent Variable	Coefficient	T Test		VIP Statistics	F Test		Adjusted R-Squared	D-W Value
			T Value	p Value		F Value	p Value		
Negligent Behavior	Constant term	2.237	14.315	0.000	—				
	Age	−0.229	−4.666	0.000	1.051	21.218	0.000	0.485	1.542
	Safety knowledge	−0.108	−2.863	0.004	1.102				
	Responsible attitude	−0.148	−4.100	0.000	1.101				

4.3.2. Analysis of Differences in Negligent Behavior

In terms of social characteristics, the test results show that gender and age have a significant impact on the negligent behavior of electric bicycle drivers. Multiple comparisons show that the frequency of negligent behavior of male drivers is significantly higher than that of female drivers. The frequency of negligent behavior of drivers aged 17–45 is significantly higher than that of drivers over 46 years old. The relevant results are shown in Table 13. The differences in negligent behaviors in driving experience were tested, and the test results show that there are significant differences in violations and accident experiences of negligent behaviors. Multiple comparisons show that drivers with previous experience of violations and accidents have a higher frequency of negligent behavior than drivers without experience of violations and accidents. The relevant results are shown in Table 14.

Table 13. Test results of negligent behavior—differences in social characteristics.

Variable		Mean Value	F Value	Saliency	Multiple Comparisons
Gender	①. Male	2.93	3.81	0.039	① > ②
	②. Female	2.05			
Age	①. Under the age of 16	1.93	4.078	0.007	② > ④
	②. 17–25	2.53			
	③. 26–45	2.43			
	④. 46 years old or above	2.04			
Level of education	①. Junior high school or below	2.63	0.056	0.812	—
	②. Senior high school	2.33			
	③. College or above	2.25			
Motor vehicle driving license	①. Have	2.09	1.797	0.181	—
	②. Do not have	2.71			
Occupation	①. Office clerk	2.10	1.86	0.173	—
	②. Student	2.34			
	③. Self-employed	2.69			
	④. Other	2.55			

4.4. Illegal Behavior

4.4.1. Multiple Regression Analysis of Violation Behavior

With negligent behavior as the dependent variable, we conducted stepwise regression analysis, and three independent variables were selected for the resulting model, namely, safety knowledge x_1, responsibility attitude x_2 and age x_5.

F = 40.543 and P = 0.000; that is, the regression equation is significant. The maximum VIF statistic is 1.500, indicating that there is no linear coincidence. The DW value of 1.765 indicates no self-related problems within the acceptable range. R^2 = 0.52, indicating that 52% of the variation in violations is caused by the variation in age, violation attitude and group behavior attitude.

$$y_3 = 0.151 * x_3 + 0.225 * x_4 - 0.125 * x_5 + 2.072 \quad (6)$$

The specific results are shown in Table 15.

4.4.2. Analysis of Differences in Violation Behavior

In terms of social characteristics, the test results show that there are significant differences in the violations of electric bicycle drivers of different ages and educational levels. Multiple comparisons show that the frequency of violations of drivers aged 17–45 years is significantly higher than that of drivers over 46 years old, and the frequency of violations of drivers with a high school education or above is higher than that of drivers with junior high school education or below. The relevant results are shown in Table 16. The test results show that violation behaviors have significant differences based on the violation situation and prior accident experience. Multiple comparisons show that drivers with previous experience of violations and accidents have a higher frequency of violations than drivers without experience of violations and accidents. The relevant results are shown in Table 17.

Table 14. Results of negligent behavior—differences in driving experience.

Variable Factor		Mean Value	F Value	Saliency	Multiple Comparisons
Vehicle type	①. Treadle type	2.36	0.05	0.823	—
	②. Motor scooter	2.42			
Driving age of the electric vehicle	①. 1–3 years	2.54	1.349	0.246	—
	②. 4–7 years	2.66			
	③. More than 8 years	2.50			
Driving frequency	①. 1–5 times per week	2.51	2.252	0.134	—
	②. 6–10 times per week	2.26			
	③. >11 times per week	2.45			
Driving distance	①. 4 km or below	2.34	2.721	0.1	—
	②. 5–10 km	2.41			
	③. 11 km or above	2.19			
Violation experience	①. Yes	2.38	6.941	0.004	① > ②
	②. No	2.25			
Accident experience	①. Yes	2.56	11.616	0.001	① > ②
	②. No	2.39			
Injury type	①. Unhurt	2.39	0.119	0.73	—
	②. Slightly wounded	2.04			
	③. Severely wounded	2.67			

Table 15. Results of multiple regression analysis of violations.

Dependent Variable	Elected to the Independent Variable	Coefficient	T Test		VIF Statistic	F Test		R-Squared	D-W Value
			T Value	*p* Value		F Value	*p* Value		
Aggression	Constant term	2.072	16.061	0.000	—	40.543	0.000	0.520	1.765
	Age	−0.125	−3.306	0.001	1.160				
	Bad attitude	0.151	2.497	0.004	1.500				
	Group behavior attitude	0.225	2.921	0.013	1.312				

Table 16. Test results of non-compliance—differences in social characteristics.

Variable		Mean Value	F Value	Saliency	Multiple Comparisons
Gender	①. Male	2.11	0.051	0.822	—
	②. Female	2.13			
Age	①. Under the age of 16	2.15	5.512	0.019	②, ③ > ①, ④
	②. 17–25	2.41			
	③. 26–45	2.39			
	④. 46 years old or above	2.07			
Level of education	①. Junior high school or below	2.32	4.841	0.028	③ > ①, ②
	②. Senior high school	2.39			
	③. College or above	2.47			
Motor vehicle driving license	①. Have	2.16	0.477	0.49	—
	②. Do not have	2.10			
Occupation	①. Office clerk	2.12	0.193	0.66	—
	②. Student	2.19			
	③. Self-employed	2.08			
	④. Other	2.03			

Table 17. Violations—results of variance test on driving experience.

Variable Factor		Mean Value	F Value	Significance	Multiple Comparisons
Vehicle type	①. Treadle type	2.05	0.171	0.68	—
	②. Motor scooter	2.09			
Driving age of the electric vehicle	①. 1–3 years	2.44	0.162	0.687	—
	②. 4–7 years	2.26			
	③. More than 8 years	2.35			
Driving frequency	①. 1–5 times per week	2.18	2.316	0.129	—
	②. 6–10 times per week	2.53			
	③. >11 times per week	2.26			
Driving Distance	①. 4 km or below	2.21	0.792	0.374	—
	②. 5–10 km	2.17			
	③. 11 km or above	2.03			
Violations experience	①. Yes	2.37	4.269	0.031	① > ②
	②. No	2.08			
Accident experience	①. Yes	2.36	2.540	0.040	① > ②
	②. No	2.07			
Injury type	①. Unhurt	2.05	0.230	0.632	—
	②. Slightly wounded	2.14			

5. Discussion

This article analyzes the influence of safety knowledge, safety attitude and other factors on risky driving behavior, and studies the differences in risky driving behavior from the perspective of personal characteristics.

As for aggressive behavior, the results show that a responsible attitude is negatively correlated with aggressive behavior. With an increase in the degree of identification with a responsible attitude, the frequency of aggression decreases. Group behavior attitude is positively correlated with aggressive behavior. The frequency of aggressive behavior increases with an increase in the degree of identification with the group behavior attitude. The estimated coefficient of group behavior attitude is 0.506, indicating that group behavior attitude is the variable with the greatest influence of all independent variables. Therefore, this study speculates that aggression occurs because of the obvious group behavior attitude of electric bicycle drivers, rather than the intentional aggression caused by other factors such as safety knowledge. Male drivers are more likely to engage in aggressive behaviors than female drivers. A study of motorcycles by Shinar [27] and others found that men were more likely to engage in aggressive behavior than women. The study also found that more educated drivers were more likely to have aggressive behavior. This is a conclusion we did not reach. There is no significant difference in aggressive behaviors in terms of age, which is likely due to the fact that electric bicycles are not as difficult to operate as motor vehicles and motorcycles.

Regarding negligent behavior, the results showed that age, safety knowledge and responsible attitude are negatively correlated with negligent behavior. The frequency of negligent behavior decreases with an increase in age, safety knowledge and the degree of identifying with a responsible attitude. These conclusions are consistent with the research results in other literature in China. For example, Chan [28] found, based on data from an e-bike questionnaire in Taiwan, China, that increasing knowledge, ability and age reduce the frequency of negligent behavior. The frequency of negligent behaviors of drivers over 45 years old is less than that of drivers between 17 and 45 years old, which is consistent with the conclusion of multiple regression analysis. Age can reduce the frequency of negligent behaviors. The frequency of negligent behaviors of drivers with previous rule-breaking and accident experience is significantly higher than that of drivers without rule-breaking and accident experience. These results are attributed to the fact that drivers failed to learn lessons from their previous errors, which caused fewer economic losses in the past due to rule-breaking and accidents.

In terms of violation behavior, the results show that with an increase in age, the frequency of violation behavior decreases greatly. Moreover, the higher the degree of identification with noncompliant attitudes and group behavior attitudes, the greater the frequency of noncompliant behavior. Drivers with high school education or above have a higher frequency of violations than drivers with middle school education or below. Shinar et al. [27] also showed that drivers with a higher level of education are more likely to commit violations. Wang et al. [3] found in their study of e-bikes that violations also showed gender differences, with male drivers having a higher frequency of violations compared to female drivers.

Safety knowledge has a significant negative correlation with unintentional negligent behaviors, but has no significant correlation with intentional violations and aggressive behaviors. This result indicates that the safety knowledge of electric bicycle drivers can be strengthened to effectively reduce the frequency of negligent behaviors among them [29]. The difference analysis should be combined to determine the group with low safety knowledgeability. Drivers who are older, experienced or who have not accepted the latest safety knowledge are more prone to act negligently. For intentional dangerous driving behavior, we can consult the safety attitudes and risk perceptions of electric bicycle drivers.

6. Conclusions

We used multiple regression analysis methods to study the impact of two dimensions of safety knowledge and safety attitudes on risky driving behavior. We analyzed the differences in the impact of the two dimensions of safety knowledge and safety attitudes on risky driving behavior from the perspective of personal characteristics. The results show:

1. It is common for electric bicycle drivers to lack driving safety knowledge, to have weak awareness of traffic safety and to engage in dangerous driving behavior. Without special training or education, electric bicycle drivers have little understanding of traffic laws and respect for regulations, a low level of driving politeness and little

awareness of defensive safe driving. They mainly rely on their driving skills to ensure their safety.
2. The improvement of safety knowledge can effectively reduce the risky driving behavior of electric bicycle drivers due to their negligence, but has no significant correlation with intentional violations and aggression.
3. Aggressive behavior occurs due to the obvious "group behavior attitude" of electric bicycle drivers. With increasing age, the frequencies of negligence and violation behavior decrease significantly.
4. Drivers of different social characteristics and driving experiences show prominent differences in the frequency of risky driving behavior. Males are more prone to aggressive and negligent behavior than females. Drivers with previous violation records are more likely to commit aggression and engage in negligent behaviors than drivers without violation records. Drivers aged 17 to 45 are more prone to aggression and negligent behaviors than drivers of other ages.

7. Applications and Suggestions

The survey data for this study are from Guilin, China; thus, the findings of this study are applicable to similar small- and medium-sized cities, which have more extensive non-motorized transportation systems and more complete urban support facilities. Residents are more accustomed to traveling short distances, and urban and rural areas are closer to the city center.

(1) Education is an effective measure to reduce risky driving. It is necessary to train and educate e-bike drivers on professional traffic safety laws and regulations and driving skills.
(2) The safety of e-bike drivers is mainly ensured by their appropriate driving behavior. A safe and convenient riding environment is conducive to improving the driving behavior of e-bike drivers. Urban street design should focus on developing e-bike-friendly city streets, setting up nonmotorized lanes and nonmotorized crossing waiting areas and avoiding secondary crossings as much as possible in areas with heavy traffic conditions.
(3) Electric bicycle drivers are prone to speeding. The oversized electric bicycles and modified vehicles should be strictly controlled. The control of the market source should be strengthened. In addition, e-bike drivers do not have an awareness of using helmets. Helmet use, along with awareness of self-defensive driving, should be promoted among e-bike drivers.
(4) As the subjects of this study are self-owned electric bicycles, the drivers will take into account their bike's economic value before engaging in risky driving behavior. When using shared e-bikes in a new environmentally friendly sharing economy, drivers need to consider fewer factors when riding. Subsequent studies can use shared e-bikes as the research objects and compare the results with those of ordinary household electric bicycles.
(5) Sustainability is undoubtedly a theme for future transportation development [30]. Motorized or nonmotorized vehicles powered by electricity have become a trend. From a sustainable perspective, configurations such as charging stations powered by renewable energy must be studied [31].

Author Contributions: Conceptualization, D.Z. and M.C.; methodology, D.Z. and M.C.; software, M.C. and H.X.; validation, D.Z., M.C. and G.G.; formal analysis, D.Z. and M.C.; investigation, M.C. and G.G.; resources, M.C. and T.W.; data curation, D.Z., M.C. and G.G.; writing—original draft preparation, D.Z., M.C. and X.S.; writing—review and editing, D.Z., M.C. and X.S.; visualization, D.Z., M.C. and H.X.; supervision, D.Z., M.C. and W.W.; project administration, M.C.; and funding acquisition, D.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Natural Science Foundation of China (grant no. 71861005, 71861006).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data used in the study are available from the corresponding author upon request.

Conflicts of Interest: The authors declare that they have no conflict of interest.

References

1. Yan, X.; Wang, T.; Ye, X.; Chen, J.; Yang, Z.; Bai, H. Recommended widths for separated bicycle lanes considering abreast riding and overtaking. *Sustainability* **2018**, *10*, 3127. [CrossRef]
2. Fishman, E.; Cherry, C. E-bikes in the mainstream: Reviewing a decade of research. *Transp. Rev.* **2016**, *36*, 72–91. [CrossRef]
3. Wang, T.; Li, W.H.; Xie, S.H.; Chen, J. Factor analysis and related factors study on electric bicycle risk driving behavior. *Chongqing Jiaotong Univ. Nat. Sci.* **2019**, *38*, 118–126. [CrossRef]
4. Yan, X.P.; Zhang, H.; Wu, C.Z.; Mao, J.; Lei, H. Research progress and the prospect of road traffic driving behavior. *J. Transp. Inf. Saf.* **2013**, *31*, 45–51.
5. Reason, J.; Manstead, A.; Stradling, S.; Baxter, J.; Campbell, K. Errors and violations on the roads: A real distinction? *Ergonomics* **1990**, *33*, 1315–1332. [CrossRef]
6. Yao, L.; Wu, C.X. Traffic safety for electric bike riders in china attitudes, risk perception, and aberrant riding behaviors. *Transp. Res. Rec.* **2012**, *2314*, 49–56. [CrossRef]
7. Tao, D.; Zhang, R.; Qu, H.D. The effects of gender, age, and personality traits on risky driving behaviors. *J. Shenzhen Univ. Sci. Eng.* **2016**, *33*, 646–652. [CrossRef]
8. Yang, S. Questionnaire design and test of its reliability and validity for electric bicycle riding behavior. *J. Transp. Eng.* **2019**, *3*, 57–62. [CrossRef]
9. Cornelia, M.; Eugen, H.C. The relation between mortality salience, traffic locus of control, and risky driving behavior. *Death Stud.* **2021**, *45*, 141–151. [CrossRef]
10. Yang, J.S. Analysis of driving behavior intervention technology to prevent road traffic accidents. *Chin. J. Ergon.* **2005**, *03*, 38–40. Available online: http://www.cqvip.com/qk/83524x/200503/20198256.html (accessed on 1 December 2021).
11. Niu, S.F.; Li, G.Q.; Zhang, S.W. Driving risk assessment model of commercial vehicle driver driven by satellite positioning data. *China J. Highw. Transp.* **2020**, *33*, 202–211. [CrossRef]
12. Zhang, X.X.; Wang, X.S.; Ma, Y.; Ma, Q.B. International Research Progress on driving behavior and driving risk. *China J. Highw. Transp.* **2020**, *33*, 1–17. [CrossRef]
13. Gao, K.; Yang, Y.; Sun, L.J.; Qu, X.B. Revealing psychological inertia in mode shift behavior and its quantitative influences on commuting trips. *Transp. Res. Part F Traffic Psychol. Behav.* **2020**, *71*, 272–287. [CrossRef]
14. Gao, K.; Sun, L.J.; Yang, Y.; Meng, F.Y.; Qu, X.B. Cumulative prospect theory coupled with multi-attribute decision making for modeling travel behavior. *Transp. Res. Part A Policy Pract.* **2021**, *148*, 1–21. [CrossRef]
15. Dan, J.Y.; Li, Z.Z. A review on the influencing factors of risky driving behavior. *Chin. J. Ergon.* **2013**, *19*, 86–91. [CrossRef]
16. Wang, C.L. Review of research on the effect of physiological factors on behavior and risk perception of drivers. *J. Saf. Sci. Technol.* **2018**, *14*, 155–159.
17. Wang, K.; Xue, Q.; Xing, Y.; Li, C. Improve aggressive driver recognition using collision surrogate measurement and imbalanced class boosting. *Int. J. Environ. Res. Public Health* **2020**, *17*, 2375. [CrossRef]
18. Useche, S.A.; Alonso, F.; Montoro, L.; Esteban, C. Explaining self-reported traffic crashes of cyclists: An empirical study based on age and road risky behaviors. *Saf. Sci.* **2019**, *22*, 627–634. [CrossRef]
19. Yang, M.; Wu, C.Z.; Zhang, H.; Li, S.Y. Influencing factors of driving risk based on critical incident events. *J. Transp. Inf. Saf.* **2018**, *36*, 34–39.
20. Wang, Y.B.; Qin, H.B.; You, Z.D.; Wang, X.S.; Zhao, X.S. Influence of driver's psychological factors on their risky driving behavior. *Auto Saf.* **2019**, *3*, 83–88.
21. Sang, H.Y. Research on the relationship among E-bike riders' attitude towards traffic safety. *J. Xinyu Univ.* **2020**, *25*, 98–106.
22. Gu, N.; Ma, N.; Sun, L. Revision of the dangerous driving behaviorscale and validity and validity test. *Chin. J. Ergon.* **2018**, *24*, 15–19. [CrossRef]
23. Ulleberg, P.; Rundmo, T. Personality, attitudes and risk perception as predictors of risky driving behaviour among young drivers. *Saf. Sci.* **2003**, *41*, 443. [CrossRef]
24. Ni, D.; Guo, F.; Zhou, Y.; Shi, C. Determination of risk perception of drivers using fuzzy-clustering analysis for road safety. *IEEE Access* **2020**, *8*, 125501–125512. [CrossRef]
25. Heckler, C.E. A Step-by-Step Approach to Using the SAS™ System for Factor Analysis and Structural Equation Modeling. *Technometrics* **2012**, *38*, 296–297. [CrossRef]
26. You, S.B.; Yan, Y. Stepwise regression analysis and its application. *Stat. Decis.* **2017**, 31–35. [CrossRef]
27. David, S.; Edna, S.; Richard, C. Self-reports of safe driving behaviors in relationship to sex, age, education and income in the US adult driving population. *Accid. Anal. Prev.* **2001**, *33*, 111–116. [CrossRef]

28. Chen, C. Personality, safety attitudes and risky driving behaviors—Evidence from young Taiwanese motorcyclists. *Accid. Anal. Prev.* **2009**, *41*, 963–968. [CrossRef]
29. Zhang, T.R.; Qu, X. The role of personality traits and driving experience in self-reported risky driving behaviors and accident risk among Chinese drivers. *Accid. Anal. Prev.* **2017**, *99*, 228–235. [CrossRef]
30. De Dios Ortúzar, J. Future transportation: Sustainability, complexity and individualization of choices. *Commun. Transp. Res.* **2021**, *1*, 100010. [CrossRef]
31. Liu, J.; Dai, Q. Portfolio Optimization of Photovoltaic/Battery Energy Storage/Electric Vehicle Charging Stations with Sustainability Perspective Based on Cumulative Prospect Theory and MOPSO. *Sustainability* **2020**, *12*, 985. [CrossRef]