Original Article

Road traffic safety: An analysis of the cross-effects of economic, road and population factors

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A R T I C L E   I N F O

A B S T R A C T

Purpose: Through the study of economic, traffic and population data related to road traffic accidents from 2004 to 2016, this paper analyzed the impact of various factors on road traffic casualties in China, and provided theoretical basis and suggestions for the road traffic safety management in China.
Methods: Based on three aspects (economy, road, population) with five factors (gross domestic product (GDP), traffic investment, new vehicle ownership, new road mileage and newly increased population), this paper collected the relevant data of road traffic accidents in 31 provinces and cities in China, from 2004 to 2016. A panel model was established to carry out empirical analysis.
Results: All factors have a significant impact on the number of road traffic accident casualties. When other factors remain unchanged, the number of road traffic casualties decreased by an average of 0.19 for every 100 million CNY increased in GDP. For every 100 million CNY increased in traffic investment, the number of road traffic casualties is reduced by an average of 13.93, indicating that economic develop-ment can improve road traffic safety to a certain extent. On the contrary, the growth in road mileage, new motor vehicles and population has increased the number of road traffic casualties. For every 10, 000 km of new road mileage, the number of traffic accident casualties has increased by 284.04. For every 10,000 newborns, the number of road traffic casualties increased by 7.33; as the number of new motor vehicles increases by 10,000, the number of road traffic casualties increased by an average of 21.77.
Conclusion: The increase of GDP and traffic investment can significantly reduce the number of road traffic casualties in China, which shows that economic development is essential to improve road traffic safety. The numbers of new road mileage, newly increased population and the new motor vehicles are positively correlated with the number of traffic accident casualties in traffic accidents, which reflects the existing problems in road design, distribution of road resources, and traffic management in China. Therefore, it is necessary to improve the economic and road related aspects to improve road traffic safety.

Introduction

With the continuous development of China's economy, the state's investment in transportation has also been increasing. In 2004, the amount of investment in transportation in China was 764.623 billion CNY, and since then it has continued to increase every year, breaking through 5 trillion CNY in 2016, an increase of 601.37%. The rapid growth of traffic investment also reflects the continuous improvement of the country's attention to traffic issues.[1] With the rapid expansion of roads, the total number of road mileage has been increasing. The total number of road mileage in China has increased from 1.87 million km in 2004 to 4.70 million km in 2016, an increase of 151.05% in 13 years. The improvement of people's living standards has not only increased the road mileage, followed by the increase in the number of motor vehicles. The number of motor vehicles in China was 107.8344 million in 2004 and reached 278.3408 million in 2016, with a growth rate of 258.12%.[2] The proliferation of motor vehicles has made the contradiction between people, cars and roads increasingly promi-nent, at the same time, it has also brought great pressure to the traffic environment. Therefore, it is still an important direction for the government and academia to study the influencing factors of road traffic accident casualties and put forward countermeasures to alleviate road traffic safety.[3]

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At present, many researchers focus their researches on the influencing factors of traffic accident casualties on people, car and road. From a human point of view, Li et al.,[4] through the regression fitting of traffic accident data, using zero-inflated negative binomial (ZINB) regression model, found that the seniority of drivers has a significant impact on the number of road traffic accident casualties, and put forward a strategy to allow highly qualified drivers to control the speed as far as possible. From the point of view of vehicle, Wang et al.[5] believe that the damage caused by dangerous goods is particularly serious in the major cargo transportation accidents in China every year, which not only caused casualties and economic losses, but also caused serious damage to the ecological environment. In terms of road factors, Shi et al.[6] applied logistic regression analysis to analyze the influencing factors of expressway traffic accidents. It was found that the main factors affecting the casualties of expressway traffic accidents are gender, accident pattern, driver type, responsibility reasons, etc. In order to study the traffic accidents in highway tunnels, Shen et al.[7] made a statistical analysis on the geographical location and casualties of highway tunnel traffic accidents occurred in China from 2001 to 2017. The study found that the average number of casualties in the tunnel is the highest. Through the study of road factors, some scholars found that the number of new road mileage has a significant impact on road traffic accident casualties. With the increase of new road mileage, the number of road traffic accident casualties will decrease significantly.[8]

Studies on road traffic safety mainly focused on the improvement of vehicles safety performance, road design improvement, optimization of road traffic environment and other aspects. However, the analysis of road traffic safety factors from the data level is not deep enough. In order to improve the traffic safety of rear-end collision between conventional driving vehicles and intelligent network vehicles, Qin et al.[9] proposed to mix conventional vehicles with intelligent network vehicles to optimize the control of traffic flow fleet to ensure road traffic safety. Si et al.[10] considered that road traffic safety is closely related to road traffic environment. By establishing an evaluation system of traffic environment factors such as weather, road surface and terrain, it was found that traffic environment factors have a great impact on traffic safety. In order to understand the impact of vehicle, road and environmental factors on road traffic safety, Chu et al.[11] found that all factors will have an impact on road traffic safety by analyzing the relationship between the factors and through the interpretation of structural diagram. Among them, the most fundamental factors affecting road traffic safety are the type of road surface, the completeness of road facilities, the number of one-way lanes and terrain features.

It can be seen that researchers have analyzed the factors of road traffic accident casualties and road traffic safety from various aspects. However, from the perspective of the impact of traffic accident casualties, it is mainly to study the impact of people, vehicles and roads on traffic accident casualties separately. There are few ways to think about the economic-road-population factors, and at the same time, there is a lack of research on the incremental impact of various variables. The policy recommendations are only on the optimization of rescue mechanism and management mechanism. From the perspective of road traffic safety, it is mainly from the macro level, policy recommendations are only based on theoretical analysis, lack of effective data support, and there is little research on road traffic safety through data analysis related to traffic accident casualties.

Based on the existing research and the panel data of China from 2004 to 2016, this paper comprehensively considered the economic, road and population factors, and selects the economic factors: gross domestic product (GDP), new motor vehicle ownership and traffic investment; road factor: new road mileage; population factor: the number of newly increased population. Through analyzing the influence of specific variables of each factor on traffic accident casualties, to put forward corresponding suggestions and management measures for the development of road traffic safety in China, so as to provide theoretical basis and data support for improving road traffic safety in China.

Methods

Data source and sample interval description

The panel data related to road traffic in 31 provinces (municipalities directly under the central government/autonomous regions) of China from 2004 to 2016 were obtained from the Traffic Administration Bureau of the Ministry of Public Security, the statistical annual report of road traffic accidents of the People's Republic of China, the website of the national bureau of statistics (http://www.stats.gov.cn/) and the websites of provincial and municipal statistical offices.

Selection and explanation of various factors

Road traffic safety is affected by population, vehicle ownership, road mileage, traffic investment and economic development. Population growth is the subjective factor affecting road traffic safety. Vehicle ownership growth is an important factor affecting road traffic safety. Road mileage expansion, traffic investment and economic development are the guarantees to improve road traffic safety.[12–14] The indicators to measure economic development are GDP, household consumption level, residents' consumption level, car ownership and so on.[15] In order to explore the specific relationship between the number of road traffic accident casualties and various factors, and then explore the direction of road traffic safety improvement, this paper preliminarily selects per capita disposable income (PDI), residents' consumption level (RCL), GDP, new road mileage, traffic investment, the newly increased population and the new vehicle ownership as explanatory variables, and taking the number of traffic accident casualties as the explained variable for regression analysis. Before the establishment of the regression model, the variables are briefly described and counted, and then the collinear analysis is carried out to eliminate the serious collinear variables to ensure the accuracy of the regression model results.

Descriptive statistics of sample data

From Table 1, we can see that the average number of traffic accident casualties in China's provinces and cities from 2004 to 2016 is 12,012. The number of traffic accident casualties is distributed between 495 (Tibet, 2016) and 89, 219 (Guangdong, 2004), with a standard deviation of 11,793.78, which indicates that there are great differences in the number of traffic accident casualties in different provinces and cities in different years. The average GDP of provinces and cities in China in different years is 1480.46 billion CNY, which ranges from 22.034 billion CNY (Tibet, 2004) to 8085.491 billion CNY (Guangdong, 2016) with a range of 1416.898 billion CNY, indicating that the economic development of different regions in different periods is extremely unbalanced. The road mileage of each province increased by an average of 7200 km per year, and the new road mileage is distributed between 1.38 (inner Mongolia, 2008) and 15.69 (Henan, 2006) km. The investment planning of road mileage varies greatly from province to city in different years.

Generally speaking, from 2004 to 2016, the average number of traffic accident casualties in China's provinces and cities is more than 10,000 per year, and the number is very large. Due to the

Table 1
Descriptive statistical results.

Variables	Sample size	Minimum	Maximum	Mean	Standard deviation
Traffic accident casualties (n)	403	495.0	89219.00	12012.00	11793.78
Residents' consumption level (¥)	403	2723.00	49617.00	11921.96	8021.76
Per capita disposable income (¥)	403	3246.64	54305.35	13698.17	8550.01
GDP (billion ¥)	403	220.34	80854.91	14804.60	14168.98
New road mileage (ten thousand km)	403	−1.38	15.69	0.72	1.63
Traffic investment (billion ¥)	403	0.57	1982.63	161.50	180.90
Newly increased population (ten thousand)	403	−372.00	321.20	24.26	60.13
New vehicle ownership (ten thousand)	403	−102.23	272.83	49.12	4.30

GDP: gross domestic product.

different levels of regional and economic development in different provinces and cities, the economic indicators of RCL, PDI and GDP are very different. It shows that the degree of economic development varies greatly in different times and regions. Although the number of population and the motor vehicle ownership sometimes increased and sometimes decreased in different years, they both generally showed an increasing trend. With the change of traffic investment, the road mileage of each province also changes accordingly, and it increases by an average of 7200 km per year.

Collinearity test

The occurrence of road traffic accidents is not the result of a single factor, but the result of the interaction of many factors.[16] Because many factors may influence each other, if there is multiple collinearity in the explanatory variables, it is not easy to distinguish the degree of their separate influence on the respective explained variables. Therefore, when analyzing the relationship between the road traffic accident casualties and RCL, PDI, GDP, new road mileage, traffic investment, newly increased population and new vehicle ownership, in order to avoid the possible high correlation among the factors and distort the estimation of the model, the multiple collinearity test is carried out on the seven explanatory variables in 31 provinces of China from 2004 to 2016 to test whether the independent variables are completely collinear. The test results are shown in the table below.

Variables selection

Table 2 shows that the tolerance of RCL and PDI <0.1, and the variance inflation factor (VIF) > 10, indicating that there is a serious collinearity between these two variables and other variables, and the tolerance values of GDP, new road mileage, traffic investment, newly increased population and new vehicle ownership are all > 0.1. And the VIF of each variable is < 10, which indicates that there is no serious collinearity between these five variables and other variables. In order to avoid the model estimation distortion caused by multiple collinearities among the factors, two variables RCL and PDI with serious collinearity are eliminated, and the

Table 2
Multiple collinearity test.

Variables	Collinearity statistics	
	Tolerance	VIF
Residents' consumption level	0.032	31.172
Per capita disposable income	0.032	31.003
Gross domestic product	0.312	3.203
New road mileage	0.920	1.087
Traffic investment	0.440	2.275
Newly increased population	0.904	1.106
New vehicle ownership	0.710	1.409

VIF: variance inflation factor, GDP: gross domestic product.

remaining five variables are taken as the explanatory variables of the model for further analysis.

Endogenous and exogenous variables

The number of casualties in traffic accidents is affected by GDP, new road mileage, traffic investment, population and vehicle ownership. It is a variable determined by the model and belongs to an endogenous variable. There is no multiple collinearity among GDP, new road mileage, traffic investment, newly increased population and new vehicle ownership, and the variables do not influence each other, indicating that their changes are determined by factors outside the model, and the relationship among them will not affect the causality within the model, so they belong to exogenous variables in the model.

Building model

In order to study the impact of GDP, new road mileage, traffic investment, newly increased population and new vehicle ownership on the number of casualties in traffic accidents in China, this paper takes panel data of 31 provinces (cities and districts) in China from 2004 to 2016 as research samples and sets the following econometric models:

$$P_{it} = C + \beta_1 GDP_{it} + \beta_2 NRM_{it} + \beta_3 TI_{it} + \beta_4 NIP_{it} + \beta_5 NVO_{it} + \mu_{it} \quad (i = 1, 2, 3...31; \ t = 1, 2, 3...13) \tag{1}$$

"i" means 31 provinces and municipalities; "t" means 13 years; P_{it} means the number of traffic accident deaths (people); C denotes the intercept term; GDP_{it} denotes the gross national product of each province and city; NRM_{it} denotes the number of new road mileage added by each province and city; TI_{it} denotes the traffic investment of each province and city; NIP_{it} denotes the number of newly increased population in each province and city; NVO_{it} denotes the number of new motor vehicles owned by each province and city; μ_{it} is a random error term.

Results

Unit root test

Although panel data can reduce the non-stationarity of data and reduce the correlation of variables, the pseudo-regression of regression model will occur because of the time trend and intercept of variables. Therefore, in order to avoid false regression and ensure the validity of the estimation results, the stability of each panel sequence is tested first.

The panel data unit root test uses the Fisher-ADF test of the heterogeneous panel unit root test and the Levin, Lin & Chut (LLC) test of the homogeneous panel unit root test. The test results are shown in Table 3.

Table 3
Unit root test results of panel data.

Variables	LLC		ADF- Fisher		Results
	Statistic	p value[a]	Statistic	p value[a]	
Traffic accident casualties	−15.7195	<0.0001	142.354	<0.0001	stability
D (GDP)	−8.09038	<0.0001	93.1695	0.0064	stability
New road mileage	−17.4677	<0.0001	216.705	<0.0001	stability
D (Traffic investment)	−10.7701	<0.0001	197.593	<0.0001	stability
Newly increased population	−6.97773	<0.0001	130.266	<0.0001	stability
New vehicle ownership	−11.2114	<0.0001	155.425	<0.0001	stability

D(*) denotes first-order difference.
LLC: Levin, Lin & Chut, GDP: gross domestic product.
[a] Indicates that asymmetric normality is used to calculate probability in Levin, Lin & Chut test, and asymptotic chi-square distribution is used to calculate probability in ADF-Fisher test.

The results of LLC test and ADF-Fisher test showed that the variables traffic accident casualties, new road mileage, newly increased population and new vehicle ownership were stable at the significant level of 1%, so the zero hypothesis of unit root was rejected. The variables GDP and traffic investment are non-stationary at the significant level of 1%, but after the first-order difference, the significant level of 1% is stable, thus rejecting the zero hypothesis of unit root at the level of 1%. The associated probabilities of the two methods reject the original hypothesis at the same time, indicating that the test results of the two methods show that there is no unit root in each variable, so there is no unit root in each variable, and all of them pass the unit root test, which is stable and can be co-integrated.

Cointegration test

The main methods of cointegration test of panel data are Kao test and Pedroni test, both of which get residual statistics from panel data for test.[17,18] Lucianc et al.[19] used Monte Carlo simulation to analyze the different cointegration test methods, and he found that Kao test had a higher efficiency than Pedroni test when T was smaller. Kao test is more suitable for large sample data, because of the large sample data and the small T value, so this paper uses Kao cointegration test. The zero hypothesis is that there is no cointegration relationship. The test results are shown in Table 4.

As shown in the Table 4, the p value of Kao test is 0.0014, so the original hypothesis is rejected at the level 1. There is a long-term cointegration relationship between the explained variable P and the explanatory variables GDP, new road mileage, traffic investment, new increased population and new vehicle ownership.

Table 4
Kao cointegration test results.

	t-statistic	p value
ADF	−2.993222	0.0014
Residual variance	5557785	
HAC variance	7461243	

ADF: augmented Dickey-Fuller test, HAC: Het-ero-skedasticity and autocorrelation consistent co-variance estimator.

Model recognition and estimation

Model recognition. The panel data regression model is mainly divided into three types: random effect model, fixed effect model and mixed estimation model. The results of likelihood ratio test for fixed applications and Hausmann test for random effects show that the p value is 0.0000, thus rejecting the original hypothesis, we should establish an individual fixed effect model (Table 5).

Model estimation. The estimated results of the model are as follows:

$$P_{it} = 15683.67 - 0.19GDP_{it} + 284.04NRM_{it} - 13.93TI_{it} + 7.33NIP_{it} + 21.77NVO_{it}$$

The results show that GDP, traffic investment and new vehicle ownership are significantly correlated with the explained variable traffic accident casualties at 1%, and new road mileage is significantly correlated with the interpreted variable traffic accident casualties at 5%, and newly increased population is significantly correlated with the interpreted variable traffic accident casualties at 10%. According to the linear regression model, GDP, traffic investment and traffic accident casualties are negatively correlated, while new road mileage, new increased population, new vehicle ownership and traffic accident casualties are positively correlated.

The negative correlation between GDP and the number of road traffic accident deaths is embodied in that when other factors remain unchanged, for every 100 million CNY increase in GDP, the number of road traffic accident deaths will decrease by an average of 0.19. The negative correlation between traffic investment and the number of road traffic accident deaths is as follows: when other conditions remain unchanged, the number of road traffic accident deaths decreases by an average of 13.93 for every 100 million CNY increase in traffic investment. The positive correlation between the new road mileage and the number of road traffic accident deaths is embodied in that when other factors remain unchanged, the number of traffic accident casualties increases by 284.04 per 10,000 km of new road mileage. There is a positive correlation between the number of newly increased population and the number of road traffic accident deaths: when other factors remain unchanged, the number of newly increased population increases by 10,000, and the number of road traffic accident deaths increases by 7.33. There is a positive correlation between the number of new vehicles and the number of road traffic accident deaths, when other conditions remain unchanged, the

Table 5
Fixed effect model.

Variables	GDP	NRM	TI	NIP	NVO	F
p value	−0.194011[a] (<0.0001)	284.0369[b] (0.0277)	−13.93141[a] (<0.0001)	7.327572[c] (0.0573)	21.77289[a] (0.0003)	92.90571

Note: [a], [b] and [c] indicate the significant levels of 1%, 5% and 10% respectively, with p value in parentheses.
GDP: gross domestic product, NRM: new road mileage, TI: traffic investment, NIP: newly increased population, NVO: new vehicle ownership.

number of road traffic accident deaths increases by an average of 21.77 per 10,000 new motor vehicles.

Discussion

Based on panel data of 31 provinces and cities in China from 2004 to 2016, this paper studies the impact of economic-road-population factors on road traffic safety in China. The impact of each specific variable is mainly in two aspects. First, there is a significant negative correlation between economic development and road traffic accident casualties. Economic development is the guarantee for improving road traffic safety. The increase of GDP and traffic investment leads to a reduction in the number of casualties in traffic accidents. It is possible that, with the development of economy, the proportion of national investment in traffic construction and network management system continues to increase, which makes various institutional innovations initially effective. At the same time, economic development improves traffic facilities and transport structure, and raised people's awareness of traffic safety. Therefore, economic development not only reduces the number of traffic casualties to a certain extent, but also promotes the improvement of road traffic safety. Second, with the increase of new road mileage, population and vehicle ownership, the number of casualties in road traffic accidents is on the rise, and the road traffic safety situation is aggravated. Newly added road mileage fails to effectively reduce the number of casualties, which closely relates to the uneven distribution of road resources, inappropriate road design and system management. The increase of population significantly relates to the increase of road traffic safety pressure, which is closely related to the weak traffic safety awareness of Chinese citizens. With the increase of new motor vehicles, the number of casualties in traffic accidents is on the rise. Theoretically, under a certain amount of motor vehicle ownership, the number of traffic casualties decreases with the increase of new road mileage. However, with the increase of vehicle ownership and the increase of road mileage, the number of traffic accidents rises with the increase of road mileage. If we do not innovate and still use traditional vehicles, it will inevitably increase the hidden dangers of road traffic safety.

Road traffic system is a dynamic system consisting of people, vehicles, roads and so on. Problems in any link may lead to accidents. With the change of economic, road and population factors, the frequency and number of conflicts and traffic accidents in various links of the system are constantly changing. To improve the level of traffic safety management, we need to think from the aspects of economy, road and population.

In order to improve road traffic safety, various potential safety risks should be taken into account. To reduce the number of casualties in road traffic accidents, the following aspects should be considered:

From the perspective of human factors, drivers are not only the perpetrators of traffic accidents, but also the direct victims of traffic accidents, so drivers' awareness of traffic safety is very important. Because of the confusion in driver training and certification management in China, drivers' consciousness of traffic safety in the whole team is weak. It is still the most important thing to enhance drivers' awareness of traffic safety and standardize drivers' behavior. Therefore, it is necessary to strengthen the driver's traffic safety training, strictly control the process of obtaining a driver's license, and conduct regular education and regular examinations for the driver.

In terms of road factors, the relevant laws and regulations of our country mainly attribute the responsibility of traffic accidents to people, which means that traffic accidents caused by road and other problems have not been taken seriously. On the contrary, the increase of new road mileage has increased the number of casualties in traffic accidents, which reflects the problems existing in

our country's road safety. Therefore, in order to reduce the number of road traffic accident casualties, it is also necessary to consider the road itself. From the point of view of road design, the relevant departments should adopt scientific and reasonable road design, optimize road sight distance design, plane design, profile design, plane combination design and other construction problems, strictly evaluate the safety of third-party roads, and carry out serious examination of road design. In addition, the layout of traffic safety facilities such as traffic signs, traffic static facilities, traffic safety facilities and traffic service facilities should be improved. From the perspective of road management, it is necessary to improve the relevant road management mechanism, establish an effective emergency response plan, clarify the division of responsibilities among departments to improve management efficiency, and improve road traffic safety for preventing traffic accidents.

From the perspective of economic factors, it is essential to ensure the economic development of our country and increase traffic investment. Economic development has a significant positive effect on reducing traffic accident casualties, and is the guarantee of promoting road traffic safety in China. At the same time, we should increase investment in road traffic construction, especially in road network management system, and restrain the increase of road traffic casualties through economic means. Only by effectively reducing the occurrence of road traffic accidents, road traffic safety can be guaranteed. In addition, The increase of motor vehicle ownership has not reduced the number of casualties in traffic accidents, which is closely related to both motor vehicles and drivers. From the perspective of motor vehicles, the performance of motor vehicles has a great impact on road traffic safety, and daily maintenance should be carried out, regularly detecting the technical performance of moving vehicles, standardizing vehicle management, and prohibiting vehicles with poor technical performance from driving on urban roads. At the same time, in order to cope with the increasingly complex driving environment, automobiles innovation is essential. In the future, automobiles should gradually realize intellectualization and networking, develop to the intelligent networked automobile industry, and use new technologies to ensure road traffic safety.

Traffic system is a huge system and the factors affecting traffic safety are interrelated and complex. Although the number of traffic casualties in China is declining, the situation of road traffic safety is not optimistic. Improving road traffic safety needs the joint efforts of individual, government and the society as a whole. In this paper, only a part of the variables of economy, road and population are selected for quantitative analysis, and the non-quantifiable factors are not taken into account. in the future, we can quantify the factors that are not considered, and predict the model to improve the depth of the study.

Ethical statement

Not applicable.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.cjtee.2019.07.004.

References

1. National Bureau of Statistics. China Statistical Yearbook: 2005–2017. http://www.stats.gov.cn/.
2. Traffic Administration Bureau of the Ministry of Public Security. *Annual Report of Road Traffic Accidents of the People's Republic of China*. 2004–2016.
3. World Health Organization. *World Report on Road Traffic Injury Prevention*. Geneva: World Health Organization; 2004.
4. Li R, Zhao LH. Analysis of factors influencing traffic accident casualties. *China Saf Sci J*. 2015;25:123–127.
5. Wang LY. Influencing factors analysis and management suggestions of dangerous goods transportation accidents. *Manag Sci*. 2016;45:33–34, 60.
6. Shi JG, Yao Y, Hou ZH, et al. Influencing factors of expressway traffic accidents. *Chin J Traumatol*. 2008;24:553–557.
7. Shen YJ, Yang Y, Zou XL, et al. Statistics of traffic accidents and assessment of casualties during operation of domestic highway tunnels. *Tunnel Constr*. 2018;38:564–574.
8. Sun LL, Wu Q, Zhao Juan, et al. Empirical study on the influencing factors of traffic accidents in China from 2004 to 2015. *J Southwest Univ (Nat Sci Ed)*. 2018;40:112–118.
9. Qin YY, Wang H. Improvement of traffic safety by intelligent network vehicle traffic flow optimization. *Chin J Highw*. 2018;31:202–210.
10. Si CD, Hu XP, Feng Y, et al. Evaluation of unascertained measurement of traffic environment impact on road safety. *Highw Eng*. 2014;39:59–62.
11. Chu XX, Zong G, Peng ZX, et al. Research on the influencing factors of road traffic safety based on ISM. *J Saf Environ*. 2017;1:1668–1672.
12. Zhai JF, He H. Exploration of safety production grid management in highway transportation industry. *Chin Highw*. 2017;23:88–89.
13. Mu RH, Dong JY. Research on road safety management system in BRICS. *Legal Expo*. 2013;12:308–309.
14. Sun LL, Liu D, Chen T, et al. Analysis on the accident casualties influenced by several economic factors based on the traffic-related data in China from 2004 to 2016. *Chin J Traumatol*. 2019;22:75–79.
15. Ren Y, Peng HX. Empirical analysis on influencing factors of traffic accident casualties in China. *Forecast*. 2013;3:1–7.
16. Gao B. Establishment of economic loss prediction model of road traffic accidents based on PLS. *J Liaoning Police Coll*. 2017;19:59–63.
17. Pedroni P. Critical values for cointegration tests in heterogeneous panels with multiple regression. *Oxf Bull Econ Stat*. 1999;61:653–670. https://doi.org/10.1111/1468-0084.61.s1.14.
18. Kao C. Spurious regression and residual-based tests for cointegration in panel data. *J Econom*. 1999;90:1–44.
19. Liang YM, Zang HM. Re-discussion on the impact of urban-rural income gap on economic growth in China: an empirical study based on provincial panel data. *Stat Inform Forum*. 2009;24:59–64.