Traffic Safety Assessment of Highway Abnormal Indivisible Load Transport under Smoke-Free Regulations

Huazhi Yuan, Lecture
Xiaodong Li, Lecture
Yu Zhang, Master
Zhenjiang Li, Engineer
Ying Yan, Professor

Huazhi Yuan, Lecture in Transportation safety, School of Civil Engineering, Lanzhou University of Technology, Lanzhou 730050, Gansu, China; yuanhz@lut.edu.cn.Xiaodong Li, Lecture in Transportation Management, Yun Cheng Transportation Bureau, Yuncheng, 044000, Shanxi, China; College of Transportation, Chang'an University, Xi'an, 710064, Shaanxi, China; 793246277@qq.com.Yu Zhang, master majoring in vehicle engineering, College of Transportation, Chang'an University, Xi'an, 710064, Shaanxi, China; zhangyu3881@163.com.Zhenjiang Li, Engineer in Transportation control and design, Shandong Provincial Communication Planning and Design Institute CO., LTD., Jinan 250031, Shandong, China; 86912969@qq.com. Ying Yan, Professor in Transportation safety support and Management, Shandong Road Region Safety and Emergency Support Laboratory, Shandong Transportation Research Institute, Jinan 250031, Shandong, China; College of Transportation, Chang'an University, Xi'an, 710064, Shaanxi, China. Correspondence: Ying Yan; yanying2199@chd.edu.cn

Abstract:A high proportion of truck drivers have smoking habits, especially for long-distance truck drivers, 90% of which have the habit of smoking. In recent years, some regulations are launched focus on the smoking behavior of drivers in the driving process. And the policies forces drivers to abandon the smoking habit.Abnormal indivisible load transport is crucial to the sustainable development of highway safety. In order to scientifically and effectively evaluate the traffic safety of highway abnormal indivisible load transportation, on the basis of extensive investigation of large transportation enterprises and management departments, combined with the method of UAV tracking and shooting video, the traffic variation features of outer profile size, load, dynamic characteristics and trajectory of abnormal indivisible load transport vehicles are obtained. Firstly, the meaning of abnormal in-divisible load transportation is defined. The traffic safety assessment of abnormal indivisible load transport is studied from the aspects of road accessibility and operation safety. Secondly, by ana-lyzing the jacking-up failure of abnormal indivisible load vehicles on convex curves, the sweeping space of the horizontal alignment, and the rollover and side slip conditions of the cross section, the road accessibility evaluation model of abnormal indivisible load vehicles under different highway alignment conditions is proposed. Thirdly, based on a certain binding strength, the constraint conditions for preventing the transverse and longitudinal sliding of the cargo are proposed, and the stability calculation method of the collapse point of the hydraulic trailer is determined. Finally, the feasibility and practicability of the safety evaluation method is verified by taking abnormal indivisible load transportation in Sichuan Province as an

example. The achievements will lay a foundation for the necessary guidance of sustainable highway transport management.With the application of these technologies, the safety of abnormal indivisible load transport under smoke-free regulations can be guaranteed.

Keywords:smoke-free; traffic safety assessment; sustainable traffic management; abnormal indivisible load transport

Tob Regul Sci.™ 2021;7(5): 879-894

DOI: doi.org/10.18001/TRS.7.5.6

INTRODUCTION

In China, cigarettes are treated as a method of releasing fatigue in driving. From the real investigated data, 90% of long-distance truck drivers have smoking habits. In the view of driving safety, there are obvious hazards of smoking while driving, and induces different kinds of traffic accidents. In recent years, China Traffic Safety Administration have adopted a variety of methods to suppress and punish the smoking behavior while driving, forcing drivers to abandon smoking while driving. This management would improve the safety of the entire freight industry from the perspective of sustainable development[1].

Under the above mentioned management policies[2], smoking banning changes drivers' driving habits, and improves the driving performance of abnormal indivisible load transport drivers[3]. However, in the period of the smoking banning policy functioning[4], how to guarantee the safety of abnormal indivisible load transport is a complicated technical problem. The traffic safety during abnormal indivisible load transport is key issue to the sustainable highway development. Compared with the ordinary goods transportation, abnormal indivisible load transportation has the characteristics of super-size, overweight, cannot be dismantled, it is easy to exceed the traffic conditions restricted by highway infrastructure, hindering or endangering the safety of public transportation.At present, the planning and construction of our country road network is mainly based on the standards of conventional vehicles and cargo transportation, not designed specifically for abnormal indivisible load transportation. The limited road structure and geometric space conditions do not match the special size of large cargo, which brings challenges to the safety and timeliness of abnormal indivisible load transportation. Due to the lack of a clear evaluation method for the safety of abnormal indivisible load transportation, the operation safety of abnormal indivisible load transportation vehicles has become more and more serious, which seriously threatens the safety of road facilities and people's lives and property.

The promulgation of relevant government regulations has solved many problems faced by the development of the field of abnormal indivisible load transportation, and to a certain extent ensured the safe passage of abnormal indivisible load transportation. Compared with a relatively sound series of laws and regulations related to the management of abnormal indivisible load transportation, the technical standards for restricting and guiding abnormal indivisible load transportation of highways are relatively lacking. Related research mainly focuses on the evaluation and calculation methods of the bearing capacity of bridges and other structures[5],some scholars also have some research on route selection[6-8]. However, the re-search on route technical indicators and geometric space constraints are all mathematical decision models, and the models lack specific quantitative indicators and technical parameters[9-11].

Based on field survey data, this paper puts forward specific and operable methods for evaluating the safety of abnormal indivisible load transportation highways through analysis of the road accessibility and operation safety of abnormal indivisible load transportation. The present paper may provide scientific basis and technical support for the safe and effective organization of abnormal indivisible load transport which may also make a significant contribution to the effective guidance of sustainable highway transport management.

FIELD INVESTIGATION

Investigation subjects and methods

Through investigation and research[12-13], some typical abnormal indivisible load transport companies which are impacted by the smoking banning policy are selected as the research subjects of this paper. These companies all executed critical smoking banning strategies and achieve good effect[14]. Some studies are conducted after the analysis of the technical demands when the smoking banning policy executed[15]. In order to grasp the dimensions, load layout, dynamic performance and other parameters of mainstream abnormal indivisible load transportation vehicles, and to clarify the safety technical conditions of abnormal indivisible load transportation vehicles when passing different grades of roads and characteristic sections, from May to September 2019, this article conducted in-depth investigations on abnormal indivisible load transportation management departments, consulting units, and transportation companies in ten provinces and cities including Shanxi, Xinjiang, Shanghai, Liaoning, Sichuan, and Yunnan. The subjects of this survey include abnormal indivisible load transportation companies, management departments, and consulting units (Table 1).

Table 1

Part of the Investigation Objects

Investigation Unit / Investigation Province	management departments	consulting units	transport enterprises
Shaanxi Province	Highway Bureau		Shaanxi Heavy Truck Transport Company, Xi 'an Anhang heavy transport company
Xinjiang Autonomous Region	Road Administration Maritime Bureau, Xinjiang PublicSecurity Department Traffic Police Corps	Xinjiang Traffic Science Research Institute, Research Institute of Xinjiang Traffic Planning, investigation and Design Bureau	Xinjiang Shunxiang Industrial Co., Ltd.
Shanghai	Shanghai Road Administration, Shanghai Traffic Police Corps		Shanghai Jiaoyun Large Parts Logistics Co., Ltd.
Liaoning Province	Highway Administration Bureau		COSCO SHIPPING Logistics Dalian Branch, Dalian Kingdom Logistics Group Co., Ltd.
Sichuan Province	Highway Administration, Highway Bureau, Large cargo area	Sichuan Highway Planning Survey & Design Institute Co., Ltd.	Sichuan Large Cargo Transportation Co., Ltd.,Orient Logistics Co., Ltd..Quanxing Logistics Co., Ltd.

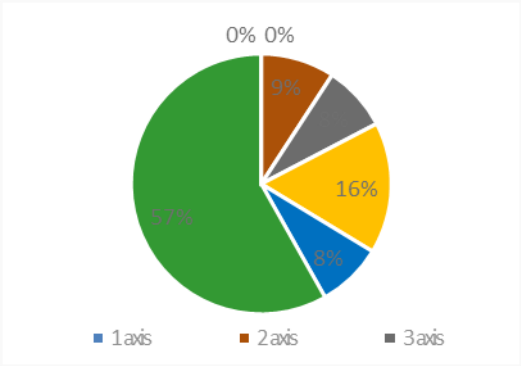
The investigation mainly takes the form of visits, seminars, on-site observations, questionnaire surveys, and other forms. At the same time, we followed the car to observe the transportation process of Sichuan DeyangHuarong Co, Ltd.'s 840-ton hydrogenation reactor. The transportation route is the Deyang-Leshan section of the special highway for abnormal indivisible load transportation in Sichuan Province (Table 2).

Table 2
Observation Instruments and Content

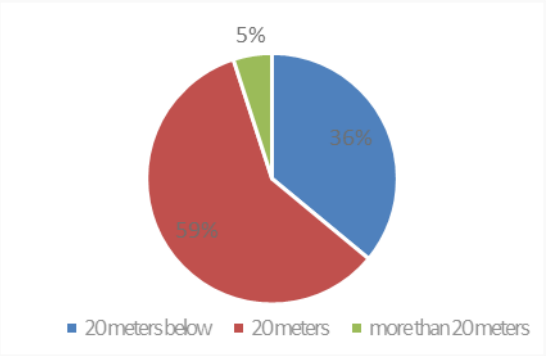
	Observation instrument	Observation content
Driver status	video camera	Driver status
	driving recorder	Lane departure degree, road environment
	camera	Driver's driving behavior, surrounding traffic environment
	EEG	Driver fatigue
Vehicle status	Driving recorder	Lane departure degree, road environment
	GPS	Vehicle speed, specific driving route
	Tire pressure monitor	Tire pressure
	ibeo Four-line Lidar	Vehicle course deviation, Avoid obstacles on the road
Cargo status	Vibrometer	Three-dimensional acceleration of cargo
	Tilt sensor	Cargo inclination
	Strain sensor	Cargo deformation
Road surroundings	Video camera	Types of obstacles and some special road environments
	Laser rangefinder	The height and width of the obstacle
	UAV	Impact on the surrounding traffic environment

Investigation results

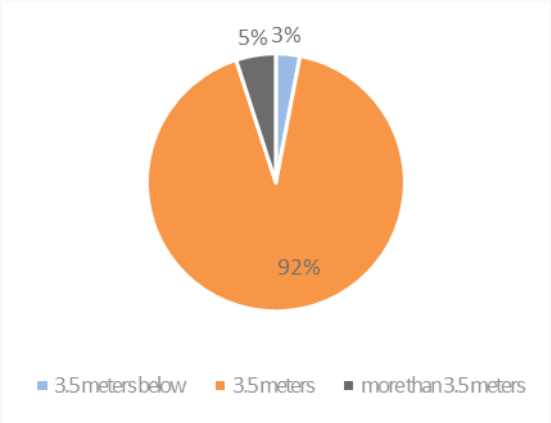
Through the analysis of the vehicle and cargo data of abnormal indivisible load transportation for Yunnan, Sichuan, and Xinjiang in 2019, it is found that the six-axis pro-portion of the distribution of the number of abnormal indivisible load transportation vehicles is the largest, reaching 57%.Construction machinery accounts for more than 90% of the types of transported goods.In the outer profile size distribution, the largest proportion is the car with a length of 20m, a width of 3.5m and a height of 4.5m.In the load distribution, the largest proportion is the car with a cargo weight of 20t, a vehicle weight of 29t, and a total weight of 49t (Figure 1, Figure 2).



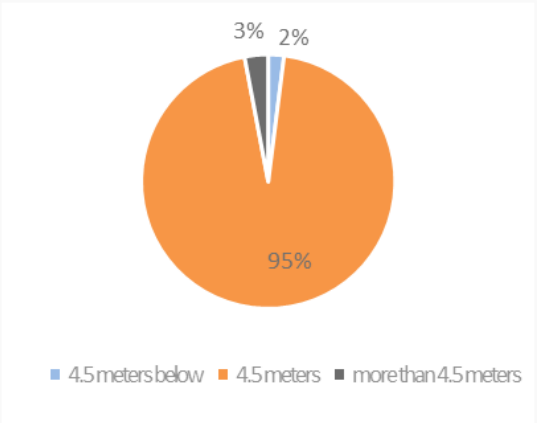
a) Axis ratio



b) Length ratio



c) Width ratio



d) Height ratio

Figure 1. Analysis of characteristics of abnormal indivisible load transportation vehicles.

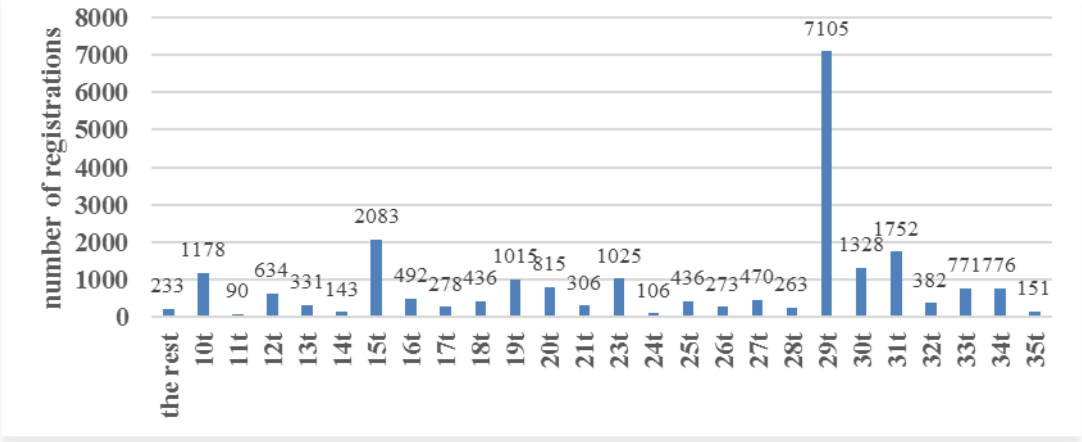


Figure 2. Distribution of abnormal indivisible load transportation weight.

The Investigation found that the safety evaluation methods, evaluation procedures, and evaluation standards of passing abnormal indivisible load transportation roads are not uniform. The road accessibility of abnormal indivisible load transportation is the primary factor for management departments and enterprises to consider transportation routes. Under certain conditions of vehicle and personnel factors, the road accessibility of abnormal indivisible load transportation is mainly determined by the geometric space of the road and the swept space of vehicles.

However, third-party assessment agencies or companies lack accessibility safety evaluation methods, and the approval department even judges the accessibility of road sections based on human subjective experience.

In addition, due to the lack of technical theories for the safety evaluation of abnormal indivisible load transportation, some enterprise transportation plans have neglected the verification of some quantitative indicators, which are mainly manifested in the verification of the stability of the hydraulic trailer and the checking of the cargo binding in the cargo factor. These factors are important conditions to ensure the passage of abnormal indivisible load transportation.

MEANING OF SAFETY ASSESSMENT OF ABNORMAL INDIVISIBLE LOAD TRANSPORT

After consulting relevant information and referring to the results of research data analysis, this article defines the meaning of abnormal indivisible load transportation as follows: using specific transportation methods and means of transportation to move goods that cannot be disintegrated and exceed the specified size or weight limit of road transportation from one place to another local transportation activity. The safety of abnormal indivisible loadtransportation mainly includes the road accessibility and operation safety. Accessibility is the basic safety condition or limit index for the limitation of the technical conditions of the highway route and the bearing capacity of various structures (bridges, culverts, subgrades, slopes, etc.) to allow abnormal indivisible load transportation to pass. Operation safety refers to the safety of transportation under the combined effect of various factors such as people, vehicles, roads and the environment that restrict the passage of abnormal indivisible load transportation. In view of the in-depth research on the check calculation method of the abnormal indivisible load transportation load carrying capacity, this paper only studies the space accessibility and the operation safety evaluation of the road limited by the geometric space of the road (Figure 3).

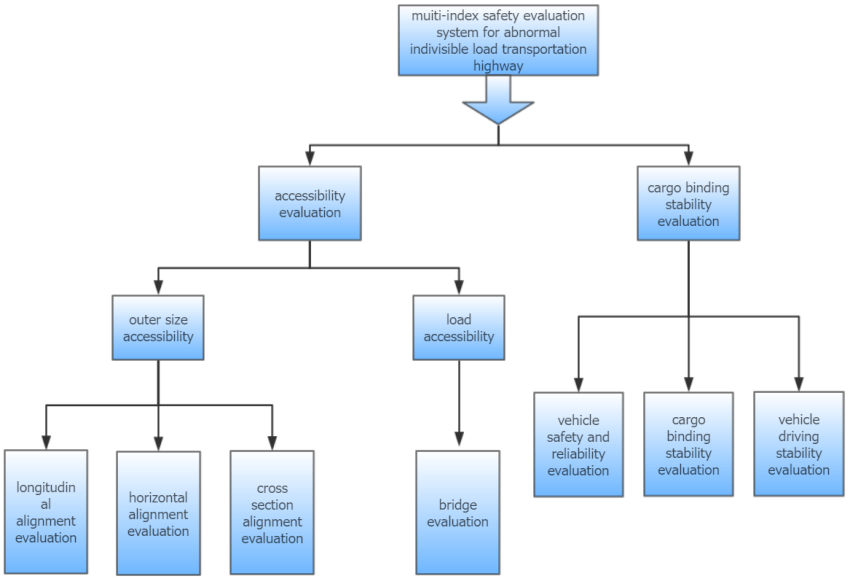


Figure 3. Multi-index safety evaluation system for abnormal indivisible load transportation highway.

EVALUATION METHODS OF ROAD ACCESSIBILITY

The jacking-up failure analysis of vertical section

When a large transport vehicle passes through various road vertical sections, the phenomenon that the vehicle cannot be held by the ground because of insufficient ground clearance is called the gap failure of the vehicle, especially in the vertical curve section, the jacking-up failure on the convex curve often occurs. The jacking-up failure occurs mainly because the vehicle length is longer, the

radius of the convex curve is larger, and when passing through the convex curve, it is affected by the minimum ground clearance in the middle of the vehicle, and cannot pass by being dragged by the ground. For large transport vehicles through the convex curve, different models have different characteristics, the performance of the jacking-up failure is not the same, the suspension of the wheel group in the middle of cross - hanging car group will be in contact with the ground and impassable, low platform, bridge trailer group of the intermediate load-bearing platform and the ground will have no gap and cannot pass. All figures and tables should be cited in the main text as Figure 1, Table 1, etc.

(1) The method of cross - hanging car group accessibility

The cross - hanging car group is a single hydraulic trailer module stitched together, the characteristics of this vehicle can be stitched into various forms based on the size of the goods. It is assumed that when the vehicle passes through the convex curve, the jacking-up failure occurs when the bottom of the vehicle intersects or is cut to the ground. L-front and rear wheel wheelbase, D-wheel diameter, D_t -convex curve diameter, h-trailer height (Figure 4).

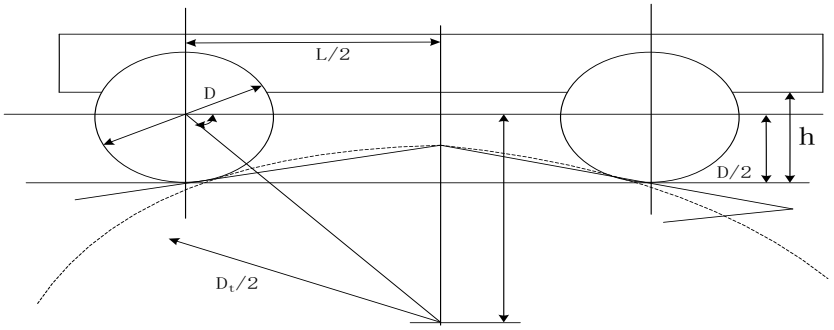


Figure 4. The jacking-up failure relation of vehicle convex curve.

From the figure above, it can be concluded that in order to avoid the jacking-up failure of the vehicle on convex curve, the height of the trailer, the diameter of the wheels, the diameter of the convex curve, the wheelbase of the front and rear wheels should meet formula 1.

$$(h-\frac{D}{2})+\sqrt{(\frac{D+D_t}{2})^2-(\frac{L}{2})^2}\le\frac{D_t}{2} \qquad (1)$$

Substituting the trailer and convex curve parameters into the formula, and the calculated result is greater than the radius of the convex curve, then the abnormal indivisible load transportation vehicle can pass the road section, otherwise, it cannot pass.

(2) Checking calculation method of low platform and bridge trailer group

Low platform trailer group it is mainly composed of front and rear hydraulic trailer groups and a concave loading platform in the middle. The concave loading platform connects the front and rear hydraulic trailer group together to form a low platform trailer group, and the cargo is loaded on the concave loading platform. The front and rear trailer groups are installed on the lifting platform, the lifting platform is generally installed in the middle position of the front and rear trailers, between the lifting platform with the carrier bridge connection, the carrying bridge is composed of a large cross-path combination frame, the large cargo loaded on the carrying bridge, the main role of the carrying bridge is to connect the front and rear trailer and carrying cargo weight. The structure of the bridge trailer group is similar to that of the low platform trailer group, and the analysis method is the same. Figure 5 is a short picture of the low platform, bridge trailer group through the convex curve, when the trailer group travels to the mid-point of the convex curve, the load-bearing platform does not touch the ground, abnormal indivisible load transportation vehicles can pass through this section of the road.

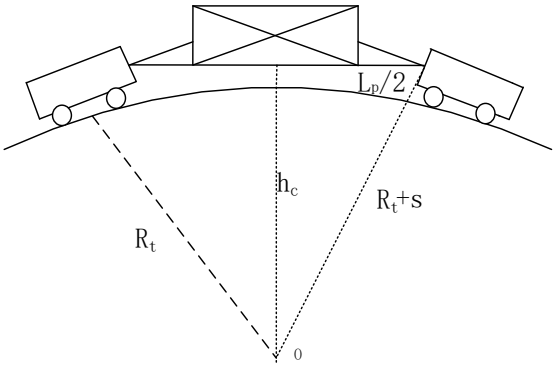


Figure 5. A simple diagram of a low platform and bridge trailer group passing through a convex curve.

According to the geometric relationship of the abnormal indivisible load transportation vehicles at the extreme position of the convex curve in Figure 5, the mathematical formulas (2) and (3) can be obtained:

$$h_c^2 = (R_t + S)^2 - (\frac{L_p}{2})^2 \quad (2)$$

$$P = h_c - R_t \quad (3)$$

In the formula : R_t −Radius of convex curve, S − The distance from the connection point of the load-bearing platform and trailer to the ground, L_p − The length of the load-bearing platform, P − Distance between load-bearing platform and ground; h_c −The distance from the center of the convex curve to the load-bearing platform. When $p > 0$, the low-platform, bridge-type trailer group can pass the road section, otherwise, it cannot pass[16].

The swept space analysis of the horizontal line

Due to the longer body size of abnormal indivisible load transportation vehicles, the turning radius of the vehicle is smaller than that of ordinary trucks. When passing a curve, especially in some mountainous roads, it is necessary to predict the vehicle's ability to pass the curve in advance and swept surface during the turn to ensure that the vehicle can pass the curve smoothly. It can be known from basic automobile theoretical knowledge that when a vehicle passes a curve, the turning radius of the vehicle in the stable steering phase is the smallest, the turning angle of the steering wheel is the largest, and the width required for the wheel to turn in the curve is the largest. If the curve meets the turning requirements of the vehicle at this stage, Then the vehicle can pass normally while ensuring that there are no obstacles in the swept surface during the turning process.

(1)Checking calculation method for cross - hanging car group and low-platform car group

During the vehicle turning process, the main study is the vehicle turning process in the stable phase.

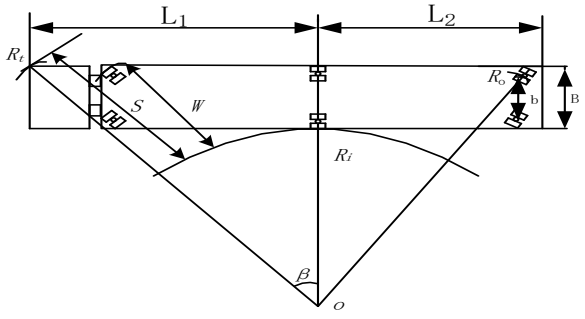


Figure 6. Cross - hanging car group turn.

The figure above, β is the steering angle of the outermost front and rear wheels, R_o is the turning radius of the front and rear outermost wheels; R_i is the radius of the middle inner wheel track; W is

the width of the curve; R_t is The outermost trajectory radius of the horizontal trailer group, S is the difference between R_t and R_i (Figure 6).

During transportation, the outermost edge of the trailer body or the external equipment on the vehicle body is in the arc trajectory curve radius of the horizontal plane in the air. The height of the swept plane is the minimum height of the outside of the vehicle body or the external equipment, which is higher than this plane during operation The road obstacles will affect the passage of trailers. The above is expressed by the following formulas (4)-(8).

$$R_o = \frac{L_2}{\sin\beta} \tag{4}$$

$$R_i \approx \sqrt{(R_o - \frac{B-b}{2})^2 - {L_2}^2} - \frac{B+b}{2} \tag{5}$$

$$W = R_o - R_i \tag{6}$$

$$R_t = \sqrt{(R_i + B)^2 + {L_1}^2} \tag{7}$$

$$S = R_t - R_i \tag{8}$$

Assuming that the width of the curve is W' and the radius of the curve's inner circle is R', the vehicle must meet the most basic accessibility in the curve, namely $R' < R_i$, and W<W'; secondly, consider whether the sweeping surface meets the requirements, that is, R_o, R_i and We must be within the range of the road surface, and there must be no obstacles higher than the plane in the curve range corresponding to S.

(2)Checking calculation method for long truck group and bridge vehicle group

The traction force of the long truck group to the rear trailer when turning is the component of the transmission force in the direction of the longitudinal axis of the cargo in the direction of the longitudinal axis of the trailer. In order to ensure that the rear trailer has sufficient traction, the angle B of the turntable of the rear trailer is generally limited to not greater than 45°. In addition, the front and rear trailers of the long-cargo trailer can also be steered independently (Figure 7).

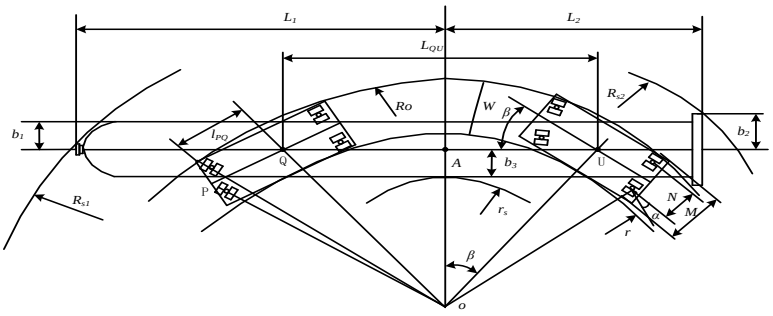


Figure 7. Long truck group turning chart.

From this, the minimum turning radius on the outside of the vehicle group can be calculated as shown in the following equation (9).

$$R_o = \sqrt{(\frac{L_{QU}}{2\sin\beta_{max}} + \frac{M}{2})^2 + {l_{PQ}}^2} \tag{9}$$

In the formula: β_{max} −the extreme corner of the rear trailer turntable; L_{QU} −the distance between the front and rear trailer turntables; l_{PQ} −distance from the first axle of the trailer to the locking axle; M −trailer width.

The calculated turning parameters are shown in the following equations (10)-(15):

$$OQ = \sqrt{(R_o - \frac{M-N}{2})^2 - {l_{PQ}}^2} - \frac{N}{2} \tag{10}$$

$$W = R_o - R_i \tag{11}$$

$$OA = \sqrt{OQ^2 - (\frac{L_{QU}}{2})^2} \tag{12}$$

$$R_{S1} \approx \sqrt{(OA + b_1)^2 + {L_1}^2} \tag{13}$$

$$R_{S2} \approx \sqrt{(OA + b_2)^2 + L_2{}^2} \quad (14)$$

$$r_s = OA - b_3 \quad (15)$$

In the formula: OQ —the distance from the first half of the trailer to the center of the curve, R_o —the turning radius of the outermost wheel at the front and rear, R_i —the turning radius inside the vehicle group is the radius when the front and rear trailers are tangent to the curve, OA—the distance from cargo center to center of curve, R_{S1} —the swept radius of cargo, R_{S2} —the swept radius at the front of the cargo, r_s —the radius of the innermost sweep of the cargo, W—the width of the curve required by the vehicle.

the rollover and side slip conditions analysis of the cross section

When abnormal indivisible load transportation vehicles (including cross - hanging car groups, low-platform vehicles, bridge vehicle groups, and long truck groups) drive along the cross slope of the road, if the cross slope angle is greater than a certain value, due to gravity, the vehicle will turn left or slide sideways (Figure 8).

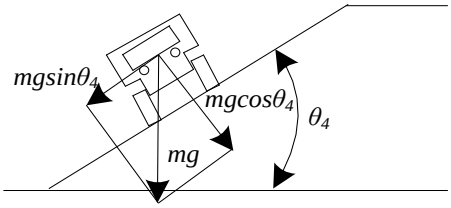


Figure 8.Schematic diagram of the parameters of the vehicle on the road cross section.

When the vehicle rolls over, the reaction force on the ground of the right wheel will be equal to zero, and the critical slope angle θ_{l5} satisfies the following formula 16:

$$h_0 mg \sin\theta_{l5} = \frac{B}{2} mg \cos\theta_{l5} \quad (16)$$

In the formula, h_o −The distance from the center of mass of the vehicle to the ground; B −the distance between the wheels; mg − vehicle weight. The following formula 17 can be obtained:

$$\theta_{l5} = \arctan\frac{B}{2h_0} \quad (17)$$

That is, when the actual slope angle, $\theta_4 \le \theta_{l5} = \arctan\frac{B}{2h_o}$ the vehicle does not roll over. When the vehicle is sliding, the critical slope angle θ_{l6} satisfies equation 18.

$$\varepsilon_h mg\cos\theta_{l6} = mg\sin\theta_{l6} \quad (18)$$

In the formula, ε_h —lateral adhesion coefficient. Therefore, as shown in equation 19.

$$\theta_{l6} = \arctan\varepsilon_h \quad (19)$$

That is, when the actual slope angle, as in formula.

$$\theta_4 \le \theta_{l6} = \arctan\varepsilon_h \quad (20)$$

The vehicle does not skid. In fact, considering that I would rather skid rather than roll over, we have formula (21):

$$\theta_{l5} > \theta_{l6} \quad (21)$$

As shown in equation 22.

$$\frac{B}{2h_o} > \varepsilon_h \quad (22)$$

Therefore, when the actual slope angle $\theta_4 < \arctan\varepsilon_h$,the vehicle neither side slips nor rolls over.

OPERATION SAFETY EVALUATION METHOD

Analysis of cargo binding stability

When abnormal indivisible load transportation vehicles are driving on the road, due to complex road conditions and unstable operation of the driver, the position of the center of gravity of the goods often moves and the vehicle is unstable. For example, when the vehicle is shifting rapidly, the cargo tends to move backwards and forwards due to inertia. In severe cases, position slippage may occur; on uneven road sections, the cargo may bump up and down due to inertia; when turning in a curve, the cargo may be due to centrifugal force may overturn. In order to overcome the movement of the center of gravity of the cargo, the cargo and the trailer should be firmly binded and reinforced after loading, and the strength of the rope can overcome the inertia and centrifugal force of the cargo[16]when the road conditions of transportation and the driver's level cannot be changed. Therefore, the stability of cargo binding is the ability to make the cargo overcome various forces

under a certain binding strength to ensure the stability of the cargo.

(1) The failure of the cargo on the trailer

When designing the binding scheme, it is necessary to ignore some particularly small forces. The force causing the longitudinal failure of the cargo mainly considers the combined action of the emergency braking inertia force F_j and the road longitudinal sliding force F_{gx}; the force causing the transverse failure of the cargo mainly considers the vehicle The sliding force F_{gy} after heeling; the vertical acceleration a_z will reduce the frictional restraint force of the cargo on the car body and increase the possibility of longitudinal and lateral failure of the cargo.

In practical applications, for convenience, the effect of forces in all directions on the cargo is often described by equivalent acceleration values. Some forces that are not related to speed, such as the sliding force on a ramp, are also converted into acceleration. According to the formula of Newton's second law, acceleration can be regarded as the force on the unit mass of goods, which intuitively reflects the strength of the force.

(2) Checking calculation of binding system

Figure 9 shows the analysis diagram of the binding force to prevent the cargo from sliding in the longitudinal direction of the car body. $F_x = ma_x$ is the longitudinal force received by the cargo, $F_\mu = mg\mu$ is the friction force between the cargo and the car body caused by gravity, a_z is the vertical acceleration caused by the uneven road, F_{kx} is the horizontal resistance that the strapping system should provide. Therefore, according to the static force balance equation, the longitudinal horizontal resistance that the strapping system should provide is $F_{kx} = ma_x - mg\mu$.

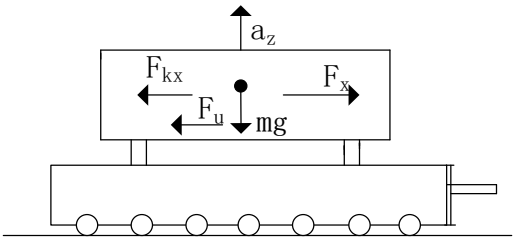


Figure 9. Force analysis of anti-longitudinal sliding

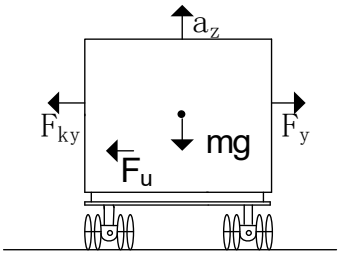


Figure 10. Force analysis for preventing lateral sliding

The horizontal resistance that each lock in the binding system can provide after being tensioned is its longitudinal component force on the one hand, and its vertical friction on the other.

Analysis of vehicle driving stability

In the process of abnormal indivisible load transportation vehicles, the use of hydraulic trailers has improved the safety of transportation to a certain extent. Nowadays, hydraulic trailers are mostly composed of single hydraulic modules. Each axis of a single hydraulic module is independent. The hydraulic cylinder of the spliced hydraulic trailer divides the hydraulic pressure into three independent hydraulic circuits. The three in-dependent hydraulic circuits bear the weight of the cargo, so that the quality of the cargo can be evenly distributed to each axle. In the process, when the road surface is uneven, the wheel is bumped up and down, or the tire is punctured in a certain place, under the action of hydraulic connection, the other axles under the other three hydraulic circuits will share the load of the axle, so that the trailer platform always maintain a stable plane[17].

However, if the hydraulic circuit pipe ruptures during driving, the pressure circuit will lose its support, and the trailer will collapse and tilt, which is called collapse point[20]. At this time, the cargo loses a certain amount of support and will also tilt, when passing through some non-straight sections, it may

even overturn, causing the cargo to lose stability. Therefore, we convert the driving stability of the vehicle into calculating the stability of the collapse point of the hydraulic trailer, and fully consider the stability of the collapse point of the trailer before transportation to avoid accidents.

(1)Analysis of lateral stability of three-point support of hydraulic trailer

When calculating the stability of the pedaling point, the first thing to know is the lateral stability of the hydraulic trailer when it is supported at three points. In order for the trailer to evenly distribute the load of each suspension and ensure the stability and reliability of the bearing surface, the suspension oil circuits are connected in series into three circuits, called three-point support[21]. The three-point support of the hydraulic vehicle is to arrange all the suspension hydraulic cylinders in three independent hydraulic circuits, and each circuit bears the weight of a fulcrum. The triangle formed by connecting the point of action of the three loops is called the supporting triangle, as shown in the triangle ΔBEF in figure 11.

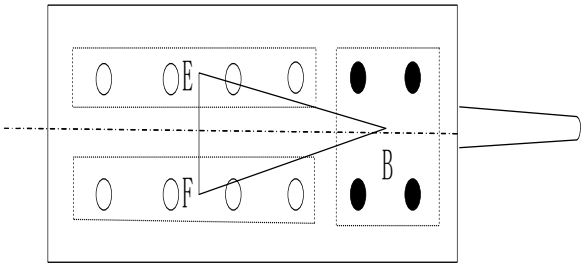


Figure 11. Hydraulic trailer system three point support

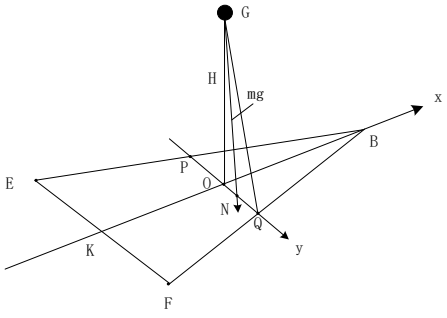


Figure 12. Stability parameter geometry

Supposing the trailer suspension oil circuit is connected in series to form 3 hydraulic circuits to form the supporting triangle shown. After the trailer is loaded, the vertical foot of the combined center of gravity is located at the point $O(x_g,0)$ on the trailer's longitudinal axis (Figure 14). On the cross slope of the road, the car body is inclined in the direction of the arrow of the y axis with x as the axis, the intersection point N of the line of gravity action and the stable surface will move to the side of Q along the line OQ parallel to the axis, when the intersection point N moves to point Q.At this time, the vehicle will be in a critical state of overturning and instability. OQ isthe lateral stability line of the trailer (Figure 12).

(2) Calculation of car body inclination angle after stepping point

The trailer is a three-point supporting point. The hydraulic oil leaks out of the pedal point at point F, and the suspension C acts as a mechanical limit (Figure 13). At this time, the car body will tilt with the line connecting the two points B and E as the axis.

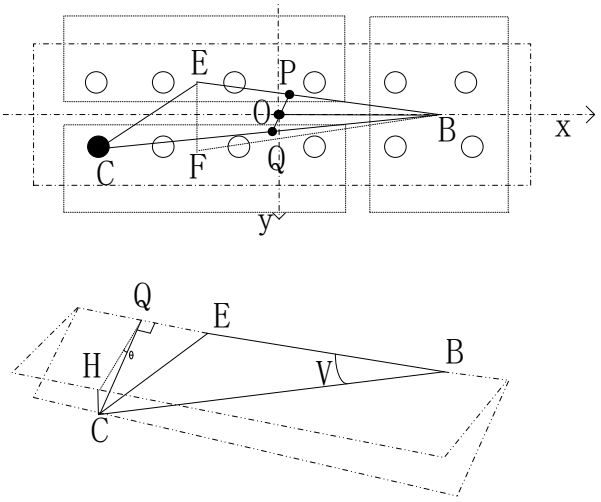


Figure 13.Diagram of supporting triangle and car body tilt Angle after stepping point

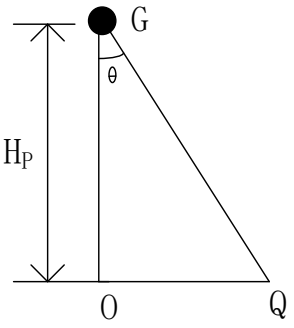


Figure 14. Critical center of gravity height for instability

(3) Critical center of gravity height calculation

When the vehicle is tilted, as shown in figure 14, the point O of the projection of the center of gravity

of the vehicle G on the stable surface will move along the PQ line to the Q direction.

RESULTS

Project description

Take the transportation petrochemical project of Sichuan DeyangHuarong Transportation Company as an example: the powder processing tank equipment is received from the designated place in Shifang City, Sichuan Province, and delivered to the designated place of Leshan City, Sichuan Province. The overall dimensions (length×width×height) of the powder processing tank is 20*6.2*4.5, and the weight is 159 tons; the vehicle distribution and loading plan is: tractor: Mercedes-Benz 8*8, the main parameters are shown in Table 3, load car plate:Seven-axis hydraulic plate, the main parameters are shown in Table 4, the combination method of the car plate: 4 vertical rows and 14 axis horizontal assembly, the size of the combined car plate is 21700*7200*1080 (±275/305) mm (Figure 15).

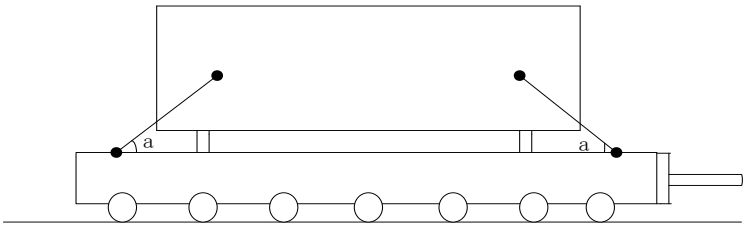


Figure 15.Binding way

Table 3
The Main Technical Parameters of Tractors are as Follows

Installation dimensions	8561*2850*3714(mm)	Self weight	48(t)
Drive way	Four bridge driver	counterweight	35(t)
Maximum power	609 horsepower	The highest torque	2400Nm,1800r/min
Maximum climbing slope	15%	Maximum allowed counterweight	35t
Number of tires	12	Tire size	14.00R20
The wheel diameter	1.116m	Front suspension length	1.014m

Table 4
Seven Axis Hydraulic Trailer Main Parameters Table

The serial number	parameter
1. Outside the profile size(mm)	10850*360*1080
2. Wheelbase (front and rear)(mm)	750/2260
3. wheelbase(mm)	1550
4. Axle weight(kg)	22000
5. Number of axle	7
6. The total quality(kg)	154000(Curb weight28000 kg)
7. Rated load(kg)	126000
8. Maximum allowable total mass of semi - trailer saddle(kg)	16000

Evaluation of the accessibility of abnormal Indivisible load transportation

Take one of Sichuan's large goods roads that the large vehicle intends to pass as an example. First, check the accessibility, and use the same method for other alternative routes. As shown in table 5, the main technical standard limit values of abnormal indivisible load transportation routes.

Table 5
Limit Values of Main Technical Standards for Abnormal Indivisible Load Transportation Routes

Horizontal curve radius(m)	250	10000	3473
Convex curve radius (m)	4500	800000	96524
Concave curve radius (m)	7300	200000	53985
Longitudinal slope (%)	0.03	2.92	0.5
Slope length (m)	100	1720	595

(1) Verification of longitudinal section alignment

The jacking failure formula of the horizontally assembled trailer group is checked as formula 1, $(h-\frac{D}{2})+\sqrt{(\frac{D+D_t}{2})^2-(\frac{L}{2})^2}\le\frac{D_t}{2}$, long axis of the trailer wheels diameter is $D=800mm$, the limit radius of the vertical curve of the road is $\frac{D_t}{2}=4500mm$, the wheelbase L of the front and rear wheels of the trailer is 1550mm, and the height h of the trailer is $1080mm$. Substitute into the formula, no jacking will occur here Invalid, can pass.

(2) Checking calculation of horizontal alignment

Since this transport vehicle is transported by a horizontal trailer, the length of the hydraulic trailer is 21.7m, the width is 7.2m, the radius of the inner circle curve of the limit curve is 250m, the total width of the channel is 18m, and the distance between the head and the wheel is 1m,the distance between the outermost and innermost wheels is 6.2m, so $L_1=11.85m$, $L_2=9.85m$, $R_o=268m$, $B=268m$, $b=6.2m$,under the known conditions, calculate R_i. Compare with the known radius of the circular curve. Substituting into equation(5)

$R_i=\sqrt{(268-\frac{7.2-6.2}{2})^2-9.85^2}-\frac{7.2+6.2}{2}=260.62\text{m}$,260.62 > 250 is derived from equation (7)

$R_t=\sqrt{(260.62+7.2)^2+11.85^2}=268.08\text{m}$, formula (8)

$S=R_t-R_i=268.08-260.62=7.46\text{m}$ .Therefore, it meets the turning requirements of the curve and the vehicle swept surface requirements.

(3) Checking calculation of cross-section linear accessibility

The maximum cross slope gradient that the abnormal indivisible load transportation vehicles passes is 2%, $S = R_t - R_i$ the height of the cargo center of the abnormal indivisible load transportation vehicles from the ground is 4m; B —the wheelbase of the vehicle is 6.2m; substituting the formula $\theta_4 \le \theta_{l6} = \arctan \varepsilon_h$, because it is a dry asphalt concrete pavement that ε_h is taken as 0.6. After calculation, the abnormal indivisible load transportation vehicles meet the traffic requirements on the cross slope and will not roll over or slip.

Evaluation of the through safety of abnormal indivisible load transportation

(1) Evaluation of cargo binding stability

The parameters of the vehicle: 14-axle 4 tandem flatbed trailer, the empty trailer mass is 40t, the wheel braking torque is 11.917KN·m, the trailer power radius is 368mm. Cargo parameters: mass m=159t. Cargo and bracket, bracket and car bodies are lined with rubber sheets. Transportation environment: long-distance road transportation, the maximum longitudinal slope along the road i=2.92%.

1) Determine the longitudinal acceleration a_x

$a_x = j_{\max} + a_{gx} = 0.75g + 0.029g = 0.78g$.

2) Determine the stability angle of the trailer with the lateral acceleration a_y as 13.7° , and take it as the maximum vehicle body inclination angle. The lateral acceleration can be determined a

$$a_y = a_{gy} = g\sin\gamma_{\max} + \mu g(1-\cos\gamma_{\max})$$
$$= g\left[\sin 13.7^\circ + 0.8\times(1-\cos 13.7^\circ)\right] = 0.26g$$

.

3) Calculated strength of strapping lock

The safety force F_P of the strapping lock is a 6×37S+FS wire rope with a diameter of 18mm,the cutting force is 168KN, new ropes used for the first time, material safety factor ψ_P is 1.3, vertical acceleration caused by dynamic load coefficient K_Z take 1.3.

In the formula, n=2 is the number of locks acting in the same longitudinal direction, the friction factor of the rubber pad between the cargo and the car body is 0.8, and the friction safety factor is 1.3 times, $\mu = 0.8/1.3$.

(2) Evaluation of vehicle driving stability

The hydraulic trailer adopts a three-supported weaving point structure, as shown in figure 10. The wheelbase of the single hydraulic trailer is 1.55m, the longitudinal distance of the trailer is 6.2m, the running height of the trailer is 1.03m, and the maximum sinking amount of the tire is 0.035m.

Since the height of the center of gravity of the truck and cargo is much smaller than the critical height of the center of gravity, it meets the driving stability requirements.

Evaluation conclusion: through the safety evaluation of this abnormal indivisible load transportation route, the safety requirements are met.

CONCLUSIONS

The research shows that, the driving habits of drivers changed after the smoking banning policy executed[17], the safety of entire abnormal indivisible load transport industry is improved, especially under the assistance of the safety assessment theory proposed in this paper[18,] he safety assessment theory effectively guaranteed the execution of the smoking banning policy. From the field data and the real performance, the safety of the whole industry is guaranteed and improved[19]. The characteristics of abnormal indivisible load transportation determine that its transportation organization process is very complicated. This article has conducted an in-depth study on the space accessibility of abnormal indivisible load transportation and the operation safety during transportation from a technical point of view. It does not involve the safety of bridges, roads and other structures assessment. The research results can be combined with the future abnormal indivisible load transportation information platform and information work, which will help to comprehensively promote the disclosure of bulk transportation traffic road related information. Through the guidance of regular inspections, timely update and release of relevant information, so that enterprises can calculate road safety traffic indicators, Compile transportation plans, so as to better integrate road resources, provide scientific basis and normative guidance for the safe passage and effective organization of abnormal indivisible load transportation, and provide effective reference for

guiding the self-discipline of the abnormal indivisible load transportation industry.

Author Declaration:

This research is not funded by any organization related to tobacco production.

Acknowledgments

This study was sponsored by the National Natural Science Foundation of China (51978069); Industry standard of Ministry of Communications (JTG-201913).

References

1. Hyland, Andrew, Joaquin Barnoya, and Juan E. Corral. Smoke-free air policies: past, present and future. *Tobacco control*.21.2 (2012): 154-161.
2. Hahn E J, Rayens M K, Butler K M, et al. Smoke-free laws and adult smoking prevalenceJ.*Preventive medicine*. 2008, 47(2): 206-209.
3. Mills, Alice L., et al. The effect of smoke-free homes on adult smoking behavior: a review. *Nicotine & Tobacco Research 11*.10 (2009): 1131-1141.
4. Vogel, Erin A., Jamie Guillory, and Pamela M. Ling. Sponsorship disclosures and perceptions of e-cigarette Instagram posts. *Tobacco Regulatory Science.* 6.5 (2020): 355-368.
5. Wu XK. Evaluation and Countermeasure Research on the Bearing Capacity of a Large Vehicle Passing Bridge. *Transportation Science & Technology*. 2019(4): 37-40.
6. Huang JM. Rapid identification method of bridge capacity for transportation of major cargoes. *Highway Traffic Science and Technology: Applied Technology Edition*. 2015, (010): 209-211.
7. Zhou GL. Rapid assessment of bridge-passing capacity of large-size transportation vehicles. *Highway Traffic Technology*. 2018, 34(05): 77-81
8. Chen XQ, Lu GQ, Zhao JS, Qu ZJ, Yang YS, and Xian JF. Traffic Flow Prediction at Varied Time Scales via Ensemble Empirical Mode Decomposition and Artificial Neural Network. *Sustainability*.2020, 12 (9):3678.
doi: 10.3390/su12093678.
9. Chen, X., S. Wu, C. Shi, Y. Huang, Y. Yang, R. Ke, and J. Zhao. 2020. Sensing Data Supported Traffic Flow Prediction via Denoising Schemes and ANN: A Comparison. *IEEE Sensors Journal:1-1*.
doi: 10.1109/JSEN.2020.3007809.
10. LUO J. Study on the route selection scheme and model about heavy-cargo highway transportation. *Journal of Xihua University (Natural Science)*. 2013, 32(4):71-76.
11. LI LX, HUANG X. Identification of the key influencing factors in the heavy cargo transportation. *Journal of Jiangnan University(Natural Science Edition)*. 2012,11(3):311-315.
12. Been, Jasper V., et al. Effect of smoke-free legislation on perinatal and child health: a systematic review and meta-analysis. *The Lancet.* 383.9928 (2014): 1549-1560.
13. Chapman, Simon, et al. The impact of smoke-free workplaces on declining cigarette consumption in Australia and the United States. *American Journal of Public Health.* 89.7 (1999): 1018-1023.
14. Williams, Rebecca S., K. Jean Phillips-Weiner, and Amy A. Vincus. Age verification and online sales of little cigars and cigarillos to minors. *Tobacco regulatory science.* 6.2 (2020): 152-163.
15. Alamar, Benjamin, and Stanton A. Glantz. Effect of smoke-free laws on bar value and profits. *American Journal of Public Health.*97.8 (2007): 1400-1402.
16. Tseng WK, Liao SX, Estimation of Vehicle Pre-Braking Speed. *Applied Mechanics & Materials*. 2012, 151: 165-169.
17. Semple, Sean, et al. Bar workers' exposure to second-hand smoke: the effect of Scottish smoke-free legislation on occupational exposure. *Annals of Occupational Hygiene*. 51.7 (2007): 571-580.
18. Lee, John Tayu, Stanton A. Glantz, and Christopher Millett. Effect of smoke-free legislation on adult smoking behaviour in England in the 18 months following implementation. *PloS one.* 6.6 (2011): e20933.
19. Ritchie, Deborah, Amanda Amos, and Claudia Martin. Public places after smoke-free—a qualitative exploration of the changes in smoking behaviour. *Health & place.* 16.3 (2010): 461-469.