

STUDY ON THE INFLUENCE OF HEAVY VEHICLES ON FREEWAY SAFETY

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ABSTRACT

Heavy vehicles mean those vehicles with bigger size, lower speed and weaker running flexibility. They have great influence on freeway safety. In terms of traffic accident statistic in recent years sampled from a typical heavy transportation freeway in China, this thesis, based on the field survey of vehicle operating speed on spots, intends to carry study on the influence of heavy vehicles on freeway safety with regard of vehicle running theory, freeway environment and drivers' characteristic, and so on. The study has shown that the main causes of accidents are driving performance loss for over-loading and significant speed variation between different vehicle types. In view of this, the author puts forward corresponding measures for safety improvement from aspects of engineering and traffic management.

Keywords: heavy vehicles, accidents, operating speed, measure of safety improvement

INTRODUCTION

Highways are designed to facilitate the flow of various modes of traffic to move passengers and goods. They are basic elements for national economic development and social progress. Heavy vehicles (the vehicle whose maximum laden mass specified by its manufacturer is larger than 4 tons) transportation is an important part of the freight transport. According to the statistics in the United States, it is about 67% of the total amount of goods transport, also in China, the data is 55.5%. With the expansion of heavy vehicles in size and weight, its side effect in road safety is appearing more and more evidence. The influences include increase variation of operating speed between different vehicle types, reduce highway capacity, and decrease mobility. At the same time, it also increases over-loading probability. They are all vital elements for freeway safety, especially the over-loading, which affects not only the mobility of vehicles but also the braking performance of heavy vehicles significantly.

CURRENT STATE OF STUDY OVERSEAS

The United States

In the United States, there are about 40000 individuals die in crashes each year, and about 5000 of these fatalities involve heavy vehicles. Efforts to improve heavy vehicle safety in USA include the 1995 U.S. DOT sponsored by Truck and Bus Safety Summit, which called for reducing the number and severity of commercial vehicle crashes. The safety issues identified at the Summit were driver fatigue, the lack of crash-cause data, technology, and uniformity in truck safety regulations. The Summit also set a goal in 1999 to reduce heavy vehicle-related fatalities by 50 percent in next 10 years. By now, the United States has already made several studies on these issues, such as "The Unsafe Driving Acts of Motorist in the Vicinity of Large Trucks", "Operational Performance Model for Freeway Truck-Lane Restrictions", etc.

Australia

In Australia, heavy vehicle safety has been an increasingly serious issue for several decades. In order to improve heavy vehicles safety, it has established several regulations and published "Heavy Vehicle Drivers

Handbook". From 1 January 1995, Heavy vehicles were registered by their manufacture's GVM(Gross Vehicle Mass) rating. A vehicle must not be operated if its load exceeds the vehicle manufacture's maximum limits or individual component manufacture's rating. Also there is a periodic National Heavy Vehicle Safety Seminar to discuss heavy vehicles safety problems in Australia.

Europe

In Europe, many countries are addressing this problem with a clear understanding of the relationships among driver, vehicle, rules and regulations, and the supporting organizations and institutions. For the sake of heavy vehicles safety, vocational education systems are established. The driver training process is selective, and it advances overall business competence as well as driving skills. They have set up a standardized curriculum that often uses advanced technologies such as simulators and password-protected Internet access. Many government regulations are designed to protect drivers by shielding them from unsafe work conditions. For example, in order to avoid fatigue driving, regulations ask drivers to have a definite length of rest time after a certain time of traveling. Also onboard recorders are required to install on vehicles to record the whole travel process. Different from other countries, European truck manufacturers are playing a significant role in improving motor carrier safety.

STUDIES IN CHINA

In China, by now, safety issues have not been given an appropriate place in highway agencies, most highway investments are expended in highway construction and maintenance area, and funds especially for road safety research and improvement are limited. In the area of freight transport, specific management regulations have not been established, saying nothing of its implementation. Any specific study about heavy vehicles safety has not been done in the past years. But to our credit, there has been an increasing awareness of road safety in highway administration.

STATISTIC OF ACCIDENT

In order to analysis the influence of heavy vehicles on freeway safety, an investigation was made on a typical heavy-duty freeway in north China. Both accident and traffic data of the last three years (2000,2001,2002) were collected. At the same time, a field survey of operating speed was made at 75 spots, and highway design material was collected also.

Accident frequency

Statistical data illustrates that, there are about 548 accidents had happened on the freeway in the past three years. Accident frequency and proportion of different vehicle types are shown as in table 1.

Table 1. Statistic of accident with auto types.

Auto	Accidents		Distribution of different vehicles proportion (%)
	Frequency	Percentage (%)	
Cars	194	35.40	35.37
Heavy vehicles	294	53.62	31.89
Light vehicles	29	5.29	19.04
Passenger cars	20	3.65	7.94
Others	11	2.01	5.76
Sum	548	100	100

Where:

Car: a vehicle for carrying people with height under 1.3m or maximum specified carrying capacity is less than 11 persons.

Passenger car: a vehicle whose maximum specified carrying capacity is larger than 25 persons.

Light vehicle: a vehicle whose maximum laden mass specified by its manufacturer is less than 4 tons or its maximum specified carrying capacity is less than 25 persons.

Heavy vehicles: a vehicle whose maximum laden mass specified by its manufacturer is larger than 4 tons

Table 1 shows that, at the freeway investigated, accidents related with heavy vehicles are the great majority with the percentage of 53.62.

Accident rate

In terms of traffic volume data collected, the average accident rates for different vehicle types are calculated, the result is illustrated as in table 2.

Table 2. Accident rate for different autos.

Auto	Accident rate (Accident/ $10^6 V \cdot KM$)
Cars	0.52
Heavy vehicles	1.45
Light vehicles	0.14
Passenger cars	0.15
Others	0.06
Total	0.56

Accident types

Due to the object of study is freeway, where vehicles from different directions are divided by medians, accidents between opposite ways can be avoided basically, accompany with the perfect safety facilities, accident types of freeway is fewer than ordinary two-lane highways. The statistic distribution of different accident types of the freeway is shown in table 3.

Table 3. Accident types.

Accident type	Accident	Percent(%)
Rear-end	253	46.17
Striking fixed object	166	30.29
Turn-over	25	4.56
Scrape in same direction	38	6.93
Others	66	12.05
Total	548	100

Accident severities of heavy vehicles

According to the statistic, the severity of accidents correlated with heavy vehicles is shown in table 4.

Table 4. Accident severities of heavy vehicles.

Auto type	Fatalities	Injuries	Accidents losses (RMB ¥)
With heavy vehicles	74	191	6767640
With passenger cars	0	1	222190
With light vehicles	1	3	171705
With cars	13	74	1982547
Single accidents	2	11	3180099
Others	36	56	2500676
Total	126	336	14824857

Where: a single accident means just a single heavy vehicle caused an accident, accidents with other auto types means double or multiple vehicles in an accident, in which, at least one of them is heavy vehicle.

From table 1 to table 4, it can conclude that, on the freeway investigated, the most important factor that influences operating safety is heavy vehicles. Among accidents related with heavy vehicles, those between heavy vehicles ranked the first place both in number and severity. The fact indicates that, strengthening the administration of heavy vehicles is a basic issue for improving current freeway safety conditions.

ANALYSIS OF ACCIDENT

Causes for total accidents

Reasons result in accident is complex. Due to lack of highway maintenance and operation data, this paper makes an investigation mainly from both vehicles and drivers. According to the investigation, main causes of accident on the freeway are concluded in table 5.

Table 5. Accident causes.

	Cause	percent (%)
Vehicles	Braking fault	4.90
	Braking badness	2.87
	Turning fault	0.25
	Lighting fault	0.06
	Others	4.45
Drivers	Fatigue	12.04
	Speeding	12.87
	Improper driving	24.27
	Driving inattentively	7.90
	Driving illegally	17.45
	Following too closely	4.59
	Others	8.34
Total		100

Table 5 illustrates that, from 2000 to 2002, among all factors that lead to the total 548 accidents, vehicles are occupied 12.53 percent, and drivers are occupied 87.47 percent.

Analysis of heavy vehicle accident

From tables above, heavy vehicle accidents is about 53.62 percent of the total. Among these heavy vehicle involved accidents, crashes between heavy vehicles and single heavy vehicles accidents, which are 74.22 percent of the total, are the great majority. In addition, heavy vehicles accidents account for about 60.32% of all fatalities, 60.12% of injuries and 67.10% of property loss. So it can conclude that heavy vehicle accidents are the primary accident form.

Over-loading

Table 1 shows that heavy vehicle accidents are the main accident type on the freeway that we studied. For its heavy duty of freight transport, the fact is rational. What surprised us most is that, among all heavy vehicles accidents, accidents between heavy vehicles ranked the first, instead of accidents with cars or other auto types. It has a significant difference from other freeways both in China and overseas. By analyzing the field investigation and visiting with freeway administrators, we found that most heavy vehicles (more than 90 percent) on the freeway are over-loading. Over-loading is the chief criminal factor for heavy vehicle accidents. Generally, the real loading of a heavy vehicle is about 1 to 3 times of its maximum mass limits specified by vehicle manufacture. Some of them are even more than 5 to 6 times, loading more than 120 tons. Over-loading not only makes it more difficult to control, but also reduces its braking ability. The main result is that the braking distance is much longer than drivers' estimation.

According to auto running theory, to stop a vehicle, three forces are needed taking into account, they are braking force, friction force between tires and pavement, and inertia force. For braking force and friction force, they can be meted by vehicles and pavement in a way. For inertia force, it lies on vehicles' mass and initial speed. Due to over-loading, the deceleration is much smaller than it should be, so both braking distance and braking time are longer than standard or a driver's estimation. Under this condition, accompany with other operation difficulties, accidents are unavoidable sometimes.

Driving inattentively

Fatigue, talking on phone or with others on driving can induce drivers' inattention. On the freeway investigated, among all heavy vehicle drivers, fatigue is fairly common. Generally, compare with cars or passenger cars, heavy vehicles have a relatively lower speed. When it is over-loading, the actually speed is much lower. Sometimes it is less than 10km/h even under free flow conditions. According to the operating speed measured, more than 5 hours are needed on the freeway just in this district of the province that the freeway belongs to. Accounting for the time needed before vehicles reach the freeway, fatigue is quite possible. On the other hand, in order to save transport time and prevent the driver from rest or rest longer during the journey, sometimes goods owners may ride vehicles themselves. Under this condition, fatigue is inevitable. Fatigue driving reduces drivers' ability of reaction and steering. Accidents that heavy vehicles stroke vehicles which parking on the paved shoulder are vivid examples of this.

Great speed differential between different auto types

Get rid of accidents between heavy vehicles or single vehicles, accidents between heavy and cars ranked the second place. Based on the field survey, it is considered that the difference of operating speed between two auto types is the main reason. The observation illustrates that the average V85 of the freeway is 93.25km/h, the data for cars is 100.50km/h, and heavy vehicles is 68km/h. The average speed of the freeway is 75.3km/h, the data for cars and heavy vehicles are 92.96km/h and 56.57km/h respectively. Since the operating speed variation of diverse vehicles is too significant, passing occurs frequently, which is another main causation of accidents.

Violation of driving regulations

In terms of field observation and accidents record, improper driving behavior is also a severe problem on the freeway. Not complying with traffic management regulations, some vehicles (sometimes even heavy vehicles) occupy the overtaking lane for too long time and make the following cars more difficult to pass them. In order to overtake the vehicle ahead, cars may have to follow the vehicle for a long distance and sometimes they even try to complete the passing process in an illegal way. If the vehicle changes lane abruptly during the process, it's very easy to cause an accident.

Following too closely

This phenomenon ever makes foreigners much astonished. On Two-lane highways or urban streets, due to the lower operating speed, it may relatively safer. But on freeways, the real speed is much higher than that on two-lane highways or urban streets, so it becomes more dangerous. Based on our investigation, even speed excesses 100km/h, distance between a car and its anterior shorter than 100m is common. For heavy vehicles, it is usually under 50m. If the front vehicle runs into any trouble unfortunately, there will be an accident for insufficient stopping distance.

STRATEGIES FOR IMPROVEMENT HEAVY VEHICLES SAFETY ON FREEWAY

Enhance over-loading management

Reform the current toll manner

For the shortage of construction fund, building capitals of most freeways are come from commercial banks' loan, so it is reasonable to collect passing fee for return the loan. At present, the general format is based on traveling times. Some freight transport enterprises, in order to saving operating cost, evade passing fee by reduce transit times is a main reason for over-loading. According to our observation, for improving freight efficiency and protecting transport vehicles, when vehicles are full-loaded, they will select freeway as the corridor, when they return with empty carrier, they will choose non-toll highways. If the charge mode is changed to toll passing fee by tons not by times, over-loading vehicles will pay much more while the empty ones will pay much less. So it can attract more empty vehicles on the freeway, and compel some severe over-loading vehicles off the freeway. Though the changing of toll manner may increase weighing devices and missionaries, it can partly solve over-loading problem and consequently improve the heavy vehicle safety.

Penalty

In China, illegal driving can be seen here and there for the Chinese freight transportation market is not very just and sound with laws, in addition, the drivers' occupation character is also not very high. In view of that, economic punishment is still a very valid means.

Regulations and enforcement

On one hand, it should be enforced that heavy vehicles must load within its limits. On the other hand, the current payment system between drivers and freight enterprises should be reformed, which means the wage of drivers should be paid by hours they need for the whole journey, not by transit times. At this point, experiment in Europe can be used as reference. Enhancing police patrol and fatigue checking is another aspects of this issue.

Drivers' education

Drivers' education should offer drivers with an extensive curriculum, which consists of traffic regulations, simulator, personal computer, and behind-the-wheel training. Deploying driver simulators defrays in-cab training costs and allows for training in all weather. With behind-the-wheel performance closely monitored, the curriculum also requires prescribed number of classroom hours. During the education process, safety consciousness education should be put on the same position as skills, even higher than skills. At the same time, reeducation of drivers should also be given the same emphasis.

Strategies for fatigue

Fatigue is a worldwide challenge for road safety. What causes fatigue is multiple and complicated. In China, the short of professional vehicle drivers is one of the reasons. Another reason is that drivers are paid by transit times not by working hours. The third is disordered market competition of goods transportation. In order to obtain the profit and save time, more and more freight enterprises deeply rely on over-loading and long-playing. The way to solve this problem include, first, defining uniform transit criterion to end vicious competition, second, reforming the payment system between drivers and enterprises, that is, paying drivers by working hours; third, enforcing drivers have certain time for rest after a defined driving hours, and onboard recorder which records the traveling process should be installed on the vehicle, and the fourth, developing special studies corresponding to this issue.

Speed management

As shown in Table 5, accidents caused by speeding are about 12.87 percent of the total, which rank 2 among all contributory factors. By estimation, if the difference on speed of various vehicles is considered, this proportion will rise to about 30 percent.

Studies by Solomon et al. show that, when operating speed of vehicles is larger than the average speed slightly, the highway has the highest security. The more the deviation is, the more the accident frequency will be. So, based on the field survey of operating speed, establishing appropriate speed limits is a basic manner to solve this problem. One objective of speed limits is to reduce cars' and passenger cars' operating speed, another is to prevent those vehicles that cannot provide the minimum limited speed from entering the freeway.

Road safety audit and reconstruction strategies

Practice overseas illustrates that road safety audit is an efficient way to improve highway safety. According to the criterion (A black-spot means a road section with 500 meters long have 5 accidents had happened in the past three years), 23 black-spots were confirmed on the freeway, which occupied 42.52 percent of all accidents and about 10.22 percent of the total length of the freeway. Improved before-after method is used to analyze the characteristics of these black spots, and corresponding improvement strategies are in developing now.

According to the scheme of administrative departments, the freeway will be reconstructed in the following years. In order to make it safer, here are two recommendations: first, widening the width of paved shoulder from 2.0m or 2.25m to 2.75m, so a fault heavy vehicle can be parked on the paved shoulder completely; second, setting Truck-only lanes for heavy vehicles for reduce interfere between different vehicle types.

Off-road factors

The object of safety cannot be fully achieved only by the restriction or regulation on on-road behavior. Many outcomes on-road are the results of systemic off-road behaviors of drivers, operators and others in the transport chain. The primary measure to solve the problem is to enhance safety culture construction of our community, whose objective is to raise the safety consciousness of the society, enterprise and everyone else. This is a long-term objective and also a hardest work of all in the area of road safety in the following years even decades.

CONCLUSIONS

Although it already ranked the second in the world, freeway is still a new matter in China, most management regulations are cited from developed countries directly. Besides the difference on civil culture background and management institution, etc., heavy freight transport with the character of serious over-loading is also a new matter to Chinese highway transportation market. All these factors give Chinese freight transport new features. In view of this, based on successful practice experience at home and abroad in the past years, a systemic study from diverse aspects of vehicles, highways, and drivers are required.

REFERENCES

1. U.S. Department of Transportation, Federal Highway Administration, Commercial Vehicle Safety-Technology and Practice in Europe, International Technology Exchange Program, May 2000.
2. U.S. Department of Transportation, Federal Highway Administration, Office of Motor Carriers and Highway Safety, The Unsafe Driving Acts of Motorists in the Vicinity of Large Trucks, Santa Barbara, California, February 1999.
3. Michael Tziotis, Recommendations for Improvement of Heavy Vehicle Safety, National heavy Vehicle Safety Seminar, Melbourne, October 2002.
4. Guo Zhongyin, Fang Shouen, Road safety engineering, China Communications Press, BeiJing, 2003.