

# STUDY ON SAFETY BENEFIT ANALYSIS OF EXPRESSWAYS IN CHINA

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## ABSTRACT

The expressway construction in China started in the late of 1980s. After rapid construction for more than twenty years, the mileage of expressways in China reached 65 thousand kilometers, occupying second in the world. The mileage of expressways in China will increase with the high speed in the future some time. The expressways have played an important supporting role for the economic and social development and the economic benefit of expressways is beyond doubt. However, the safety benefit of expressways in China is often overlooked.

The development process of expressways in China and the role in the economic and social development are analyzed in the paper. Moreover, the development process and characteristics of road accidents on expressways are analyzed. The safety performance of expressways is analyzed compared with ordinary highways. The analysis result shows that the road safety on expressways has entered a new phase of continuous improvement and the safety performance of expressways is much better than ordinary highways in China. The analysis of the safety benefit of expressways is proposed. And the analysis result shows that the safety benefit of expressways is enormous and should not be overlooked.

## 1. INTRODUCTION

Since the completion and operation of the first expressway in late 1980s, China's expressways have recorded a great achievement. Currently, China ranks the second in terms of expressway mileage in the world. It has been widely recognized that the construction and operation of expressways have played an important supporting role for the economic and social development. However, the safety benefit of expressways in China is often overlooked.

## 2. DEVELOPMENT OF EXPRESSWAYS

China's expressway construction started in the late of 1980s, half a century later than western developed countries. It has the following three major development phases.

### 2.1. The phase of start-up construction

This phase started from the end of 1980s to 1997. At the beginning of Reform and Opening up, with the fast economic development, passenger and freight transportation capacity in China increased dramatically, making the arterial highways crowded, and prone to accidents. To alleviate the bottleneck of highway transportation, China began to construct expressways [1]. In 1988, Shanghai-Jiading Expressway, the first of its kind in Mainland China, was completed construction and put into operation. By the end of 1997, the mileage of expressways reached to 4771 kilometers. Expressways such as Shenyang-Dalian, Beijing-Tianjin-Tanggu, Chengdu-Chongqing and Jinan-Qingdao have completed construction. Many great technical breakthroughs had been made in the construction of

expressways. All these have accumulated rich experiences for the industry from the perspective of design, construction, supervision, operation and maintenance.

## 2.2. The phase of rapid development

This phase started from 1998 to 2004. In 1998, in order to deal with Asian financial crisis, China accelerated the construction of transportation infrastructure, which boosted the expressways into a rapid development phase. During this period of time, expressways achieved a leap forward development basically with the annual newly added traffic mileage reaching 4217 kilometers. In 1999, the traffic expressways exceeded 10,000 kilometers nation-wide. By the end of 2002, the mileage reached to 25,000, ranking the second in the world. By the end of 2004, the mileage exceeded 30,000 kilometers standing at 34,288 kilometers. Apart from Tibet Autonomous Region, all the provinces, autonomous regions and municipalities across the country have got access to expressways. With the successive operation of a batch of long-distance and cross-provincial expressways such as Beijing-Shenyang, Beijing-Shanghai, Beijing-Shijiazhuang-Taiyuan, Shanghai-Ningbo-Hangzhou, Shanghai-Hangzhou-Ningbo, the transportation intensity of major road transport corridors have been alleviated obviously [1].

## 2.3. The phase of sustainable, rapid and orderly development

This phase started from 2005. On December 17, 2004, the State Council reviewed and approved the **National Expressway Plan**. According to the Plan, China will construct a national expressway network covering 85,000 kilometers with 7 radiation lines started from Beijing, 9 vertical lines and 18 horizontal lines [2]. Since then, China's expressway entered into a new period of sustainable, rapid and orderly development. This phase also witnessed rapid development of expressways with the annual newly added traffic mileage reaching to 6,504 kilometers and expressway played a more important role in improving economic and social development. The mileage in the end of 2004, the end of 2005, the end of 2007, the end of 2008 and the end of 2010 exceeded 30,000, 40,000, 50,000, 60,000 and 70,000 kilometers respectively, shown in Figure 1. By the end of 2010, China's expressway traffic mileage reached to about 73,300 kilometers. By judging the current expressway construction progress, the goals set in the Plan will be achieved in several years. China's expressway construction speed is beyond imagination by any other countries.

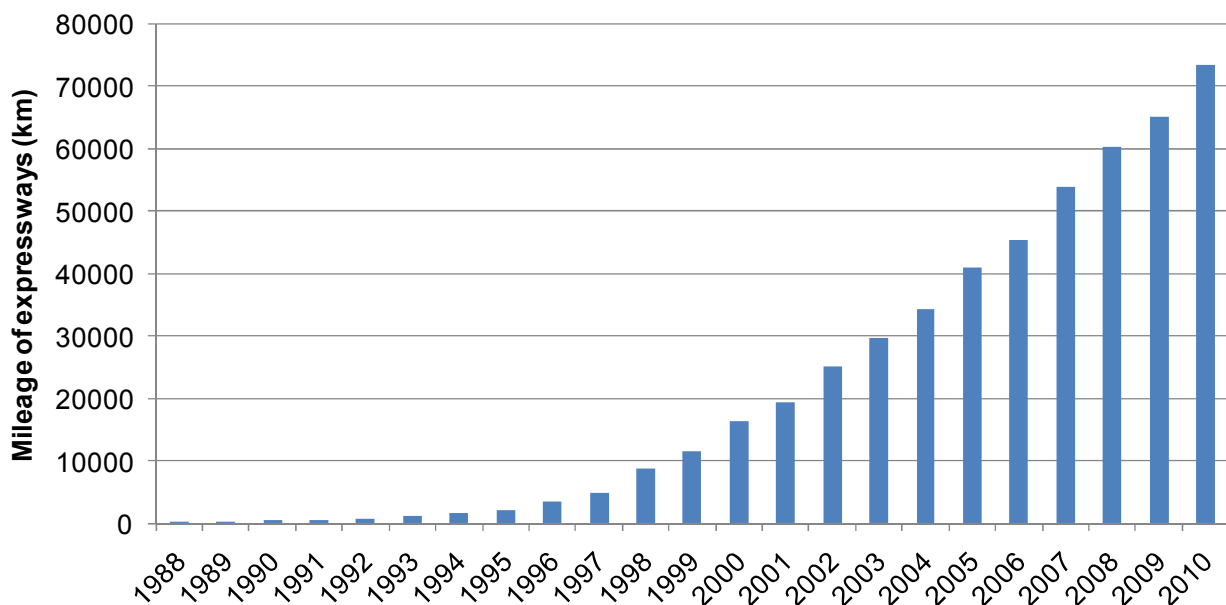


Figure 1 - Development Milestones of China's expressways (1988-2010)

At present, the expressway network featuring rational layout, accessibility to all the directions, highly efficient operation has been taken shape and the scale benefit has shown initial effect. Although China's expressway has made a great progress, its density is still relatively low compared with western developed countries, shown in Table 1. To meet the demands of establishing moderately prosperous society in the next 20 years and realize modernization in the middle of this century, China needs to build up 100,000-120,000 kilometers of expressways including national expressways and non-national ones[1]. Therefore, China's expressway will still in a high speed development phase for a period of time in the future.

Table 1 - Expressway density comparison [1]

Index	U.S.	Japan	Britain	France	Germany	Italy	China
Total mileage (10k kilometers)	8.87	0.61	0.34	1.1	1.15	1.15	7.33
Density (kilometers/100 square kilometers)	0.95	1.61	1.47	1.99	3.1	2.43	0.76

The practice of developed countries shows that the construction and development of expressways can effectively promote national economic growth, boost the balanced development of national land resources, facilitate urbanization, improve people's living quality, and increase employment in relevant industries such as automobile industry. It is estimated that an investment of 100 million RMB in expressway construction can finally create a GDP of around 300 million RMB and 2,000 jobs in road construction industry directly [1]. The high speed of expressways can greatly reduce travel time, fuel consumption, mechanical wear and transportation cost, and at the same time elongated vehicle life. Research shows that if calculated at the transportation cost in 2007, the construction of 100 kilometers expressways can save 75 million RMB of freight fee and 2,100 tons of diesel and gasoline annually [3].

### 3. FEATURES OF ACCIDENTS ON EXPRESSWAYS

Safety is one of the natural properties of expressways. Expressway safety should be analyzed by the accidents.

#### 3.1. Number of accidents is decreasing constantly

From 1994-2009, expressway accidents have shown obvious features. The number of accidents has been increasing year on year from 1994-2003 and decreasing rapidly since 2004. The number of accidents on expressways in 2009 was equivalent to that of 1997, shown in Figure 2.

Many reasons attributed to the increasing number of accidents year on year before 2003: (1) When expressway accident rate did not change, because the mileage of expressways increased greatly and the mileage of vehicle travelled on the expressways also increased year on year, as a result road accidents on expressways increased accordingly. (2) By the end of 2003, the mileage in China was less than 30,000 kilometers. The average mileage in 30 provinces in mainland China except Tibet Autonomous Region was less than 1,000 kilometers. And a majority of drivers were unfamiliar with expressways and lack of necessary skills of driving on the expressways. Therefore, inexperience in the beginning of expressways operation resulted in many accidents. Many expressways have suffered a

period of highly frequent accidents at the beginning of operation, such as Shenyang-Dalian, Shanghai-Jiaxing, Xilin, and Beijing section of Beijing-Tianjin-Tanggu expressways [5].

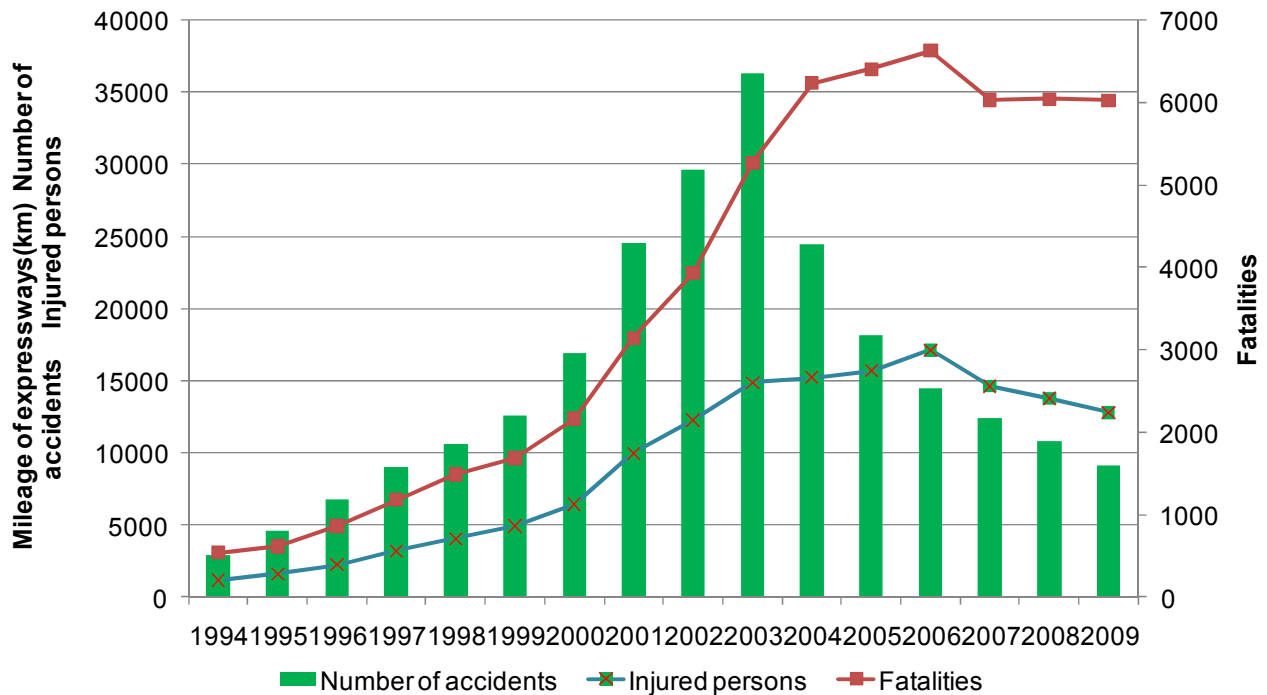


Figure 2 – Accidents on expressways in China (1994-2009) [4]

The reasons for the rapid decline of accidents after 2004 are as follows: (1) Since 2004, China's road accident statistics range has made a great change according to *Law of the Road and Traffic Safety of the People's Republic of China*. Thanks to the change, a great number of property loss accidents which were used to be regarded as general accident were treated with streamlined procedures and were away from the statistics range, therefore reducing the number of accidents greatly [6]. (2) In response to high frequency of accidents, Chinese government has adopted a series of systemic and targeted measures since 2003, and has reined in the trend of high frequency in a short period of time. And the accidents on expressways have been suppressed effectively. These measures were the core reason of reducing accidents by rapidly improving the traffic safety of expressways and effectively controlling traffic accidents. (3) Since 2004, with the fast development of China's expressway's construction, expressway network has been gradually taken shape, and many drivers are getting familiar with expressways, making traffic accidents reduced and safety improved.

### 3.2. Fatalities keeps stable after a sustained increase, but its proportion is still high

Before 2006, the accident fatalities on expressways had been increasing all the time. The main reason was that when the fatality kept at a certain level, because the rapid mileage increase of expressways and growth of ever mileage of vehicles travelled on expressways resulted in the ever increasing fatality. In addition, as mentioned above, since 2004, China has expanded its statistics range of accidents. The increased range of "road" and "accident" increased the fatalities.

From 2007-2009, the measures taken by Chinese government began to show effects, reining in the annual fatalities at 6,030 despite the mileage increase of expressways and vehicles travelled on expressways.

It should be noted that although the fatalities has been stable from 2007-2009, its proportion of the accident fatalities on expressways has been rising year on year, shown in Table 2. In 2009, the proportion rose to 8.90% of the total fatalities, while at the same time the expressway mileage accounted for only 1.69% of the total. This means that expressways have played a bigger role in economic and social development, but it also means that the traffic safety of China's expressway is still not that optimistic.

Table 2 - Proportion of traffic mileage and accidents (2004-2009) \*

Year	Proportion of expressways			
	Number of accidents	Fatalities	Number of injured persons	Mileage
2004	4.72%	5.82%	3.16%	1.83%
2005	4.04%	6.49%	3.34%	2.12%
2006	3.81%	7.43%	3.97%	1.31%
2007	3.78%	7.39%	3.85%	1.50%
2008	4.09%	8.22%	4.52%	1.62%
2009	3.84%	8.90%	4.65%	1.69%

\* Data source: Ministry of Public Security, Annual Bulletin of Traffic Accident Statistics of People's Republic of China (2004-2009). Since 2006, the rural roads have been included in road mileage statistics.

### 3.3. Mortality rate is obviously higher than that of the whole road network

High speed is one of the natural properties of expressways. High speed will increase the severity of accidents. Mortality rate is an indicator measuring the accident severity, and it is the ratio between the fatalities and total casualties of accidents. The mortality rate of expressways is obviously higher than that of the whole ordinary road network, shown in Figure 3. Moreover, the mortality rate of expressways has been rising in recent years with that reaching 32.05% in 2009 while that of the whole ordinary road accidents in the same year was only 19.76%. That is to say, 1 of the 3 casualties in expressway accidents will die, showing that the mortality rate of expressways is very high. Though the mortality of expressways is normally higher than that of the whole road network, higher mortality rate also reflects in another way that the medical relief after the accident needs to be improved urgently.

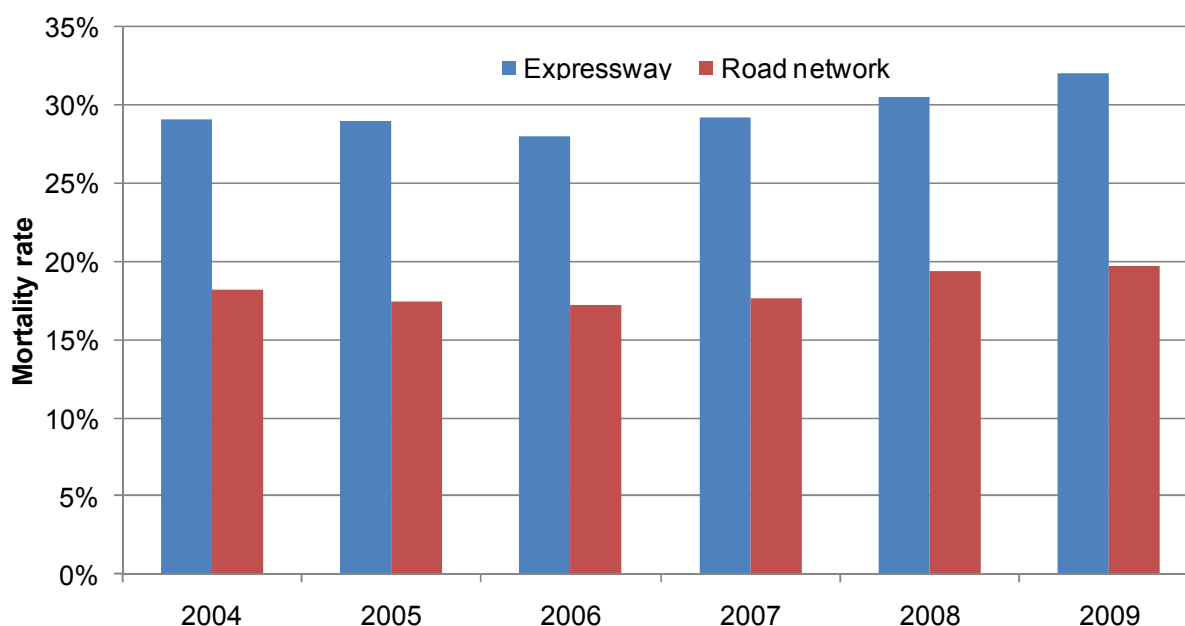


Figure 3 - Mortality rates of expressways and the whole road network (2004-2009)

\*Data source: Ministry of Public Security, Annual Bulletin of Traffic Accident Statistics of People's Republic of China (2004-2009).

### 3.4. Speeding and fatigue driving are the major reasons of accidents

Expressways have the features of good road indicators, good quality roadway, fully enclosure, no interference of passengers and slow speed vehicles and improved safety facilities, but vehicles are prone to be speeding. On the other hand, the few interference and good traffic condition make drivers numb and slow to response to the changes of speed. But if that lasts long, it will make drivers nervous both in their vision and psychology, resulting in fatigue driving. According to statistics, in 2009 expressway accidents caused by fatigue and speeding accounted for 10.07% and 8.69% of the total road accidents, and the fatalities reached to 9.8% and 10.55% respectively of the total [4].

## 4. SAFETY BENEFIT OF EXPRESSWAYS

Apart from analysis on expressways' contribution to economic and social development, some scholars also conducted researches on the evaluation methods of safety benefit. References [7] and [8] analyzed the differences in road type and traffic condition between the expressway network and the general road network, establish a model between road service level and road accidents rate, put forward the models and methods to calculate direct and indirect economic losses caused by accidents, and use the "comparative analysis approach of with and without" to calculate safety benefit of expressways. However, because of the difficulties in acquiring data and quantifying some indexes, the research on safety benefit is now limited to theory and there has no credible research results in this respect in China.

### 4.1. Safety benefit of expressways is much higher than that of national highway network

Though expressway accidents have been decreasing over these years, the fatalities has not changed from 2007 to 2009. To evaluate if expressway safety is improved or not, the mileage of the vehicle kilometres travelled should be considered. The accident rate per 100 million vehicle kilometres travelled and the fatality rate per 100 million vehicle kilometres travelled can objectively reflect safety situation on the expressways.

China's expressway safety has been improved over these years. The accident rate per 100 million vehicle kilometres travelled of expressways has been reduced from 21.9 in 2003 to 2.3 in 2009 and the fatality rate per 100 million vehicle kilometres travelled of expressways has been decreased from 2.2 in 2003 to 1.5 in 2009, shown in Figure 4. The safety benefit of expressways is playing a role.

### 4.2. Safety benefit evaluation of expressways

Compared with national highway network, the accident rate and fatality rate per 100 million vehicle kilometres travelled of expressways are much lower. For instance, in 2005, the rates of expressways stood at 7.4 and 2.6 respectively, while that of national highway network was 17.6 and 5.7 respectively. In 2009, the rates of expressways were 2.3 and 1.5 against 5.6 and 2.5 for national highway network, shown in Figure 4. That is to say, the safety benefit of expressways is much higher than that of national highway network.

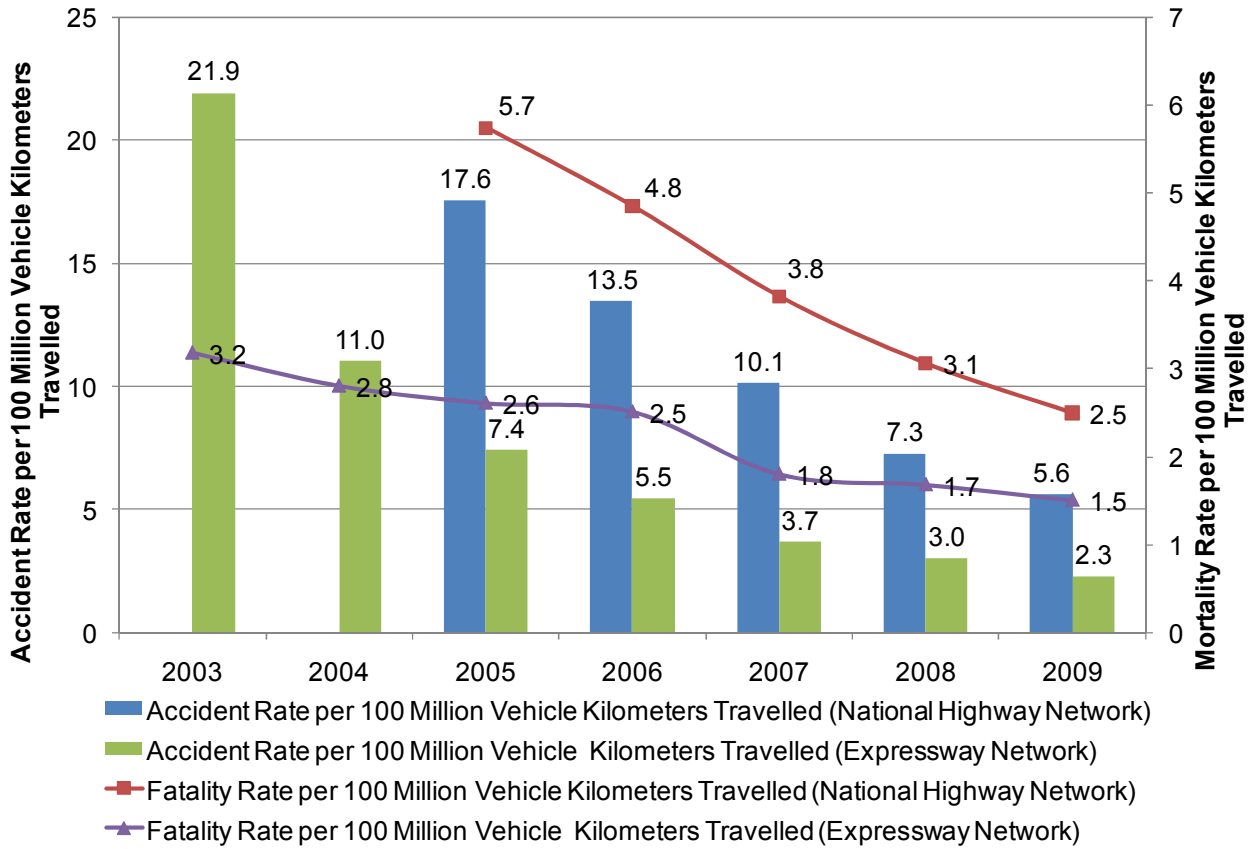


Figure 4 - Transportation accident rates of expressways and national highway network (2003-2009) [6,9]

Assume that the annual average daily vehicle kilometres travelled of expressways is  $MVT_{ex}$ , the annual number of accidents of expressways is  $N_{ex}$ , the fatalities is  $F_{ex}$ ; assume that the accident rate and fatality rate per 100 million vehicle kilometres travelled of national highway network is  $AR_{nh}$  and  $FR_{nh}$  respectively; assume that the national highway network is responsible for all mileage of the vehicle kilometres travelled of expressways, then the number and fatalities happened on the national highway network of this mileage is  $N_{nh-ex}$  and  $F_{nh-ex}$  respectively, and:

$$\begin{cases} N_{nh-ex} = 365MVT_{ex} \square AR_{nh} \\ F_{nh-ex} = 365MVT_{ex} \square FR_{nh} \end{cases} \quad (1)$$

Compare  $N_{nh-ex}$  and  $F_{nh-ex}$  with the actual number of accidents  $N_{ex}$  and fatalities  $F_{ex}$  of expressways, the two variables,  $\Delta N_{ex}$  and  $\Delta F_{ex}$ , can be calculated, shown in Formula 2. The two variables are the changes of accidents due to the existence of expressways. This is the safety benefit of expressways.

$$\begin{cases} \Delta N_{ex} = N_{nh-ex} - N_{ex} \\ \Delta F_{ex} = F_{nh-ex} - F_{ex} \end{cases} \quad (2)$$

If  $\Delta N_{ex}$  and  $\Delta F_{ex}$  are all positive, that means expressways can reduce accidents and casualties compared with national highway network. If  $\Delta N_{ex}$  and  $\Delta F_{ex}$  are all negative,

that means expressways can increase accidents and casualties compared with national highway network.

After applying the accident data of expressways and national highway network in 2009 into the two formulas, we can see that  $\Delta N_{ex}$  is 13,407 and  $\Delta F_{ex}$  is 3,973, meaning that expressways helped to reduce 13,407 accidents and 3,973 fatalities, accounting for 5.62% and 5.86% of the total. In 2009 alone, the expressways reduced accidents by 5.62 percentage points and fatalities by 5.86 percentage points, so the safety benefit of expressways is very huge.

Reference [10] proposed the average cost for accident casualties in 2006. Average cost of casualties means the average damage fee for each casualty in the accident within a certain region in the calculation year, including medical fees, output damage, injury and sorrow damage, damage for decline of life quality and funeral expense. Of which, the average cost of one death, or  $ACF_{2006}$  was 948,877 RMB, that of severe injury, or  $ACSI_{2006}$  was 234,387 RMB and that of light injury, or  $ACLI_{2006}$  was 29,187 RMB.

As mentioned above, in 2009 the accident fatality rate was 19.76%, and if the reduced fatality was  $\Delta F_{ex}$  because of expressways, we can calculate that the number of casualties was reduced by  $\Delta I_{ex}$  :

$$\Delta I_{ex} = \frac{1 - 19.76\%}{19.76\%} \Delta F_{ex} \quad (3)$$

The result:  $\Delta I_{ex} = 16,133$  . According to experience, among the casualties, 30% were heavy injuries and the rest were light ones, it can be concluded that the number of heavy injuries reduced in 2009, or  $\Delta I_{ex-s}$  was 4,840 and light injuries, or  $\Delta I_{ex-m}$  was 11,293.

In conclusion, based on the average cost for accident casualties in 2006, the reduced accidents damages with the existence of expressways or safety benefit of expressways  $SB_{ex}$  in 2009 was:

$$SB_{ex} = \Delta F_{ex} \square ACF_{2006} + \Delta I_{ex-s} \square ACSI_{2006} + \Delta I_{ex-m} \square ACLI_{2006} \quad (4)$$

The detailed calculation is shown in Table 3. Because the average cost of accidents in 2009 was higher than 2006, therefore safety benefit of expressways in 2009 will exceed 5.234 billion RMB.

Table 3 - Safety benefit of expressway (2009)

Casualty degree	Death	Heavy injuries	Light injuries
Cost (RMB)	948,877	234,384	29,187
Decreased number	3,973	4,840	11,293
Subtotal (10 thousand RMB)	376,988.83	113,441.86	32,960.88
Total (1 billion RMB)	5.234		



## CONCLUSION

By analyzing the expressways development, contribution to economic and social development and also the features of accidents on expressways, we found that China's expressway traffic safety is improving gradually with the accident rate and fatality rate much lower than that of national highway network. The calculation method of the safety benefit of expressways is proposed, and the result find that expressways have a great safety benefit with that in 2009 exceeding 5.234 billion RMB. Therefore, the safety benefit of expressways in China should not be overlooked.

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