# A STUDY ON CHINA'S EXPRESSWAY SPEED MANAGEMENT MODELS AND CASE ANALYSIS

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## ABSTRACT

With the rapid increase in expressway mileage, more and more problems are emerging in taking the design speed as the top speed limit value. How to scientifically manage expressway speed is increasingly becoming a prominent issue. Considering the two objectives of efficiency and safety and China's actual demand for expressway speed management, this study explores China's expressway speed management models and their adaptability on the basis of a large volume of data. Meanwhile, the concept of pace speed is introduced into this study, and an evaluation method that is suitable for China's expressway speed management models is proposed. Finally, in a case study of typical expressway, after the speed limit program is formulated and speed management model is adjusted, the objective evaluation results can be obtained based on the quantitative analysis and testing of traffic flow and traffic safety.

**KEY WORDS:** speed management; speed limit ; evaluation ; operating speed ; pace speed

## 0. PREFACE

With the gradual formation of China's expressway infrastructure construction in scale and of the expressway network, expressway have become the aorta of rapid social development and the important travel mode of the residents. However, the improvement of expressway driving environment and the enhancement of vehicle performance highlight the conflict between the expectation of drivers for speed and the low speed limit in the expressways. Currently, China's expressway speed control is mainly based on the expressway design speed, a single and fixed speed limit. Usually, the speed limit value is set equal to or 10km/h less than the design speed value. In China's current expressway design specifications, the design speed can not accurately reflect the actual driving conditions or the operating speed. Taking the actual situation mentioned above and the need of expressway speed management into consideration, this study analyzes different models of the speed limit based on a lot of data, focuses on the effect evaluation of the adjustment of the speed limit models, and applies this method into practice.

## 1. ANALYSIS OF SPEED MANAGEMENT MODELS

The Expressway Speed Management models in China include single speed limit, different

speed limits for different vehicles, and different speed limits for different lanes.

### 1.1 Single speed limit

Single speed limit provides the only one speed limit in some section of the expressway for all vehicles in all lanes that they should not drive above or below this fixed value. This kind of model is suitable for some sections where different speeds for different vehicles have little effect on the operating safety, or for some special sections where a single speed limit is needed.

### 1.2 Different speed limits for different vehicles

This kind of model means to set different speed limits for different vehicles according to the characteristics of traffic flow, the requirements of vehicle operating safety and management. The vehicles can be divided into two categories, namely vehicles for passengers and vehicles for goods, or cars and large vehicles; they can also be divided into three categories: cars, buses and trucks.

### 1.3 Different speed limits for different lanes

This model requires vehicles traveling in different lanes to follow the speed limits as shown in the corresponding lanes. Generally, speed limit signs should be installed by the door frame, hanging above the corresponding lanes, and text markings on the road can also be used (Figure 1-1).
Different speed limits for different lanes can reduce the speed difference in the same lane and the change operation between different lanes, avoid mutual interference of the vehicles, improve traffic flow operation, and help to enhance the safety and road capacity. How to choose the range of speed limit values for lanes need a strict analysis of road traffic conditions. Otherwise，an unreasonable speed limit will lost its meaning, or even artificially cause speed difference among vehicles, and make it a risk for security.


Figure 1-1 different speed limits for different lanes

## 2. ADAPTABILITYOF EXPRESSWAY SPEED MANAGEMENT

Most people will follow certain behavior that is reasonable at some extent during their daily life, so that most of our laws are reflections of people's common behavior. The traffic laws and regulations are also established on the basis of behavior observation of most vehicle drivers in different conditions. And only those laws and regulations that reflect the common behavior of most vehicle drivers can be verified to be successful. The arbitrary restrictions of laws on the behavior of most vehicle drivers mean an encouragement of large-scale irregularities. Without the support from the majority, the objective of changing the driving behavior by laws and regulations will definitely fail.

The same principle can also be used in expressway speed management. Only when it meets the operational characteristics of most vehicles, the speed limit management model can be obeyed by the expressway users and to be effective. So, the adaptability of speed limit programs need to be analyzed according to the actual operating speeds of the vehicles.

### 2.1 Adaptability of single speed limits

Expressway safety speed limit is generally set at 110~120km/h, which is a general adopted value by the international community, as well as a security alert value derived from analysis of a large number of statistics. Single speed limit is adopted in most china's expressways, and usually its value is 100km/h. However, our survey data (Table 2-1) show that this speed limit value is clearly low because the 85th percent speed ($V_{85}$) in the linear sections is generally between 101~125km/h. The speed difference between cars and trucks are wide, so the single speed limit cannot meet the operational requirements of different vehicles.

Table 2-1 $V_{85}$ in expressway traffic flow

| Vehicle | Straight section | Curve section * | Top of the upgrade section |
|---|---|---|---|
| All vehicles | 101 ~ 125 | 91 ~ 107 | 83 ~ 108 |
| Cars | 117 | 112 | 101 |
| Trucks | 83 | 78 | 63 |

* refers to curve section with its radius ≤1000m road

### 2.2 Adaptability of different speed limits for different lanes

On the basis of a large number of observational data, we can see the speed distribution of different lanes (Table 2-2) in the four-lane expressways. In the inner lane, the $V_{15}$ is between 100 ~ 129km/h and $V_{15}$ (the 15th percent speed) is between 60 ~ 95km/h, while in

the outside lane, the V85 is between 83 ~ 112km/h and $V_{15}$ is between 53 ~ 78km/h. There exists a great difference between the two lanes in the same direction, and it is not possible to reduce the operating speed by adopting different speed limits for different lanes, so it is no need to take this model in this situation.

Table 2-2 vehicle speeds in straight sections of four-lane expressways (km/h)

| lanes | Total number of lanes (two directions) | $\overline{V}$ * | $V_{15}$ | $V_{85}$ | $V_{P20}$** |
|---|---|---|---|---|---|
| Inside lane | Four-lane | 87 ~ 109 | 60 ~ 95 | 100 ~ 129 | 100 ~ 117 |
| Outside lane | Four-lane | 71 ~ 98 | 53 ~ 78 | 83 ~ 127 | 72 ~ 105 |

* $\overline{V}$ is an average velocity of cross-section.

** $V_{P20}$ is the pace speed with speed interval being 20 km/h

The contrast of vehicle speed distribution in different lanes in straight sections of six-lane expressways (Table 2-3) shows that along the direction of traffic, the vehicle speed in the fast lane is significantly higher than that in the other two lanes, and there is almost no overlap between the speed ranges in the inside lane and the middle lane. As for the pace speed, the bottom speed value in the middle lane is very close to that in the outside lane, while the top speed value is higher, so that there is a large overlap interval between the speeds in the middle and outside lanes.

Table 2-3 vehicle speed in linear sections of six-lane expressways (km / h)

| Lanes | Total number of lanes (two directions) | $\overline{V}$ | $V_{15}$ | $V_{85}$ | $V_{P20}$ |
|---|---|---|---|---|---|
| Fast lane | six-lane | 101 ~ 114 | 85 ~ 97 | 111 ~ 127 | 106 ~ 113 |
| Center lane | six-lane | 81 ~ 97 | 62 ~ 77 | 99 ~ 112 | 74 ~ 108 |
| nearside lane | six-lane | 67 ~ 77 | 54 ~ 62 | 79 ~ 89 | 73 ~ 81 |

* $\overline{V}$ is an average speed of cross-section.

** $V_{P20}$ is the pace speed with speed interval being 20 km/h

The survey for sections which have already taken the model of adopting different speed limits for different lanes shows that when adopting this kind of model, it is necessary to take many factors into consideration, such as traffic volume, ratio of different vehicle types, number of lanes, distribution ratio of the vehicle speed and other factors, and to use a variety of speed limit values (top or bottom limit). Otherwise, the speed limit range is hard to be followed, and the effect of adopting different speed limits for different lanes is not obvious.

2.3 Adaptability of different speed limits for different type of vehicles

There is a high rate of trucks in vehicles travelling in China's expressways, so the state of China's expressways is a mixed traffic. Over the last decade, the performance of cars is greatly improved, while the overall performance of trucks is still relatively low and cannot achieve an effective match with the expressway traffic, causing a clear speed difference between different vehicles in expressways. The operating speed difference between cars and trucks is 25km/h ~ 45km/h (Table 2-1). This obvious difference between small vehicles represented by cars and large vehicles represented by trucks makes it possible to adopt different speed limits for different vehicles.

Due to the huge weight and inertia of trucks, the consequences of accidents are usually very serious when they get involved. According to the survey findings of several expressways in Guangdong Province, 97.5% of the major traffic accidents are caused by the trucks. The trucks should be the key vehicles in speed management. So, it is necessary to adopt different speed limits for different vehicles to avoid potential safety problems existed in single speed limit.

## 3. METHOD FOR EVALUATION OF SPEED LIMIT MODELS

In China, different methods have been gradually adopted in some provinces and cities to adjust the speed limit values, but little has been done in quantitative effect evaluation of the speed limit adjustment on expressway operational efficiency and safety. Therefore, this study focuses on the effect evaluation of speed limit adjustment, and applies this method into practice.

3.1 Basic principles for evaluation

As a management tool, speed limit has a various purposes, such as security, energy, environment, and so forth. Considering the basic point of adjusting China's expressway speed limit, this study takes safety and efficiency as evaluation criteria. Since the evaluation system is required to evaluate the object scientifically, accurately and comprehensively, as well as to be practical, the establishment of evaluation system must follow the following principles :

(1)Select a reasonable number of structural levels and indicators

Practically, only those simple and effective methods can get a wider range of applications. Therefore, it is a must to think comprehensively and properly select the most representative indicators to show their values in practice.

(2)Meaning of every indicator must be clear and cannot be the same as the other

Meaning of every indicator must be clear; otherwise it will influence the evaluation result, or

even make the evaluation a failure. It is also of great importance that meanings of the indicators should not be the same between any two of them, and this is a guarantee of the independence among the indicators in the same level.

(3)Select more quantitative indicators combined with some qualitative ones

In order to ensure the objectivity of the evaluation, the number of qualitative indicators in the evaluation system should not be too much, and these qualitative indicators should also be properly processed by some mathematical tools to be more quantified, and easy to be calculated.

In addition, the indicators are also required to be comparable to compare and analyze the evaluation results of different sections, or the same section in different stages.

## 3.2 Selection of evaluation method and indicators

### 3.2.1 *Evaluation method*

Generally, the method for evaluation is to compare the indicators changes before and after the adjustment of speed limit. What we need to pay attention to is that when the evaluation period is relatively long, the comparison should be carried out between the value of indicators after the adjustment of sped limit model and the expected value of indicators in "Zero" program (without taking any adjustment) to reduce the influence of inherent tendency of change

### 3.2.2 *Traffic efficiency evaluation*

The main consideration in traffic efficiency evaluation is the changes of overall operation of traffic flow before and after the adjustment of the speed limits, and the operating speed is taken as the evaluation indicator. In practice, the V85 in the vehicle free flow speed cumulative distribution curves is the most common measure of running speed in specific location.

### 3.2.3 *Safety evaluation*

Safety evaluation mainly analyzes the impact of speed limit adjustment on expressway traffic safety. In order to reflect the changes in traffic safety more comprehensively, the evaluation should be carried out by using direct and indirect indicators respectively.

(1)direct indicators

Direct indicators refers to traffic accident indicators, including the number of accidents, accident rate, accident severity, direct economic losses caused by accidents, and the changing rate of the number (rate) of accidents, etc. The direct indicators with comparability can be selected according to the actual situation to use in the evaluation.

(2)indirect indicators

Some other relative researches show that the risk of expressway accidents is related to the difference between operating speeds of vehicles, and the accident rate will be at the lowest level when vehicles run at the average speed, while the accident rate will increase no matter the operating speed of vehicles is higher or lower than the average speed. So, this study use pace speed, which characterizes the homogeneity of the operating speed of vehicles, to evaluate the changes of expressway traffic safety. Considering the big difference in speed due to the difference of vehicles performance, the speed interval is taken as 20km/h. [1] [2]

## 4. CASE STUDY

In order to verify the applicability of the speed limit model and the effectiveness of the evaluation method, this study selects a expressway where a speed limit adjustment has been carried out.

### 4.1 Overview of the Project

The design speed of this expressway is 100km/h, where section A has two-way six lanes and section B has two-way 4 lanes. The alignment of this expressway is relatively smooth, and the minimum radius of the horizontal curve is 1000m. The original speed limit model of this expressway was single speed limit, and its top speed limit value was 100km/h, equal to its design speed. However, in the long-term operation, this speed limit value was seriously conflict to the expected speed value of car drivers, so over-speeding is a common thing in this expressway.

After conducting a lot of survey and research, the speed limit model in this expressway was adjusted to different speed limits for different vehicles in April 2009. The top speed limit values for cars and large vehicles in section A are set at 120km/h and 100 km/h respectively, while in section B are 110km/h and 100 km/h. At the same time the large vehicles are required to drive keep right (Figure 4-1).


Figure 4-1 sign of different speed limits for different vehicles

4.2 Implementation of evaluation

In order to explore the impact of speed limit adjustment, some typical cross-sections are selected to compare the changes of vehicle speeds in these points before and after the reconstruction of the speed limit signs. Along this expressway, 8 observational sites are chosen from section A, and 4 others are chosen from Section B. The radar speed indicators are used to test the spot speeds of cars and trucks. In this survey, those speed data influenced by other vehicles have been excluded.

4.3 Operational efficiency evaluation

A statistical analysis is made on the observational data, and the calculated operating speeds of different vehicles are listed in Table 4-1 and Table 4-2.

Table 4-1 speed changes of different vehicles in section A

| Sections | vehicles | before the adjustment | | | after the adjustment | | |
|---|---|---|---|---|---|---|---|
| | | $\bar{V}$ | $V_{85}$ | $V_{p20}$ | $\bar{V}$ | $V_{85}$ | $V_{p20}$ |
| General section | cars | 100.3 | 114 | 101 | 106.5 | 119 | 114 |
| | trucks | 70.8 | 82 | 80 | 67 | 79 | 73 |
| | All | — | 108 | 98 | — | 114 | 116 |
| Tunnel Section | cars | 89.3 | 106 | 95 | 89.5 | 103 | 97 |
| | trucks | 70.5 | 87 | 74 | 65 | 75 | 71 |
| | All | — | 99 | 88 | — | 97 | 86 |
| Whole line | All | — | 104 | 93 | — | 106 | 101 |

Table 4-2 speed changes of different vehicles in section B

| Sections | vehicles | before the adjustment | | | after the adjustment | | |
|---|---|---|---|---|---|---|---|
| | | $\bar{V}$ | $V_{85}$ | $V_{p20}$ | $\bar{V}$ | $V_{85}$ | $V_{p20}$ |
| General section | cars | 92.8 | 108 | 101 | 96.3 | 111 | 106 |
| | trucks | 63.3 | 76 | 74 | 64.8 | 74 | 74 |
| | All | — | 102 | 89 | — | 105 | 100 |

The statistic data derived from the speed changes of different vehicles before and after the reconstruction of the speed limit signs show that, in general sections, the speed of cars after the reconstruction of the speed limit signs increases by 2.8-4.3% than that before, while trucks increase by 2.6-3.7%. The adjustment of speed limits and the carry out of strategy “large vehicles keep right” has enhanced the operational efficiency of cars, and decreased the operating speed of trucks.

## 4.4 Safety evaluation

### 4.4.1 *Pace speed evaluation*

Data in Table 4-1 and Table 4-2 show that the pace speed of cars after the reconstruction of speed limit signs is increased, and is much closer to the operating speed. That is to say, the operating speed of cars is more homogeneous, and traffic flow is more smoothly. While the pace speed of trucks is decreased and closer to the operating speed, which show that the speed difference between the trucks is narrowing, and it is conducive to traffic safety. But the risk of accident may also be increased when the cars and trucks run in the same lane since the speed difference between them is increased.

### 4.4.2 *Accident Evaluation*

From the collection and analysis of the traffic accident data before and after the reconstruction of the expressway speed limit signs (Table 4-3 and Table 4-4), we can see that before the adjustment, the monthly average accident number in section A is 6.3, equal to that in the same period of the previous year; while after the adjustment, the monthly average accident number is 13.4, a little bit lower than that of the same period of the previous year, 13.6.

As for section B, before the adjustment, the monthly average accident number is 5.3, decreased by 20.9% from 6.7 in the same period of the previous year; while after the adjustment, the monthly average accident number is 12.2, decreased by 2.4% from 12.5 in the same period of the previous year.

Table 4-3 changes of monthly average accident number in section A

| Year | Jan ~ Mar | change rate over the previous year | May ~ Oct | change rate over the previous year |
|---|---|---|---|---|
| 2006 | 10.3 | — | 14.2 | — |
| 2007 | 4.0 | -61.2% | 9.2 | -35.2% |
| 2008 | 6.3 | 57.5% | 13.6 | 47.8% |
| 2009 | 6.3 | 0.0% | 13.4 | -1.5% |

Table 4-4 changes of monthly average accident number in section B

| Year | Jan ~ Mar | change rate over the previous year | May ~ Oct | change rate over the previous year |
|---|---|---|---|---|
| 2006 | 7 | — | 9.16 | — |
| 2007 | 6.3 | -10.0% | 9.83 | 7.3% |
| 2008 | 6.7 | 6.3% | 12.5 | 27.2% |
| 2009 | 5.3 | -20.9% | 12.2 | -2.4% |

From the accident analysis, we can see that, comparing with the same period of the

previous years, there is no big change in traffic accidents after the adjustment of expressway speed limit signs, and the change rate keeps at a very low level. So, the adjustment of the speed limit signs has no significant impact on the traffic accident.

### 4.5 Conclusions

After analyzing the practical case by using the evaluation method proposed in this study, the following basic conclusions can be drawn:

(1) The adjustment of speed limit model in this project has increased the operating speed of cars and is conducive to the improvement of the expressway traffic efficiency. However, the speed increase of cars is much lower than that of the speed limit, indicating that the operating speed of vehicles is affected by many factors, not just by the speed limit.

(2) Homogeneity of both cars and trucks is raised, but the risk of accidents is also increased when they mixed in one lane since the speed difference between them is widened.

(3) The accident analysis shows that the number of accidents or growth rate after the adjustment is lower than that in the same period of the previous year, but there is no sufficient evidence to show that the traffic safety has improved significantly after the adjustment of speed limit value and speed management model.

## 5. LAST WORDS

Considering the two objectives of efficiency and safety and in order to meet China’s actual demand for expressway speed management, this study explores the adaptability of China's expressway speeds management models and find out that the model of setting different speeds for different vehicles is suitable to China’s expressway speeds management. Meanwhile, the method for evaluation of adjusting expressway speed management model and evaluation indicators are also proposed in this study. This evaluation method is applied and verified in a quantitative case study, and objective evaluation results are obtained.

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