THE PRACTICE OF ROAD SAFETY AUDIT ON EXPRESSWAYS IN CHINA

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ABSTRACT
In order to provide some countermeasures for alleviating severe traffic safety situation on expressways in China, a brief introduction to originality and development of road safety audit in developed countries is firstly provided in the paper. Then, the current practice of road safety audit on expressways in China is described. Also, the factors affecting the implementation of road safety audit are analyzed, and suggestions for promoting the application of road safety audit on expressways are proposed. Lastly, the development tendency of road safety audit on expressways is discussed and a case study based on both analysis of operating speed difference and expert experience is given.

1 INTRODUCTION
Road safety audit (RSA) can be defined as “a formal examination of a future road or traffic project or an existing road, in which an independent, qualified team reports on the project’s crash potential and safety performance”.

The concept of RSA was initiated in the United Kingdom in the early 1980’s, where the first formal guidelines were published. Then, it spread to Australia and New Zealand in the early 1990’s. During the past twenty years, RSA has been introduced to other countries such as Denmark, Canada and the United States. As a preventive measure, RSA has been proved to be highly effective in identifying and reducing the crash potential when implemented at the planning and design stages of highway projects.

RSA was introduced to China in the middle of 1990s and primarily conducted at design stages of expressway projects with loan from World Bank. In recent years, the number of fatalities due to traffic accidents occurred on expressways are rapidly increasing. Figure 1 shows the special severe road traffic accident with 36 fatalities occurred on Baomao expressway in City of Yan’an on August 26, 2012. As a result of the impending demand for RSA to life cycle of expressway projects, the Ministry of Transport (MOT) published Guidelines for Safety Audit of Highway in 2004 and the guidelines is currently under revision. The audit contents and audit methods for expressways and Class I highways are...
provided in this guidelines. At the same time, several representative literatures on RSA were published to guide the application of RSA in China.

![Figure 1: The Scene of the “8.26” Traffic Accident](image)

2 THE CURRENT RSA PRACTICE ON EXPRESSWAYS IN CHINA

To grasp the current RSA practice on expressways in China, a survey was carried out and aimed at both highway authorities and experts in traffic safety. The objectives of the survey were to determine the extent to which RSA was being conducted on expressways, obtain the suitable method for organizing RSA, and propose suggestions for promoting its application in China. Some results from the survey were summarized as follows:

(1) Highway authorities and experts are aware of the effectiveness of RSA to improve traffic safety and the respondents have common understandings in the severity of traffic safety issue and the necessity of the implementation of RSA on expressways in China.

(2) The statistical results from the survey showed most highway authorities did not conduct RSA and few experts did participate in RSA. These indicate the application of RSA to expressways in China is less common.

(3) Most of audited projects were to identify accident-prone sections on expressways, and more recent audits were conducted on expressways at design stages located in developed provinces or hilly provinces.

(4) The respondents believe factors affecting the practice of RSA on expressways include the support of highway authorities, financial resources, experiences of audit team, the aversion of the designer to RSA, and the independence of audit team.

3 FACTORS AFFECTING RSA PRACTICE ON EXPRESSWAYS IN CHINA

According to the findings of the survey, the application of RSA to expressways is limited, even though the benefits have been demonstrated to enhance the overall safety performance of expressway system. The primary sponsors of RSA are owners of new expressway projects. Based on the understandings of authors in RSA and analysis of relevant information, factors affecting RSA practice on expressways are various. The major factors are summarized below:
Currently, there are no national highway safety strategies in China and the application of RSA is not obligatory for any expressway projects. The implementation of RSA on expressways mainly relies on the owner’s attention to traffic safety.

The MOT is responsible for road building, road maintenance, and driver training. The Ministry of Public Security is responsible for traffic enforcement and driver licensing. The State Administration of Work Safety (SAWS) is responsible for monitoring transportation safety, with particular emphasis on major crashes involving several fatalities. This managing system will deter the application of RSA due to the disorder and ambiguity of safety liability.

The effect of road traffic conditions, for instance, geometric alignment, pavement surface conditions, roadside environment, traffic composition, etc., on traffic safety has not clearly been quantified. It is believed that the most effective countermeasures for improving traffic safety is to reduce driver error or illegal manoeuvre.

Highway authorities lack of standards and specifications on RSA that are suitable for the situation in China. No practical tools for RSA are available and this makes it difficult in conducting RSA on expressways to some extent.

4 SUGGESTIONS FOR PROMOTING THE PRACTICE OF RSA ON EXPRESSWAYS IN CHINA

Taking account of the situation in China, the following specific suggestions for promoting the practice of RSA are proposed by assimilating experience abroad and experience from other industries in China.

(1) The understanding of highway authorities and traffic engineering technicians in RSA, especially the role and significance of RSA to traffic safety, should be further improved.

(2) The MOT should promote the application of RSA to expressways at the design stage of demonstrated projects in each province, and its application can be gradually expanded based on accumulated experiences and theories.

(3) It is suggested to further study RSA, make experiments, solicit opinions, and develop technical standards and specifications on RSA related to expressways, and engineering technicians can refer to these materials and make better decisions in designing expressways and identifying accident-prone sections.

(4) Conducting RSA on new expressway projects should become a legal procedure, and then the scope of audited projects will be gradually expanded to existing expressways and other classified highway projects in the future.

(5) The training and continuous education for traffic safety auditors should be conducted periodically and a database should be established for convenient management of auditors.

In addition, specific suggestions for the selection of RSA stages, the organization of RSA and the audit process are made.

- Selection of RSA stages
  
  RSA can be conducted at different stages including feasibility, draft design, detailed design, pre-opening and post-opening stage of a expressway project. At each stage, an audit should focus on different issues. For example, a feasibility stage audit is concentrated on safety issues associated with options such as route locations, layout of interchanges. A draft design stage audit mainly includes the evaluation of general design standards. A detailed design stage audit will lay particular emphasis on installation of traffic safety facilities. In general, these audits are not applied to all stages of an expressway project. For major new
expressway projects, RSA can be conducted at the planning or design stage and will result in the most successful improvements because it generally has more time available in which to redesign, fewer constraints and more cost effective. For minor new expressway projects, the draft design stage audit is priority.

- The organization of RSA

There are several modes for organizing RSA while ensuring the audit team has the appropriate training, expertise and independence of the design team. The most effective mode for organizing RSA is to engage a specialist audit team that has skills and experiences in traffic safety engineering and is independent of the project. At present, the implementation of RSA in China is still progressing, and relevant policies are not well established. RSA can be conducted by experienced researchers or consulting firms in the fields of highway planning and design, accident studies and traffic safety.

- The audit process

As set forth in the definition, RSA is a formal process that requires a step-by-step procedure to be followed. In this paper, a suggested audit process for expressway projects consists of selection of an audit team, provision of background information, initial meeting, assessment of background information, site inspection, audit report preparation, and completion meeting.

5 THE DEVELOPMENT TENDENCY OF RSA ON EXPRESSWAYS

Recently, many quantitative and qualitative audit methods such as safety checklists, design consistency, vehicle stability and driver workload for expressways have been developed in China, and the most often used audit method is based on operating speed. This method includes the prediction of operating speed and audit criteria. Here, the prediction models of operating speed for horizontal curve on expressway are shown in Table 1.

<table>
<thead>
<tr>
<th>Type of curve connection</th>
<th>Prediction models</th>
</tr>
</thead>
</table>
| Entrance tangent-curve   | \( \text{Passenger Car: } v_{\text{middle}} = -24.212 + 0.834v_{\text{in}} + 5.729\ln R_{\text{nov}} \\
                      | \( +1.522\ln R_{\text{nov}} \) \\
                      | \( \text{Truck: } v_{\text{middle}} = -9.432 + 0.963v_{\text{in}} \) |
| Entrance curve-curve     | \( \text{Passenger Car: } v_{\text{middle}} = 1.277 + 0.942v_{\text{in}} + 6.19\ln R_{\text{nov}} - 5.959\ln R_{\text{old}} \)
                      | \( \text{Truck: } v_{\text{middle}} = -24.472 + 0.990v_{\text{in}} + 3.629\ln R_{\text{nov}} \) |
| Exit curve-tangent       | \( \text{Passenger Car: } v_{\text{out}} = 11.946 + 0.908v_{\text{middle}} \)
                      | \( \text{Truck: } v_{\text{out}} = 5.217 + 0.926v_{\text{middle}} \) |
| Exit curve-curve         | \( \text{Passenger Car: } v_{\text{out}} = -11.299 + 0.936v_{\text{middle}} - 2.060\ln R_{\text{nov}} + 5.203\ln R_{\text{fvery}} \)
                      | \( \text{Truck: } v_{\text{out}} = -10.05\ln R_{\text{nov}} + 0.329\ln R_{\text{fvery}} \) |

Table 1: Prediction models of operating speed for horizontal curve
Here: $v_{in}$—operating speed at entrance of curve, $v_{middle}$—operating speed at midpoint of curve, $v_{out}$—operating speed at exit of curve, $R_{front}$—radius of previous curve, $R_{now}$—radius of current curve, $R_{back}$—radius of subsequent curve.

Based on predicted operating speed difference, the geometric alignment design can be audited using the following criteria.

**Table 2: Safety audit criteria based on operating speed difference**

<table>
<thead>
<tr>
<th>Safety level</th>
<th>Speed difference $\Delta V$ (km/h)</th>
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<tbody>
<tr>
<td>Good</td>
<td>$\Delta V &lt; 10$</td>
</tr>
<tr>
<td>Fair</td>
<td>$10 \leq \Delta V \leq 20$</td>
</tr>
<tr>
<td>Poor</td>
<td>$\Delta V &gt; 20$</td>
</tr>
</tbody>
</table>

Here: $\Delta V_{ps}$—predicted operating speed difference of two successive road sections.

With the aid of above mentioned audit methods, the application of RSA on expressways will be expanded and its effectiveness will be further elevated in the future. Currently, the central government is putting more emphases on traffic safety, as a useful tool in preventing traffic accidents, RSA will play a significant role in highway traffic safety, especially for expressways.

6 CASE STUDY

This case study resulted from the pre-opening stage audit carried on AB Expressway at the request of AB Expressway headquarter.

The audit team consisted of 7 members specializing in geometric alignment, traffic engineering, traffic safety, subgrade and pavement design, bridge engineering, and tunnel engineering.

(1) Analysis of operating speed difference for passenger car

Firstly, the audit team predicts the operating speed for passenger car at both directions of AB Expressway using prediction models. Then operating speed differences of successive sections are calculated and results are shown in the following figures.
For passenger car, operating speed difference of successive sections along direction A to B is always less than 10km/h. This indicates that safety level is good.

For passenger car, only one of operating speed differences along direction B to A is larger than 10km/h, and it is also less than 20km/h. This indicates that safety level is acceptable.

(2) Safety deficiencies identified by on-site visit

Using the checklist developed for the pre-opening stage audit prior to the audit, the audit team reviewed the drawings and inspected the expressway during the daytime and again at night. Safety deficiencies are identified and countermeasures are given as follows.

1) Tunnels

There is lack of treatment for headwall of tunnel portals and it is potentially dangerous for vehicles entering the tunnel because of the change of roadway environment. It is suggested to shield the headwall with a longitudinal traffic barrier.
Figure 4: No Treatment for Head Wall of Tunnel Portals

2) Traffic signs
   Traffic signs are obstructed by trees. It is difficult for drivers to read the information provided by the sign. It is suggested that trees be removed or traffic signs be relocated.

Figure 5: Traffic Signs Are Obstructed by Trees

3) Traffic barriers
   There are no transition sections between concrete barriers and w-beam barriers. It is suggested transition sections be designed to strengthen the connection between concrete barriers and w-beam barriers.
4) Clear zone
Sign support is located within the roadside clear zone. It is possible to be impacted by an errant vehicle leaving the roadway. It is suggested to reduce impact severity using an appropriate breakaway device or shield the support with a longitudinal traffic barrier.

5) Interchange exit ramp
The grades of some down-hill slopes for interchange exit ramps are large. It is difficult for drivers to recognize the ramp alignment while driving on deceleration lane. It is suggested speed-reduction markings be delineated and sight inducement be strengthened at the exit area.
7 CONCLUSIONS

In this paper, the current status of RSA practice on expressways in China is described and the relevant affecting factors are analyzed. Suggestions for promoting the application of RSA in China are put forward. Also, the development tendency of RSA on expressways and the conduct of RSA on AB expressway in China are also introduced. The further work will focus on the following tasks:

(1) Propose standards and specifications for RSA on expressways.
(2) Establish procedures and administrating regulations of RSA on expressways.

REFERENCES

JTG/T B05-2004, Guidelines for Safety Audit of Highways [S].