A CASE STUDY ON SAFETY MEASURES AT MEDIAN OPENINGS
ON FOUR-LANE TRUNK ROADS IN CHINA

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ABSTRACT

This paper describes the safety improvements that were made to an 11km long section of Class-I highway in Hexian county in the province of Anhui (chainage K45 to chainage K56) and summarizes the results of tests used to evaluate the likely changes in risk.

Class-I highways mainly function as arterial highways with high design speeds (e.g. 80km/h, 100km/h) but have at-grade intersections and access points (that is, they are not accessed controlled). They typically have two lanes in each direction with a median.

Following the occurrence of two deaths and four injuries on the road section during a four month period, conditions on the road were examined, including conducting a ChinaRAP assessment, and improvements were rapidly made. The improvements included speed management, adjustment of median openings, installation of protected turn lanes and delineation.

In the 12 months after the improvements were made, no fatal or serious crashes occurred. Evaluations also show that there have been reductions in speed, improvements in the ChinaRAP risk scores and good acceptance of the changes by the local community.
Introduction

By the end of 2014, the total length of highways in China had reached 4.46 million kilometers, including 85,400 kilometers of Class-I highway (1.9% of the total length). In total there were 108,795 injury crashes resulting in 40,676 fatalities in 2014, and Class-I highways accounted for 8.3% of the crashes and 9.98% of the fatalities. Therefore, improving road safety on Class-I highways is crucially important.

The common cross-section of a Class-I highway is as shown in Figure 1. Highways of this class usually have two-lanes in each direction that are separated by a median. Class-I highways mainly function as arterial highways with high design speeds (e.g. 80km/h, 100km/h) but have at-grade intersections and access points (that is, they are not accessed controlled). Because of high population density, especially in non-mountainous areas, and the daily needs of residents along the highways, Class-I highways often have many median openings in addition to those at intersections. Conflicts between high-speed through traffic and lower-speed local and cross traffic and pedestrians at these median openings are often the cause of serious injuries and deaths.

This paper describes the safety improvements that were made to one such section of Class-I highway in Hexian county in the province of Anhui (chainage K45 to chainage K56) and summarizes the results tests used to evaluate the likely changes in risk. The safety improvements made reflect improvements that have been successfully applied to similar sections of Class-I highway in China.

Figure 1  Common cross-section of four-lane Class-I highway

PROJECT ROAD CONTEXT

S105 is the major arterial highway connecting Hexian with Chaohu and the Nanjing urban area in Anhui province. The K45-K56 section, as shown in Figure 2, is of typical Class-I highway design with a design (and posted) speed of 80km/h. The total width of the road, including the median, is 24.5m.
There are 4 expressways connecting to the project road: G4211 Ningwu expressway (east), S22 Changhe expressway (south), G5011 Wuhe expressway (west) and G40 Hushan expressway (north). These four expressways cater for long-distance transportation in Hexian, but in recent times urban growth has weakened the arterial highway function of S105.

Since the opening of S105, the traffic volume has rapidly increased as has traffic crash frequency. According to the traffic crash files, four traffic crashes occurred on the K45-K56 section from October 2013 to January 2014, which lead to two deaths and four injuries. All four traffic crashes occurred at median openings and all involved through-traffic colliding with pedestrians or cross traffic.

Road conditions
The road traffic conditions along the section of road is complex: 39.1% of the length is urbanized; there are 3 signalized intersections and 22 other median openings; and there are 41 access points on the eastbound carriageway and 56 access points on the westbound carriageway.

Traffic volume
According to 24-hour 7-day continuous observation data, the daily traffic volume on the section of road is 9,605 vehicles per day (vpd). As shown in Figure 3, numerous type of vehicles use the road though passenger cars for the majority of traffic, accounting for 67.5%. The traffic volume of 22 openings at median had been observed.
Figure 3  S105 vehicle type statistics (veh)

Speed
On-site speed observations indicated that the operating speed (operating speed in this paper refers to 85th percentile speed) in urbanized parts of the road is 72km/h and the average speed is 57km/h (with a standard deviation of 17km/h) and on other parts of the road the operating speed is 82km/h and the average speed is 62km/h (with a standard deviation of 20km/h).

The observations also indicated that there is a large speed differential between vehicle types, such as between faster-moving cars and slower-moving tractors. The operating speed in urbanized parts of the road for cars is 73km/h, for motorcycles is 58km/h and for trucks is 71km/h. The operating speed on other parts of the road for cars is 85km/h, for motorcycles is 62km/h and for trucks is 80km/h.

Risk Analysis
ChinaRAP results
ChinaRAP is a partnership between the Research Institute of Highway (RIOH), Ministry of Transport and the International Road Assessment Program (iRAP). Road infrastructure risks are quantitatively assessed by roadside severity, geometric alignment, pavement conditions and other traffic operation parameters. The road risk level is categorized into five grades, whereby Grade one represents lowest risk and Grade five is the highest risk. (the methodology of ChinaRAP refers to the references)

Risk profiles produce using in the ChinaRAP risk assessment for vehicles are illustrated in Figures 4 and 5. In these charts, the risk scores are plotted on the vertical axis and the distance along the road is plotted along the horizontal axis. A higher score is associated with a higher level of risk. The black, red, orange, yellow and green bands illustrate the five risk grades. In these charts, the spikes in risk primarily occur at intersections and median openings, where the risk of right-angle and read-end crashes is highest. These openings are also locations where pedestrians often cross the road.
The average risk value along the section of road is 8.71. In the eastbound direction the average value is 8.67 and in the westbound direction the average value is 8.74. Both directions are rated as Grade 3. The westbound section has a higher risk value because of a greater degree of urbanization and access density, which is associated with more potential conflicts.

![Figure 4 Risk distribution for vehicle occupants on eastbound S105](image1)

![Figure 5 Risk distribution for vehicle occupants on westbound S105](image2)

**High risk spot analysis**

Referring to Figures 4 and 5, relatively high-risk spots are as follows:

1. Signalized controlled intersections, as in Figure 6, with high traffic volume and lack of channelization.

![Image of a signalized intersection on a road]

(1) Lack of channelization
(2) Inconsistency between traffic signs and road markings

*Figure 6 Signalized controlled intersections*

(2) Vehicles cross the openings without channelization, as in Figure 7. The width of median is 2m and the distance between the curb and markings is 0.5m. The median gap is not wide enough to safety accommodate a stopped vehicle, which adds to the risk.

*Figure 7 Opening crossings*

(3) Pedestrian, non-motorized vehicle and motorcycles can cross through openings, as in Figure 8. The movements are often not easily observed by faster-moving through traffic.

*Figure 8 Pedestrian crossings*

(4) Pedestrians crossing the median where there is no opening, as in Figure 9.

*Figure 9 Pedestrian crossing at median with plantings and no opening*
(5) The section of road includes an 800m long curve that has an 850m radius and 46° left turn angle at this curve, observed vehicle speeds increased between the tangent segment and curve segment. This high speed at the curved segment leads to high risk of run-off or central crossing collisions. At the location there is evidence of a traffic crash at the median, as shown in Figure10.

![Figure 10 Central area crossing traffic crash spots at curve segments](image)

**Safety countermeasures**

**Strategy**

As discussed earlier, urbanization has weakened the arterial function of the project road. The safety strategy adopted for the road involves the formalization of that trend and shifts the function to more safely meet the local commercial and residential road use. Key principles of the strategy were:

- For low traffic volume, high risk and high access-density conditions, the number of median openings should be consolidated.
- For high traffic volume, high risk and low access-density conditions, median opening designs should be optimized.
- For high risk segments not involving median openings, prominent risk factors should be eliminated or alleviated.

**Improvements**

**Speed management**

On sections where the median opening frequency is high, the speed limit was reduced from 80km/h to 70km/h in order to decrease the risk of vehicle crossing conflicts. At chainage K48+200, traffic police installed speed camera.

**Access management**

According to the observed traffic volume data at the median openings, taking into account risk assessment results and the spacing between openings, some of the openings for vehicles
openings for pedestrians were closed. In some cases, some openings originally used by vehicles were restricted to pedestrian access only. Road side access points were closed or optimized depending on appearance of farming roads, minor roads or conditions.

Design optimization
The designs of numerous openings was optimized so that visibility and sight distances were significantly improved, reducing the risk of crashes.

At signalized intersections, left turn or right turn lanes were added and corresponding turn phases were added to the signals. Traffic signs and road markings were also improved, such as adding traffic lane guidance signs, increasing the spacing between stop lines and zebra crossings, as shown in Figure 12.

![Figure 12 Signalized controlled intersection optimization](image)

At unsignalized intersections, the following improvements were made (see figure 13): stop or yield signs were installed on intersecting roads; left turn lanes were added at locations where intersecting traffic volumes are high (see Figure 13 (1)); speed reduction line marking was installed on the through road at locations where the intersecting traffic volumes are low (see Figure 13(2)).

![Figure 13 Unsignalized intersection optimizations](image)

(1) Left turn with high traffic volume
At median openings at pedestrian crossings, the following improvements were made (see Figure 14): the opening with was reduced and bollards were installed to prevent vehicles from using the opening; warning signs were installed; red and white retro-reflective sheeting was added to guardrails adjacent to the pedestrian crossing which provides good warning to drivers both during daytime and night.

Countermeasures at other high risk spots

Physical separation barriers were installed in the median from chainage K51 to K56 in order to prevent from walking and direct pedestrians to safer crossing points. Longitudinal speed reduction road markings and curve delineator signs were applied at the curve from chainage K54+126 to K54+817.

Effectiveness assessment

The results of an assessment of the effectiveness are summarized below in Table 1. The results indicate that although traffic volumes were largely unchanged, improvements in crashes, speeds and risk scores were recorded after the road upgrades.

Table 1 Effectiveness assessment results
### Table 1: Crash and Speed Data

<table>
<thead>
<tr>
<th>Metric</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal and serious injury crashes</td>
<td>4 (Oct ‘13 – Jan ‘14)</td>
<td>0 (Nov ‘14 - Oct ‘15)</td>
</tr>
<tr>
<td>Average speed (urban)</td>
<td>57km/h (st. dev. 17km/h)</td>
<td>58km/h (st. dev. 17km/h)</td>
</tr>
<tr>
<td>85th percentile speed (urban)</td>
<td>72 km/h</td>
<td>73 km/h</td>
</tr>
<tr>
<td>Average speed (non-urban)</td>
<td>62km/h (st. dev. 20km/h)</td>
<td>58km/h (st. dev. 16km/h)</td>
</tr>
<tr>
<td>85th percentile speed (non-urban)</td>
<td>82 km/h</td>
<td>73 km/h</td>
</tr>
<tr>
<td>Average ChinaRAP risk score</td>
<td>8.71 (Grade 3)</td>
<td>4.55 (Grade 2)</td>
</tr>
<tr>
<td>Traffic volume</td>
<td>9,605 vpd</td>
<td></td>
</tr>
</tbody>
</table>

In addition the reductions in speed reported in Table 1, average speeds decreased greatly at the curves at chainage K48+790 (where the speed camera was installed) and chainage K54+600 curve (where speed reduction markings and curve delineators were installed).

A survey of residents was also conducted by questionnaire and 36 valid questionnaires were received. All the interviewees supported improvements and were accepting of the inconvenience due to closure of some median openings.

### Before-and-after photos

Examples of the road improvements are shown below in Figure 15. Images on the left are before the improvements and images on the right are after the improvements.

1. **Vehicle cross-median harden and left-turn lane applied**

2. **Vehicle cross-speed reduction road markings**
Conclusions

This paper describes the safety improvements that were made to an 11km long section of Class-I highway in Hexian county in the province of Anhui (chainage K45 to chainage K56) and summarizes the results of tests used to evaluate the likely changes in risk.

Class-I highways mainly function as arterial highways with high design speeds (e.g. 80km/h, 100km/h) but have at-grade intersections and access points (that is, they are not accessed controlled). They typically have two lanes in each direction with a median.

Following the occurrence of two deaths and four injuries on the road section during a four month period, conditions on the road were examined, including conducting a ChinaRAP assessment, and improvements were rapidly made. In the 12 months after the improvements were made, no fatal or serious crashes occurred. The improvements included:

- consolidation of median openings and access points (including closure of some medians, including to prevent jay-walking)
- restricting movements at some median openings to pedestrians only
- significantly enhancing the visibility of pedestrian crossings
• reducing the speed limit from 80km/h to 70km/h and installation of speed cameras at one location
• enhanced delineation at unsignalized intersections and at a significant curve
• installation of protected turn lanes at larger intersections turn phases at signalized intersections.

Evaluations also show that there have been reductions in speed, improvements in the ChinaRAP risk scores and good acceptance of the changes by the local community.

In this project several engineering improvements were introduced. However, to make further road safety gains, particularly to prevent jay walking and conducting of agricultural activities on the paved shoulder, systematic measures such as awareness campaigns, education and enforcement should be enhanced.

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REFERENCES

