Safety Audit of Construction Drawing Design of the NR3 Highway Reconstruction & Expansion Project and Traffic Safety Developing Suggestion in Cambodia

Baiyan Gong1,a, Shengde Di1,b, Siyuan Hao1,c, Lei Chen1,d, Zhiwei Zhou1,e

1Research Institute of Highway Ministry of Transport, RIOH, MOT, Beijing, China

a* 87248309@qq.com, b13141318384@126.com, chaosiyuan626@126.com,
d61975289@qq.com, ezw.zhou@rioh.cn

Abstract—The highway safety audit is a means to improve the safety level and service ability of highway. Based on the safety audit of Cambodian highway in the construction drawing design and the investigation on the local road network conditions, the countermeasures for improving the road traffic safety and the suggestions for the future development of road traffic safety are put forward.

1. INTRODUCTION
The project team worked in Cambodia on December 2019, investigated the road traffic safety situation and carried out safety evaluation work at the construction drawing stage of the reconstruction and expansion project to a specific section of NR3 Highway selected by the Ministry of Public Works and Transport of Cambodia. Through the safety evaluation of specific roads and the investigation of road network safety status, the paper puts forward suggestions for the future development of road traffic safety.

2. SAFETY AUDIT OF CONSTRUCTION DRAWING DESIGN OF THE NR3 HIGHWAY RECONSTRUCTION & EXPANSION PROJECT

2.1. Overview of Safety Audit
The highway safety audit (HSA), also referred to as Road Safety Audit (RSA) can help effectively integrate the new concept of traffic safety design at the engineering feasibility study stage, preliminary design stage, construction drawing design stage, delivery stage and post-evaluation stage. Its core is to evaluate the impact of roads and their facilities and traffic environments on traffic safety, with an aim to provide favorable conditions for increasing traffic safety through audits, thereby reducing traffic accidents and the degree of traffic accident hazards, and improving the safety level.

The highway traffic safety audit and risk assessment have been widely used in China’s highway field. China has accumulated rich practical experience, and achieved good results in this regard, which is of great importance for curbing the occurrence of serious and major traffic accidents. Moreover, China, on the basis of summarizing the aforementioned implementation experience, has formed a relatively mature safety audit and risk assessment standard system, and issued and implemented several documents such as the Specifications for Highway Safety Audit (JTG B05-2015) and Technical Guideline for Implementation of Highway Safety and Life Protection Projects (issued by the Ministry of Transport), which further standardizes and guides the implementation of safety audit and safety risk assessment.
assessment in China's highway industry, and also provides support for the promotion and application of safety audit and risk assessment work.

2.1.1. Purpose and Basis of Safety Audit
No. 3 Highway is one of the typical representatives of Cambodia’s national highways. Its current grade is equivalent to tertiary highway standards in China. As some roads are in poor condition, have low technical standards and are located at urban entrances and road sections that run through towns, the problem of urbanization and mixed traffic is prominent. The road undertakes great traffic pressure, which seriously affects its service level. The reconstruction and expansion project aims to reconstruct and expand the original road into a first-grade highway that uses two-way four-lane, and a design speed of 80km/h. As a national trunk highway in Cambodia, the design index for this project is high. After the project is completed and opened for traffic, it’s expected there will be a large traffic volume and a fast speed. Besides, the villages and factories are concentrated on the roadside, and motor and non-motor vehicles are greatly mixed, which will lead to serious traffic safety problems. The project is currently at the stage of completing construction drawing design and starting engineering construction. The safety audit to be carried out at this stage will help to provide targeted recommendations for road alignment optimization, traffic safety facilities improvement, etc., offer suggestions on safe operation of the project after it’s completed and opened for traffic and improve its safety level.

The safety audit of the reconstruction and expansion project at the construction drawing stage aims to discover the "hidden" design defects and the factors likely to cause accidents, reduce potential risks in driving safety, and propose targeted safety improvement measures and suggestions.

The basis for this audit to NR3 Highway Reconstruction and Expansion Project in Cambodia mainly includes the following standards, specifications and documents of China and Cambodia:

- Specifications for Highway Safety Audit (JTG B05-2015, short for “Safety Audit Specifications”).
- Specifications for Cambodia Road Traffic Signs (2018 edition).
- Construction Drawing Design Documents of the NR3 Highway Reconstruction and Expansion Project in Cambodia, China Road & Bridge Corporation, May 2018.
- Survey materials such as photos, videos, speed observations, etc. along the road, December 2019.

2.1.2. Audit Methods and Contents
The audit methods are mainly based on China’s safety audit standards and existing road safety audit manuals of foreign countries. By reference to mature road safety research results and on the basis of summing up the experience and lessons learned in the design and operation of existing roads, it carries out safety audit on the reconstruction and expansion project of the project’s specific section at the construction drawing stage. Main contents of the audit:

- Overall Audit on design compliance, and coordination and consistency of the running speed;
- Route audit: Audit on plane, vertical section, cross section, superelevation, sight distance, and combination audit on horizontal and vertical sections
- Subgrade pavement and roadside audit; Roadside safety clear zone, roadside skid resistance, road surface drainage, etc.
- Bridge audit: Bridge alignment design, bridge-subgrade transition, bridge pier and abutment protection, etc.
- Intersection audit: Crossing form, position, line, angle, sight distance, etc.
- Audit on traffic engineering and facilities along the route; Signs, markings, guardrails, etc.
- Put forward audit conclusions and safety measures based on the audits above

2.1.3. Working Process of the Audit
After confirming to carry out safety audit on the construction drawings for reconstruction and expansion of NR3 Highway in Cambodia, we organized various professional and technical personnel to establish a safety audit project team responsible for the safety audit work.
The project team of safety audit first communicated with the design team, collected design documents and other relevant materials, and learned in detail about the technical standards of this project, as well as the basic information of geological and climatic conditions along the section, route plan, subgrade and pavement, bridge and culvert, route intersection, traffic safety facilities, etc. In addition, the project team carried out an on-site investigation on the environment, road characteristics and traffic operation along the section in this project.

2.2. Overview of the Construction Project
The template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

2.3. Overall Audit of the Construction Project
According to the on-site investigation and discussion and after taking into full consideration the traffic characteristics, safety characteristics and road safety status along the whole line, the traffic circulation of NR3 Highway in Cambodia has the following two characteristics:
- The roads have a low technical standard, but a high functional level.
- Although the surface of No. 3 Highway is badly damaged and the cross section is not wide enough, the road has a high index of horizontal and vertical lines.

2.3.1. Traffic Volume
In order to understand current traffic circulation status of NR3 Highway, the project team selected a long straight section and a curve section as its objects of the survey in December 2019. It observed the traffic flow of two sections in half an hour at 14:00-16:00 on December 21, 2019. The statistics of their traffic volume is as Table 1.

| Vehicle Type                | 30-minute traffic volume (number of vehicles) | Long straight section | Curve section |
|-----------------------------|-----------------------------------------------|-----------------------|---------------|
|                             |                                               | To Kampot | To Phnom Penh | Total | To Kampot | To Phnom Penh | Total       |
| Small-sized passenger cars  |                                               | 141       | 98            | 239   | 204       | 80            | 284         |
| Large-sized passenger cars  |                                               | 2         | 4             | 6     | 2         | 8             | 8           |
| Small-sized trucks          |                                               | 29        | 21            | 50    | 28        | 28            | 56          |
| Large-sized trucks          |                                               | 14        | 20            | 33    | 8         | 6             | 14          |
| Outsize trucks              |                                               | 15        | 12            | 27    | 12        | 12            | 24          |
| Motorcycles                 |                                               | 143       | 135           | 278   | 196       | 164           | 360         |
| Total                       |                                               | 342       | 290           | 632   | 454       | 292           | 746         |

2.3.2. Traffic Composition
According to the observation, the traffic compositions of the project’s long straight section and curve section are respectively shown in the Fig.1 and Fig.2. As the figure shows, the traffic flow of two sections is mainly composed of small-sized passenger cars and motorcycles, of which the motorcycles account for the largest proportion, i.e., 44% and 48% in two sections, respectively. At the same time, affected by reconstruction and expansion construction of the project, the trucks in two sections occupy a
high proportion. Especially in the long straight section, the large-sized and outsize trucks occupy a significant proportion, reaching 9%.

![FIG.1 TRAFFIC COMPOSITION OF LONG STRAIGHT SECTION](image1)

2.3.3. Running Speed

According to the results of on-site speed observation and analysis conducted by the project team, the driving speed of various vehicle types at two observation points is shown in Table 2 and Table 3.

| Vehicle Type         | To Kampot     | To Phnom Penh |
|----------------------|---------------|---------------|
|                      | Average value | 85% level     | Maximum value | Average value | 85% level | Maximum value |
| Small-sized passenger cars | 54           | 65            | 77            | 57           | 66         | 94            |
| Large-sized passenger cars | 40           | 42            | 42            | 37           | 38         | 40            |
| Small-sized trucks   | 43           | 47            | 51            | 43           | 49         | 59            |
| Large-sized trucks   | 43           | 46            | 50            | 41           | 42         | 53            |
| Outsize trucks       | 43           | 46            | 52            | 32           | 31         | 40            |
| Motorcycles          | 38           | 40            | 42            | 45           | 52         | 59            |
TABLE III. VEHICLE RUNNING SPEED DISTRIBUTION OF CURVE SECTION

| Vehicle Type            | To Kampot Average value | 85% level | Maximum value | To Phnom Penh Average value | 85% level | Maximum value |
|-------------------------|-------------------------|-----------|---------------|-----------------------------|-----------|---------------|
| Small-sized passenger cars | 58                      | 70        | 83            | 58                          | 69        | 98            |
| Large-sized passenger cars | 37                      | 37        | 38            | 40                          | 40        | 42            |
| Small-sized trucks       | 48                      | 64        | 70            | 44                          | 47        | 57            |
| Large-sized trucks       | 46                      | 47        | 68            | 48                          | 50        | 57            |
| Outsize trucks           | 46                      | 50        | 51            | 37                          | 37        | 40            |
| Motorcycles              | 50                      | 52        | 54            | 51                          | 57        | 62            |

Given the above contents, the overall audit opinions on this project are as follows:

- NR3 highway currently has a small traffic volume, which is basically in free flow. The traffic is mainly composed of small-sized passenger cars and motorcycles. Affected by the project reconstruction and expansion, this section also has relatively high proportion of trucks.

- From on-site observations on the traffic flow, we found that although the road is being reconstructed and expanded and has poor road surface conditions, the running speed of small-sized passenger cars is still generally high, while that of outsize trucks is the lowest among all models.

- Although no major accidents have occurred on NR3 Highway in recent years, the running speed of vehicles will be improved and more traffic flow will be attracted upon completion of the reconstruction and expansion project. With an increase in the traffic volume and running speed, the risk and severity of accidents will be on the rise accordingly. Therefore, it’s necessary to strengthen publicity and speed control at the later stage.

2.4. Safety Audit on Route\(^{[1]}\)\(^{[2]}\)

The overall alignment of the project is generally good, but there are many designs where the straight line is too long, the length of the straight line between concentric and reverse circular curves is too short, the slope of the longitudinal slope is less than 0.3%, and the length of the slope and vertical curve is too short, which doesn't not meet the requirements of relevant standards and specifications. It’s suggested to improve the indicators that fail to meet the warning function of section safety facilities, so as to eliminate security risks.

2.5. Safety Audit on Subgrade Pavement and Drainage\(^{[3]}\)\(^{[4]}\)

On the section audited, there are few high-slope sections on the roadside, and the roadside safety has two extremes: Many residential buildings are located on the roadside of sections that cross villages and towns, and the factories are directly connected with local roads, which greatly threatens the driving safety; the roadside of sections that don’t cross villages and towns is spacious and has a good view, with a higher safety level.

The subgrade and pavement drainage design of the section audited meets relevant requirements of the Specification;

As the roadside of general sections has a wide and open view, the driver may increase his driving speed. When entering the sections that cross villages and towns, there are many interferences on the roadside, and the driver is difficult to adjust his speed in time, easy to cause traffic accidents. So it’s
necessary to strengthen the transition design between different road sections, so as to remind the driver of slowing down before entering the sections that cross villages and towns. During the rainy season, the section audited has a large amount of short-term rainfall. The project's drainage facilities should be designed to meet the drainage demands in this case.

2.6. Safety Audit on Traffic Engineering and Facilities along the Route

This project sets adequate signs, markings and safety measures along the line, basically meeting the needs of safe operation. However, the end of the guardrail adopts the anchor block structure and doesn’t set delineators, which threatens the driving safety at night. It’s suggested to take corresponding optimization measures.

2.7. Safety Audit on Reconstruction and Expansion of the Project

2.7.1. Analysis of the Impact of Substructure Construction on Safety

During the construction of pile foundation, bearing platform, pier body straining beam, etc., close the area affected by construction; lay out traffic signs, warning signs and other traffic safety facilities along the line. Relevant temporary traffic facilities shall meet requirements, without using non-standard products.

Strengthen safety education among workers. It’s strictly forbidden to run around in the operation area and road driving area.

Reasonably plan the route of material handling vehicles.

Do a good job in setting drainage facilities during construction.

2.7.2. Analysis of the Impact of Subgrade Construction on the Traffic of Existing Roads

During holidays, especially two days at the beginning and end of the holiday, the traffic volume on expressways will increase significantly to about 2.5-3 times the daily traffic volume at most. The number of traffic accidents can reach 5 times the number at ordinary times. Therefore, the project team suggests: During holidays, the construction should not occupy existing roads and other lanes as much as possible, so that the impact of construction on normal traffic operations can be minimized.

The construction unit should work with the design and construction, and other relevant departments and units to dynamically formulate the implementation plan of traffic control by stage and in a timely manner, publish various traffic conversion and control information at the construction stage that has a great impact on traffic involved in the traffic organization design, take actions in a unified and coordinated way, communicate with each other in a timely manner and implement orderly management, so as to ensure the smooth traffic flow.

2.8. Conclusion and Suggestions of the Audit

The analysis of traffic circulation characteristics, status and accident data as well as the evaluation on alignment conformity, subgrade and pavement drainage, bridge, intersection, traffic engineering and facilities along the line, etc. have shown that, the overall alignment of the project is generally good, the use of main design indicators and the layout of facilities along the line basically meet the driving safety requirements of the reconstruction and expansion project. Main audit conclusions and recommendations:

- The overall alignment of the project is generally good, but there are many designs where the straight line is too long, the length of the straight line between concentric and reverse circular curves is too short, the slope of the longitudinal slope is less than 0.3%, and the length of the slope and vertical curve is too short, which doesn't meet the requirements of relevant standards and specifications. It’s suggested to improve the indicators that fail to meet the warning function of section safety facilities, so as to eliminate security risks.

- To address the inadequate channelization design at the intersection with No. 22 Highway, it’s suggested to give priority to set it as signal crossing; at the same time, demolish the houses and other buildings on the roadside and strictly control illegal parking; use the medial strip to set a
dedicated lane for turning left; widen the right side to add lanes for turning right, including right-turn deceleration lanes, auxiliary lanes, and turn lanes; set reminder signs and take speed management measures in front of the sections that cross villages and towns before and after the intersections.

In summary, the existing roads of NR3 Highway—the main national trunk road in Cambodia have good alignment conditions and dense villages and towns on the roadside, bringing more roadside interferences. This reconstruction and expansion project will not only significantly improve the road traffic conditions, but highlight the safety issues, mainly including the inconsistency between the road infrastructure and its functions. Specifically, on the one hand, the road has a higher technical level, and witnesses a higher driving speed of vehicles; on the other hand, there are many roadside interferences, as well as dense access points and pedestrian crossings. The frequent occurrence of traffic accidents caused by this contradiction has become an important lesson learned in the development of China's highways. To this end, it’s suggested that, when implementing the reconstruction and expansion project of NR3 Highway, related parties should communicate with the Cambodian government departments, improve the road design indicators, optimize supporting safety facilities according to the suggestions proposed in this Report on the premise of doing a good job in road access management and strengthening the traffic safety awareness education among masses on the roadside, so as to ensure the traffic safety on NR3 Highway after the reconstruction and expansion project is completed and is open to traffic.

3. SUGGESTIONS ON ROAD TRAFFIC SAFETY DEVELOPMENT

After the establishment of the Royal Government of Cambodia in 1993, it implemented a free market economy, promoted economic privatization and free trade, put economic development and poverty eradication as a top priority, and formulated many policy measures to improve the investment environment, attract foreign investment and reduce administrative expenses, etc. After years of recovery and development, Cambodia has seen a tremendous economic growth, with great progress also made in its transportation network. At present, its transportation network is mainly composed of highways and inland river transportation. 8 major highways nationwide are distributed with Phnom Penh as the center, and are now being gradually converted into classified highways with bituminous pavement. In the existing trunk road network system in Cambodia, there emerged many problems, including backward road facilities, low road network density, low overall pavement rate, insufficient access depth, unclear architecture and road function positioning, and imperfect main road trunk road interconnection system. These problems restrict external contacts and are not conducive for various regions to give full play to their regional advantages. Transportation infrastructure have become one of the obstacles hindering the transformation of Cambodian industry from scale development to structured development. Highway infrastructure and transportation capacity are seriously lagging behind, restricting the economic development in every possible aspect.

Through the communication with the local highway management department and the investigation on the roads around Phnom Penh, especially the NR3 highway, it is found that the development status of Cambodian highway is very similar to that of China's highway at the beginning of this century. The existing roads are only to meet the needs of people's daily life. the original national road network planning is insufficient, there is less of awareness of traffic safety. Taking the reconstruction and expansion project of NR3 highway as an example, due to the lack of technical guidance, the original road not only has a low technical level, but also has dense roadside villages and factories, resulting in many and dense roadside access points. The reconstruction and expansion project will greatly improve the technical grade and traffic efficiency of the original road. However, with the great improvement of road surface conditions and traffic conditions, the vehicle running speed will also be significantly improved. The complex roadside environment is bound to cause traffic accidents, etc. All has been fully confirmed in the development process of China's highways in the past 20 years.
On the other hand, through the communication with the highway management department of Cambodia, it is found that the road design standards of different countries such as Europe, America, Japan, South Korea and China are difficult to choose. Therefore, suggestions for the development of road traffic safety in Cambodia are as follows:

- They should establish a transportation personnel training mechanism, and focus on training highway design, construction, management, maintenance and other professionals to adapt to the explosive growth of infrastructure construction.
- They should establish our own local transportation industry standard system as soon as possible. The standard of overall, general, construction, management, maintenance and operation will be formulated and the system will be established on the basis of focusing on technical standards, taking management standards and safety standards into consideration.

4. CONCLUSION
The development status of Cambodian highway is very similar to China's highway at the beginning of this century. The existing roads are only to meet the needs of people's daily life, the original national road network planning is insufficient, lack of traffic safety awareness. China's highway development in the past 20 years has accumulated rich experience and technical solutions. China can establish a long-term cooperation mechanism with Cambodia, apply China's mature road traffic safety technology to Cambodia's highway construction, and jointly establish a good regional road traffic environment.

ACKNOWLEDGMENT
This research was supported by the Lancang-Mekong Cooperation Special Fund Project of Ministry of Transport.

REFERENCES
[1] JTG B05-2015 Specifications for Highway Safety Audit
[2] JTG D20-2017 Design Specification for Highway Alignment
[3] JTG D30-2015 Specifications for Design of Highway Subgrades
[4] JTG/T D33-2012 Specifications for Drainage Design of Highway
[5] Specifications for Cambodia Road Traffic Signs
[6] JTG D81-2017 Design Specifications for Highway Safety Facilities