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Identifying Critical Safety Issues on Two-Lane National Highways in India – A Case Study from NH 117 and NH 60

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Abstract

Safety performance of two-lane highways is a major concern for developing countries like India. So, study on identification of risk factors on such highways is of immense interest in mitigating road accidents. Although, there are several recognized practices for identifying road safety deficiencies but most of them depend on accident records. Road Safety Audit (RSA) is a cost effective proactive tool to check that the roads have been designed and built to the highest safety standards for all types of road users. It is an efficient method for improving road safety especially in countries like India where there is lack of proper maintenance of accident database. The present study aims to identify the critical safety issues observed during RSA on two major two-lane undivided highways in the state of West Bengal, India. Both the highway carries considerable amount of traffic and passes through numerous built up areas, markets and industrial belts. Several risk factors were identified at different hazardous locations along the highway stretches during the RSA. Lack of proper infrastructure, interaction of vulnerable road users (VRU) with high speed traffic and faulty geometric design are some of the most alarming safety deficiencies identified through the audit process. The insights obtained from the RSA report could not have been gained from the accident reports alone. Finally, countermeasures were suggested based on the observations made during the RSA.

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Keywords: accident risk factors; Road Safety Audit; two-lane highways; countermeasuers

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1. Introduction

In India approximately 40% of road accident fatalities occur on two-lane rural highways (MoRTH, 2016). Safety performance of two-lane highways is of major concern in the country primarily due to relatively poor road geometrics and as that the traffic from two directions is not separated, resulting in higher number of accidents with high severity. The first step undertaken for proposing any accident prevention strategy mostly focus on identifying the root causes, so that eradicating it can prevent future accidents (Thomas et al., 2013). The search for effective countermeasures has encouraged many accident investigation studies globally, analyzing the characteristics and circumstances of an accident to identify common factors leading to their occurrence. A study of previous literatures indicates that in most of the research related to two-lane highways, efforts have been made to identify risk factors through accident modelling (Shankar et. al, 1995; Abdel-Aty and Radwan, 2000; Pardillo and Llamas, 2003; Zhang and Ivan, 2005; Cafiso et al., 2008; Chiou et al., 2010). However, in India, often the road accident records are not maintained properly, and the rate of underreporting is very high for crashes of low severities. Further there is little or no coordinated effort in the road agencies to collect and maintain database on roadway inventory, geometric design and traffic regulation and control making accident modelling rather difficult.

While accident analysis is a reactive technique, proactive safety assessment such as Road Safety Audit (RSA) is a very efficient technique to identify potential road safety problems in such scenarios. The sole objective of the process is to minimize future road accident occurrence and severity by systematically identifying potential risk factors for existing or new roads by an independent audit team at the stages of operation, and planning, design or construction stages respectively.

RSA was originated in Great Britain and is now adopted by several countries around the world as an efficient road safety assessment tool. UK, Australia and several countries from Europe have been immensely benefitted from RSA over the last decade. It is also used as a model in many countries for the formulation of guidelines and planning of road networks (Jain et al., 2011). Of late RSA is being implemented on the existing and proposed new highways in India to minimize the growth of accidents on roads. As a result, various central and state agencies have commenced RSA for several projects. The present study aimed to discuss on the identified risk factors observed on 2 two-lane National Highways (NH) in the state of West Bengal, and propose appropriate countermeasures to mitigate accidents from hazardous locations.

2. Literature Review

2.1. RSA in world

RSA was first conducted in the United Kingdom in the 1980's. However, RSA was not adopted in many developed countries including the United States until 1996 (NCHRP, 2004). Through the 1990s, RSA was introduced to other countries such as Denmark, Canada, the Netherlands, Germany, Switzerland, Sweden and South Africa. By the early 90's RSA was adopted in Australia and New Zealand. In 2005, Pikunas and Pumputis (2005) deliberated the need of RSA system in Lithuania. The authors suggested including RSA as an essential tool into national road safety strategy can benefit road sector to a greater extent. In recent years, RSA has been actively implemented in the developing countries such as Malaysia, Bangladesh, India, and Mozambique and in countries such as Singapore and United Arab Emirates. Presently, the World Bank and European Transport Safety Council are actively promoting RSA as part of national road safety programs (FHWA, 2006).

Among some recent studies conducted, Ahmed et al. (2013), compared the contents of safety guidelines of seven countries, in which the documents were critically reviewed under seven parameters. Individual RSA document was studied methodically, and the parameters were compared meticulously, so that limitations or strengths of any guideline document could be easily identified. This method enabled to identify the shortcomings and any potential improvements of the guideline documents that could be recommended through this study. Importance was given to study the check list or forms attached in the guidelines. It was found that the qualifications of auditors or the requirements of the team were not highlighted equally in the documents and even the legal liability aspects were not given any emphasis in three of the seven guideline documents.

Vardaki et al. (2014) elaborated on the method followed in RSA of Attica Freeway in New York. The RSA team not only focused on identifying potentially dangerous roadway environment but also discussed on misleading or missing information on the road. The major safety issues identified by them were grouped into specific areas such as Signage, Roadside hazards, Issues related to Cross sections, Stopping Sight Distance, Decision Sight Distance, Driver Behavioral issues and Issues related to Vulnerable road users.

Pietrantonio and Bornsztein (2015) conducted an exploratory study on signalized intersections in the city of São Paulo, Brazil. The performance of RSA application is evaluated using weighted indices of concordance and disagreement. The ratings of detection or omission for the observations gathered in the accident analysis at the intersection were complemented by a statistical analysis of the influence of selected covariates on these scores. The conclusions were useful for the selection of alternative RSA procedures in agencies responsible for promoting or enforcing RSA and in professional teams carrying out RSA tasks.

Gashi et al. (2016) argued that although road accidents are caused by a combination of factors, there is less understanding of the relationships between accidents and those factors causing them, or contributing to the causes. The authors carried out their study for the Western Balkan Countries (WBC), which are among the worst road safety performers in Europe based on road fatalities per population. The study gave a comprehensive idea of the current road safety conditions from the design point of view in Western Balkan Countries with focus to the road network of Albania and Kosovo as they are the two nations with significant number of fatalities. A section of recently constructed dual carriageway in Kosovo was studied where significant deficiency of design in terms of road safety was noticed. A few more road sections in these two countries were analysed where safety was not incorporated in the design.

Huvarinen et al. (2017) emphasized that mere observance of road design and construction standards does not guarantee safety of traffic. The authors applied RSA to the risks outside the framework of standards and codes, and found the process to be cost effective. Moreover, the authors found that RSA has the potential for improving the intra-industry cooperation besides decreasing the accident rate. The thorough traffic safety audit performed at all the phases of the road construction and operation helps in determination and elimination of errors at an early stage. The study proposed that the safety audit should be combined with the experience of road sector and other field's experts for making the design of future roads in Russia more user-friendly. This will confirm to higher traffic safety level due to prevention of errors in road users' behaviour making it more predictable and safe.

Jovana et al. (2017) in a recent study collected most common road safety deficiencies identified by the authors in the context of South Eastern Europe. It was found that in different South-Eastern Europe countries RSA, Road Safety Inspection (RSI), as well as Black Spot Management (BSM) was introduced. Typical road safety engineering deficiencies have been presented in 8 different subsections, based on PIARC (World Road Association) RSA approach. This paper presents collected common road safety difficulties with relevant illustrations of associated accident risks.

2.2. RSA in India

India has just started realizing the importance of RSAs. At present there is no formal qualification in Safety Audit or Road Safety Engineering and only a few training programs are designed and conducted to produce Road Safety Auditors. The first RSA was carried out by CRRI in 2000 on Indore Bypass. In the year 2002, Ministry of Road Transport and Highways sponsored the project on "Development of Safety Audit Methodology for Existing Roadway Sections". The National Highway Authority of India (NHAI) thereafter entrusted CRRI to carry out RSA of engineering design for construction packages under on NH-2. Gradually it was recognized that RSA are to be under taken for all road types.

With the number of fatal road accidents increasing in India, the International Road Federation (IRF) has emphasized the need for regular RSAs, which have been made mandatory by the Ministry of Road Transport and Highways. Although RSA is much talked about in seminars and workshops in India, a proper RSA policy is missing at National and State levels.

The first RSA guidelines were produced in 2003 and revised in 2009 by CRRI. But still there is a need to make highway professionals aware and knowledgeable in making roads safer and the highway authorities will need to commit themselves much more seriously on road safety aspects.

As per the recently approved road safety manual the experts must carry out safety audits, not just during the design and implementation phases of the projects, but also in the post operation period to identify and rectify deficiencies.

Rao et al. (2003) carried out an accident study between Anakapalli and Visakhapatnam of NH-5. The RSA revealed that the main reason of high number of crashes on the four-lane divided highways is the direct access of the local traffic to the NHs. Moreover, median openings at a frequent interval resulted in wrong maneuvering by the road users. The analysis also indicated that vehicle drivers are mostly responsible for the accidents as they fail to perceive the situation ahead because of poor reflexes, fatigue, inexperience or intoxication. The RSA team suggested proper traffic guidance and control system and adequate infrastructural facilities to guide road users ensuring safety.

In 2010, a comprehensive manual on RSA, IRC: SP:88 was published in India. It is a guideline for RSA to the decision makers, engineers, and technicians in road sectors, providing procedures for applying quality assurance to road project from the road safety perspective. This manual is under revision for further improvement.

In a study conducted by Jain et al. (2011), the authors aimed to evaluate RSA of a section of four-lane divided NH-58. The study focused on evaluating the benefits of the proposed actions that have emanated from deficiencies identified through the audit process. The RSA team found that truck parking on highways reduced the effective width of carriageway and creates traffic hazards to high speed moving traffics. Unauthorized median openings were another potential threat identified in the audit. The Vulnerable Road User (VRU) like pedestrians and cyclists needed to be facilitated on priority. However, no design related deficiencies emerged from the study.

The case study by Kumar and Chowdary (2018) on the four-lane NH -65 indicated that road markings, condition of shoulder, condition of carriageway and median opening are the significant contributing factor for accidents. It was also observed that the moderately moving vehicular traffic, that generally occupies innermost lane of the highway, creates traffic glitches for the fast-moving vehicular traffic. The need of service road along the highway to segregate the slow moving vehicular traffic from fast moving vehicular traffic was evident from the study. The RSA report insisted that all the illegal median gaps should be closed and necessary provisions such as foot-over bridges must be provided for the local neighborhood to cross the highway on the priority basis. The undeveloped minor and major crossings along the road should be developed with necessary lighting provisions to reduce the accident rate. Footpath for the pedestrian should be developed and properly maintained near the habitant areas, industries, educational institutions and guard rail to be provided along the entire length of the footpath. The authors suggested development of special facilities for the differently abled people at bus stops.

Very few studies have been conducted till date on RSA findings particularly on NHs in India. Most of the studies conducted give a general overview of the RSA procedure. Only few studies attempted to discuss on the risk factors identified from the RSA. There are very few if any studies related to identification of risk factors for two-lane Indian highways from RSA. The traffic operation on a four-lane highway is very different from a two-lane highway; as a result, the safety issues are also different and more critical when compared. Keeping that in mind, the object the study is to discuss the RSA findings of 2 two-lane highways in eastern India and elaborate on the safety issues identified through the audit process.

3. Methodology of the Study

RSA is a recognized technique for safety assessment of accident prone locations. RSAs can be conducted at five stages to ensure that the needs of all road users are considered during each phase of project development –

(i) planning phase;
(ii) preliminary design phase;
(iii) detailed design phase
(iv) construction phase
(v) operation and maintenance phase of an existing road

In the present context, the RSA was performed on existing road at operation and maintenance stage. The following steps are followed in this project.

3.1. Formation of Audit Team

The RSA team comprised of traffic engineers with suitable training, skills and experience in Road Safety Engineering work and/or Collision Investigation. The team was managed by an Audit Team Leader. The audit team members were well versed in the most recent practices and developments in the field. The members possessed a clear understanding of how the best practiced highway design principles may benefit road safety.

3.2. Road Safety Audit Process

The audit process included inspection of operating condition of both the highways during day and night. To do that the RSA team travelled through the entire project corridor and identified several safety critical components. Notes were taken on the way with respect to horizontal and vertical alignments; available sight distance; layouts of curves and intersections/interchanges; road cross-section; bridges and culverts; side drains; provision for parked vehicles, slow moving vehicles (tractors, bullock carts, bicycles) and pedestrians; bus bays; truck parking etc. In addition to these the audit team examined appropriate markings and signs, presence of clear zone, road side friction, traffic control devices, lighting requirement and other interim measures. During the sight visit the team gave importance in observing the type of geometry and traffic behavior at a site, which will lead to certain type of conflicts and crash types with probable severity level. All recommendations related to safety audit were compiled in the form of a draft audit report.

3.3. Identification of risk factors at hazardous location

Based on RSA, potential safety hazards were identified at the critical locations. The audit team observed and assessed all the risk elements along the project highway and any unsafe road geometry, traffic operation, sub-standard design elements, and lack of appropriate infrastructure was noted. Based on the findings of RSA, suitable countermeasures were proposed.

4. Description of Study Area

Of the 2 highways selected for RSA, the 137-km long NH 117 runs north to south, through three major districts of West Bengal, i.e. Howrah, Kolkata and South 24 Parganas (Fig. 1). However, in Howrah district, NH 117 is a four-lane divided highway that starts at an interchange with NH 6 and reduces to a two-lane highway at Joka. This highway predominantly runs through densely populated urban stretches along the three districts. The road is primarily maintained by Public Works Department, Govt. of West Bengal (WBPWD). It is the major arterial connecting the district of South 24 Parganas with Kolkata the capital of West Bengal. South 24 Parganas being highly populated, a considerable portion of the highway passes through dense settlement and built up areas where interactions between high speed traffic and vulnerable road users are very high. Further, at several major junctions, the existing capacity is limited, leading to high traffic congestion and delays, which is often being compensated over other stretches of this highway by travelling at very high speed in a reckless manner. Such reckless driving at high speed along with poor road use, and several geometric deficiencies have led to formation of several high crash locations on NH 117 where fatal crashes are frequent.

The total length of project stretches of NH-60 that runs through West Bengal (under the jurisdiction of WBPWD) is 307.24 km, which runs through five districts of Paschim Medinipur, Bankura, Paschim Bardhaman, Birbhum and Murshidabad. Most of the project stretch passes through rural stretches of the districts. The first section of the project corridor passes through Paschim Medinipur district, which is very important with respect to agricultural activities and as a result substantial commercial vehicle movement can be observed. Similarly, in the Bankura stretch, although the majority portion is rural in nature, a major thermal power plant and tourist spots are situated. Paschim Bardhaman, being one of the most important industrial district in the state generate significant commercial vehicle volume on this stretch. This highway also passes through Birbhum, where Siuri, the district head-quarter and Bolpur, a famous tourist attraction is situated. As a result, significant private vehicles also ply throughout the year on

this stretch. Due to presence of commercial activities, education and residential areas, this section also has a significant mix of traffic of both motorized and non-motorized including pedestrians in several locations.

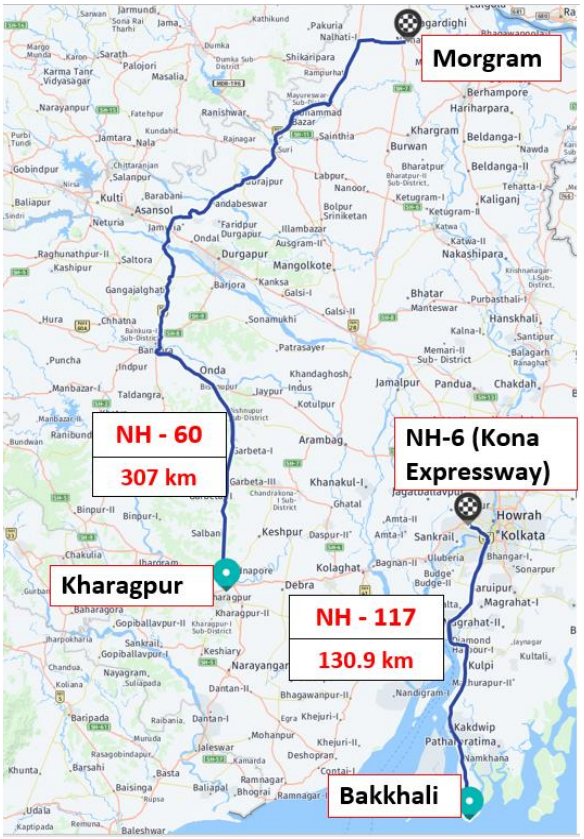

Fig. 1. Road length of highways selected for Road Safety Audit (RSA)

5. RSA findings and recommendations

The hazardous elements identified by the RSA team were grouped into three major categories– Road geometry, Infrastructure and Road users. Each hazardous element is associated with numerous risk factors. The risk elements are discussed in detail in the following section. A comprehensive list of the risk factors associated with a hazardous element and the corresponding proposed countermeasures are presented in Table 1-3.

5.1. Road Geometry

High-speed facilities such as NHs should conform to high geometric design standards. However, faulty road geometry was identified as a major risk factor for both the NHs. Several shortcomings in the geometric design of the road alignment existed along the project stretches. The safety deficiencies in road geometry are discussed under the following head –

5.1.1. Horizontal curves

Horizontal curves were found to be the most accident-prone locations along both the highways. Frequent head on conflicts were observed on the horizontal curves. In some curves the lateral shift of vehicles was quite high. The

RSA team noticed that most of the curves lacked sufficient sight distance, primarily due to inadequate set back distance. Further, even in absence of adequate sight distance the vehicles tend to overtake along such curves (Fig. 2). The curves situated in built up areas had frequent pedestrian and NMT interactions which were assessed as more hazardous as the severity outcome at such curves will be higher

Fig. 2. Vehicle overtaking at horizontal curve

5.1.2. Intersections

Most of the intersections along the highways were unsignalised and uncontrolled. Several intersections were located on the curve. The approach speed of vehicles from the minor road was high and drivers seldom stopped or reduced their speed before merging with the major road traffic. Moreover, as the opposing traffic were not separated vehicles were found to take wrong turns. During the audit visit the RSA team found several vehicles taking such wrong turns at the intersection posing high danger (Fig. 3). Further, the approach of such intersections was often not visible due to encroachments, therefore the drivers were unable to judge the situation ahead, which resulted in chaotic maneuver. In addition to that the presence of bus stops and auto stands enhanced the problems at the intersections. Such intersection can result in lateral swipes, head on or rear end collisions. In most of the intersections there were no stop line or zebra cross marking and proper signages were also missing.

Fig. 3. Wrong turn by two-wheeler at intersections

5.1.3. Straight Segments

The major safety issue noticed at the straight segments was reckless driving of the vehicles. Since most of the road networks passes through congested locations the drivers generally try to compensate the time travelling at a high speed through the long straight segments. Reckless driving and unruly overtaking (Fig. 4) was very common at these locations. The situation worsened at night when the approach of small streets was hard to notice and unexpectedly pedestrians or NMTs came in the way. Overtaking sight distance was also not adequate along most of the straight segments. There were no speed limits or overtaking prohibition signs to alert the drivers.

Fig. 4. Vehicle overtaking at straight segments

Table 1. Identified Risk Factors and Proposed Countermeasures for Road Geometry Related Safety Issues

Sl.	Risk Element	Risk factors	Proposed Countermeasures
1	Horizontal Curves	• Restricted sight distance • Vehicles overtaking at blind curves • Inadequate superelevation	• Segregate conflicting traffic from opposite direction by flexible pole barriers • Centre and edge line rumble strips to warn and alert drivers • Proper delineation and warning signs should be provided
2	Intersections	• Mostly unsignalised and uncontrolled • Many are located under the influence area of curve • Restricted sight distance from minor roads • Market areas and high side friction • Undisciplined driving • Illegal vehicle parking and auto stands restricting view	• Channelize vehicular movements wherever possible • Restrict speed on minor road before merging by speed humps • Corners should be flared for better turning movements • Flexible pole barriers to separate conflicting traffic at major and minor road • Shift bus stops and auto stands to the far side of the intersection • Proper road marking and signs to be provided
3	Straight Segments	• Inadequate Overtaking side distance • Reckless driving	• Centre line rumble strip to alert drivers in monotonous long straight sections • Extra half lane width for passing can be provided at the sections where overtaking sight distance is inadequate • Speed limits and Warning signs for no overtaking zones should be provided

5.2. Infrastructure

Both the highways were found to carry a huge amount of traffic throughout the year. There were areas where interaction among vulnerable road users and high-speed traffic was quite high, yet the highways lacked suitable infrastructure. Only a few designated bus stops were provided along the highway even though it passes through major cities, towns and tourist locations. Several substandard narrow bridges were identified by the audit team during the RSA. Although the proportion of heavy vehicle was higher no provision was made to provide appropriate truck lay-bys at suitable places. Even basic pedestrian facilities were not provided near critical locations like school, colleges or hospitals. In addition to that, locations with high built-up areas had poor illumination which made visibility of NMTs and pedestrians almost impossible at night.

5.2.1. Bus bays

Lack of designated bus bays was a crucial issue for both the highways. The buses stopped anywhere and everywhere to collect passengers. Even pedestrians were found waiting for the buses on the carriageway. It was often observed that cars were trying to overtake the buses from behind without having a clear view of the traffic approaching from the opposite side (Fig. 5). This may result in head on collisions. The situation is more critical near the intersection when the vehicle overtaking a stopped bus could not see the vehicle entering from the minor road at high speed. Even the sudden braking of the bus to collect passengers may result in rear end collisions.

Fig. 5. Overtaking from behind a stopped bus

5.2.2. Narrow bridges

Another safety critical infrastructure identified by the RSA team was the narrow bridges. The number of narrow bridges were higher on NH 60 as compared to NH 117. In most of the cases the approach road to a narrow bridge had no warning signs or speed limits mentioned. In most of the cases the guardrails were broken and covered with dense vegetation (Fig. 6). In few cases the abutments posed as road side hazard. Due to sudden decrease in the lane width the maneuvering at such narrow bridges were found to be dangerous specially at night.

(a) (b)

Fig. 6. Safety Issues at Narrow Bridges (a) No proper signages and dense vegetation (b) Broken parapet wall

5.2.3. Illegal truck parking

Illegal truck parking was found along long stretches of the highway. The illegal truck parking resulted in edge drop and poor visibility (Fig. 7). Moreover, the effective width of the carriageway decreased. Since large proportion of heavy vehicles plied through these highways provision should be made to construct truck lay bays with necessary facilities. In industrial areas where truck parking is utmost necessary proper paved shoulders should be provided. In addition to that proper information signs to notify the drivers of the truck parking and edge rumble to alert drivers if they are driving off should be provided.

Fig. 7. Illegal Truck Parking along NH 60

5.2.4. Illumination

Most of the unsignalised intersections and built up areas were not adequately illuminated. As a result, spotting a pedestrian or NMT at night was a challenging job for the driver. Sudden exposure of pedestrian or NMTs can lead to severe accidents at such locations. High mast street lamps should be provided at such intersections and stretches with high number of access points. Moreover, speed limits and warning signs should be provided at such locations to alert the drivers to control speed and be prepared for any sudden action.

5.2.5. Pedestrian facility

Although numerous market areas, schools, colleges, offices and hospitals were noticed along the road sides and high amount of pedestrian volume was found at these locations the basic pedestrian facilities were missing in most of the locations (Fig. 8). *Although a* few locations were provided with pedestrian sidewalks they were occupied by

hawkers and illegally parked two wheelers and bicycles. As a result, pedestrians prefer*red* to walk on the carriageway instead. None of the intersections had proper cross walk facility and pedestrians *were found* cross*ing* the road at any point. In few places such as near schools or markets, pedestrians were found to occupy almost half of the carriageway. In general highways are built for higher mobility and lesser accessibility, but in case of such highways which runs through important towns and have considerable built up area all along providing proper access to the highway is a necessity.

Fig. 8. Lack of Pedestrian facility (a) School children walking on the carriageway (b) Pedestrian crossing the road carelessly

5.2.6. Dumped Construction Materials

Dumped construction material were found at several places along the road stretch. The effective width of the carriageway decreased with such stocked material on the carriageway (Fig. 9). Moreover, it posed hazard to NMTs and Pedestrians as they may skid while speeding or giving pass to other vehicles.

Fig. 9. Stocked Material near approach of narrow bridge

Table 2. Identified Risk Factors and Proposed Countermeasures for Road Infrastructure Related Safety Issues

Sl.	Risk Element	Risk factors	Proposed Countermeasures
1	Bus bays	• Designated Bus stops are unused/inaccessible • Ad hoc Bus stops • Bus stops at intersections	• Off street bus stops should be provided at specific locations • Designated bus stops should be well maintained • Shift bus stops at least 100m from intersection area • Enforce fines if buses do not stop at designated bus stops
2	Narrow bridges	• Sudden reduction in lane width • Presence of concrete parapet wall pose as a hazard • Vehicles speeding / overtaking near narrow bridge • Problem compounded at night due to low visibility	• Proper warning signs should be provided before the approach of a narrow bridge • The guard rail should be properly embedded in the parapet wall • The approach of the narrow bridge should be free from vegetation to provide a clear view of the bridge
3	Illegal Truck Parking	• Edge drop • Restricted vision specially at night	• Provide proper truck lay byes • Provide wide paved shoulders for truck parking • Provide edge rumble strips to alert drivers if they are moving off road
4	Illumination	• No/Poor visibility at junctions and built up areas specially at night	• High mast illumination should be provided at uncontrolled intersections and built up areas
5	Pedestrian facility	• Improper/Inadequate pedestrian facility	• Proper maintenance of pedestrian facility • Pedestrian facility should be made free from hawkers and encroachments • Proper cross walks should be provided at regular interval • Speed tables should be provided near hospital and schools to reduce speed on major • Simple ITS solutions can be applied in areas with high access density
6	Dumped construction material	• Dumping of construction material on shoulder and carriageway	• Dumping of construction material on the side of the highway should be prohibited and local authorities and police should enforce fines for such activities

5.3. Road Users

Road users are a vital component of the road system. An efficient road system should incorporate the need and safety of all road users. The volume of vulnerable road users was high on the study highways. However, from the RSA the auditors could make out that the design of highway did not consider vulnerable road user as a component.

5.3.1. Pedestrians

Pedestrians were found to be the most vulnerable road users. The RSA team found that on both the highways the pedestrian and traffic interaction was high. Even after that the highways lacked adequate and suitable pedestrian safety measures. In this context the RSA team suggested to adopt “The Swedish Vision zero” philosophy which uses the principle of Integration and Separation. (Austroads, 2009). For example, high pedestrian traffic should not be exposed to high speed. This can be done either by ‘separating’ the pedestrians from vehicles by

providing proper pedestrian infrastructure or by lowering the travel speed limit to maximum 40 km/h to 'integrate' the various road users. In general, some form of traffic calming and signage can be used to assist road users in recognizing the low speed environment.

5.3.2. NMTs

NMTs were also present in high proportion on both the highways. School children on NMTs were the riskiest road users as they had less judgement of vehicle speed and were often found to travel in a group blocking almost a lane of the highway. In some cases, it was observed that the NMTs were heavy loaded and were unstable. During the night time it was very difficult to spot NMTs along the road especially near intersections or curves where they generally slowed down for taking turn (Fig. 10). NMTs should not be allowed on highways without retro reflective stickers on them. Provisions should be made for bike lanes on both sides for safe movement of students.

Fig. 10. Poor visibility of Pedestrian and NMTs at night

5.3.3. Other vehicle users

Fig. 11. Two-wheeler rider without helmet

A common observation was made by the audit team that most of the drivers were unaware of the safety aspects of driving. Most of the two-wheeler riders drove impudently along the highway without wearing helmets (Fig. 11).

Even the drivers of public vehicles were found to overtake slow moving vehicles recklessly near curves. Moreover, at intersections several vehicles were taking wrong turns and were overspending.

Table 3 Identified Risk Factors and Proposed Countermeasures for Road User Related Safety Issues

Sl.	Risk Element	Risk factors	Proposed Countermeasures
1	Pedestrians	• Risky crossing of roads • High pedestrian volume at market areas	• Separate pedestrians from high speed traffic by providing pedestrian guard rails at risky areas • Speed limits of vehicles should be restricted to maximum of 40km/h near market and built up areas
2	NMTS	• Unsafe crossing and merging maneuvering	• Wide paved shoulders should be provided where the volume of non-motorized traffic is high and especially near markets and school areas. • NMTs at night should have retro reflective stickers in their vehicle so that they are spotted well in advance • Safety edge should be provided at the sections with high edge drop so that it is easy for the NMTs to mount.
3	Other vehicle drivers	• Reckless overtaking • Speeding at built up area • Not following traffic rules	• Strong enforcement by local police authority • Awareness for road safety should be spread among the local people and they should be educated to abide by safety rules

6. Conclusions

In the present study, the primary scope of the RSA was to identify the critical safety deficiencies at the risk prone zones on the two-lane highways and provide appropriate recommendations. During the audit several risk factors were identified, and it clearly emerged that the elements of risk in case of a two-lane highway were different when compared with a four-lane highway. The risk factors were grouped under the three categories – Road geometry, Infrastructure, and Road Users. Although signs and markings were missing in some of the critical locations but in the Indian context absence of such passive safety devices (signs are marking) are probably less detrimental than poor design, absence of adequate infrastructure and improper road use. The salient findings emerged from the RSA based safety assessments are as follows –

- Sight distance is one of the major requirements on high-speed corridors such as NHs, but lack of adequate sight distance was consistently observed at the horizontal curves, and at the intersection approaches throughout the two study highways.
- The absence of appropriate infrastructure had led to exposure of vulnerable road users to high speed traffic in many locations. Moreover, in few places although the infrastructure was provided they were misused or were unutilized. Suitable and feasible infrastructure such as bus bays at the far side of the intersection, pedestrian crossing near schools and hospitals, high mast lamps near built up areas and uncontrolled intersections etc., should be provided after a thorough study of the road environment. Further, the local police authorities should enforce that the facilities are utilized.
- Managing the inter relationship between travel speed, road infrastructure design and road users is the key concept of safety on highways. However, speed limits or speed zones were seldom noticed at the highway stretches. As with the change in road environment the nature of the highway changes it is important to specify speed limits specially at built up areas, near schools, markets etc. Even in curve and straight segments with inadequate sight distance the speed limits should be provided.
- Finally, it was observed that the road users lack the basic concept of road safety. This is due to the fact that road users are not accustomed to high speed facilities through dense built up areas. Education and awareness among the road users can influence and change their present attitudes and behaviors**.** Introducing

school-based road safety education can instill safe attitudes of young people early which can reduce the number of road accidents in future. Spreading consciousness about traffic rules and safe road driving can help in producing better drivers.

Nevertheless, it is a fact that road safety is a complex issue and is characterized by different sectors such as road engineering, human psychology, vehicle design etc. A systematic incorporation of engineering measures with planning and enforcement can improve better and safer road use.

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