Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Motorcycle Travel Safety Audit - A Pilot Work

Sasanka Bhushan Pulipati[a]*, Chiranjeevi Devi Chamakuri[a], Srikanth Donepudi[a],Praveen Pamireddy[a]

[a]*Vellore Institute of Technology, Vellore, 632014, India*

Abstract

Reducing road accidents and the resulting casualty has become one of the top priorities. Road safety audit (RSA) is used as a preventive measure, where an independent audit team reviews a road project in various phases of development and suggests improvements to prevent the risk of accidents. Similar to RSA, the authors propose an audit procedure for motorcycle travel safety. They focus on motorcycles because a) motorcycle accidents contribute to one-third of all road accident fatalities in India and b) road safety audit, which does not consider any specific vehicle, may miss many factors which may affect safety of motorcycle travel, which is more vulnerable to road hazards than bigger vehicles. A motorcycle travel safety audit of a corridor or region, as proposed by the authors, is a holistic process where all factors related to motorcycle travel safety such as design of road facilities, traffic operations, regulations and interventions are assessed, and remedial measures are recommended. As a pilot work, the authors prepare a checklist for performing such an audit on urban corridors and implement it on a set of road corridors in Vellore. In addition to basic questions seen in a road safety audit, the questions in the checklist include the factors which contribute to motorcycle accident identified through a web-based motorcycle traveler survey. Once fully developed, this audit process can be implemented in urban areas by the local transportation authorities. The checklist has provision for finding an audit score for each corridor or region, which can be used to prioritize the corridors for implementation of countermeasures.

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY.

Keywords: Motorcycle travel; safety audit; checklist; road accidents; traveler survey

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: author@institute.xxx

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY

1. Introduction

Indian roads recorded nearly 4.8 lakh accidents in 2016. These contributed to nearly 5 lakh injuries and 1.5 lakh deaths (Transport Research Wing Ministry of Road Transport and Highways Government of India 2017). Each injury or death causes enormous loss of valuable life, loss of production, pain and grief to the family concerned. Even assigning a small compensation amount of ₹ 2 lakh (US$ 3,000) to each death and ₹ 50,000 (US$ 750) to each injury, this equals to a loss of nearly Rs. 5,500 crores (US $825 million) per year. The governments at local level to national level have taken steps to curb the accidents but no significant improvement is seen. Globally, tackling the accidents starts by collecting data on accidents and analyzing the causes for accidents. Actions to curb accidents and injuries such as improving the road design, implementing the traveller education and enforcement measures bud from the accident analysis.

More than 75% of motor vehicles in India are motorcycles. After walking, riding motorcycles takes up the biggest share in modes used for travel in India (Associates and Ministry of Urban Development 2008). Especially, in medium size cities and for middle class families, motorcycle can be considered as the most affordable and convenient. A look into the 2016 accident data reveals that motorcycles are involved in more than one third of all accidents in India; motorcycle riders are 34.8% of persons killed in road accidents (Transport Research Wing Ministry of Road Transport and Highways Government of India 2017). So, India can improve road safety significantly by preventing motorcycle accidents. For middle class families which use motorcycles to work every day, this is going to save a lot of lives and money.

Audit is a professional term often used by institutions to allow an external individual or organization to conduct an inspection about their assets or technology. Safety audit is a type of audit in which potential threats in the safety system are identified before they have an impact on society. In the same lines, in road safety audit, the auditors check whether the functionality, characteristics and properties of each element related to a road are meeting the requirements for road user safety, and provide suggestions to increase safety level on that road.

Road safety audit is conducted for a roadway that is being built. Existing roads may also be audited so that its design may be improved for providing better safety. Audit may be conducted in different phases of road development such as planning, design, construction or pre-opening. Usually, the auditor assesses the condition of the project against a checklist or a questionnaire which contains all design parameters. Manuals on road safety audit are available in India and abroad (Dundee city council 2005; PIARC Technical Committe C3.1 2011; The Indian Roads Congress 2010). These contain the road safety audit procedure and the checklist for different classes of road facilities.

Unlike in the UK and other countries where the concept of road safety audit has originated in, motorcycles are the most frequently used vehicles on Indian roads. Furthermore, due to its two-wheel configuration, many road and operational conditions which may not pose a hazard to bigger vehicles may do so to motorcycle. Since motorcycle travelers are involved in largest share of accidents, there is a need for customizing the audit to motorcycle user safety. So the authors aim to develop a procedure for motorcycle travel safety audit. A motorcycle travel safety audit of a corridor or region, as proposed by the authors, is a holistic process where all factors related to motorcycle travel safety such as design of road facilities, traffic operations, regulations and interventions are assessed, and remedial measures are recommended. This effort is divided into three parts – identifying the factors that contribute to motorcycle accidents, preparing an audit checklist and testing it by implementing on a sample of corridors, and preparing a procedure to prioritize corridors and the countermeasures recommended.

As a beginning, the authors identify a set of factors contributing to motorcycle accidents through a motorcycle riders' survey. They prepare a draft checklist and audit a few sections of major urban roads in Vellore, Tamil Nadu. The current paper describes this pilot work and discusses the steps towards a comprehensive effort.

The second section reviews the literature on the causes of motorcycle accidents. The third section highlights the differences between motorcycle travel safety audit and a general road safety audit. The methodology followed in developing the audit process is detailed in the fourth section. The fifth section discusses the results of the study. The paper concludes in the sixth section with some ideas for future research.

2. Literature on causes of motorcycle accidents

Globally, research on causes of motorcycle accidents has been limited perhaps because motorcycle's share in travel is low in many developed countries. Majority of those studies and reports are available from Europe. The authors present a brief review of recent literature with regards to the causes of motorcycle accidents.

In their review of literature on motorcycle collisions in the US, Huang and Preston (2004) find two major groups of causes for motorcycle collisions. The first group relates to difficulty of drivers of other vehicles to detect motorcycle as it is small and usually less frequent on the road. This is called poor conspicuity. The second group relates to the extensive risk taking behavior of motorcycle riders such as rash driving and being under intoxication. A scoping study prepared for the Department of Transport, UK has reviewed motorcycle accidents in UK and Germany. This study finds that in nearly 60% of motorcycle accidents, motorcycle collides with car. In about 20% of the cases, motorcycle alone is involved. When car is involved, higher amount of casualty is seen. This report stresses for better protective equipment to reduce the injury severity (Elliott et al. 2003).

The World Health Organization (WHO) (2017) discusses three types of factors that contribute to powered two wheeler related injuries. They are related to road user, road environment and the vehicle. Road user related are: non-use of helmets, drinking and driving, driving under intoxication, excessive speed, unfamiliar or inexperienced drivers, braking errors, zig-zag driving, and other aggressive behavior on the road. Road environment related include: mixed traffic systems, road infrastructure design that does is not suitable for motorcycles, road surface conditions that are unsafe to motorcycles, and roadside hazards such as trees, poles and guardrails. Factors related to the vehicle are: instability of motorcycle and lack of sufficient crash protection. There are other risk factors such as lack of inclusive urban planning which leads to too many cars and lack of facilities for motorcycle use and limited public transport infrastructure which increases the use of motorcycles (World Health Organization 2017).

In a recent study performed in Malaysia, Manan et al. (2017) uses multinomial and mixed models to determine risk factors in motorcycle related traffic crashes. In case of motorcycle-alone fatal crash, higher risk is found in the case of curve road sections, no road marking, smooth, rut and corrugation of road surface and travel in late-night hours. In the case of motorcycle fatal crashes involving multiple vehicles, factors such as expressway, primary and secondary roads, speed limit more than 70km/h, roads with non-permissible marking, i.e. double lane line and daylight condition seem to increase the probability of their occurrence. In a similar study in Texas, most motorcycle crashes are caused by distraction of drivers and lack of conspicuity of motorcycles. Critical reasons for motorcyclist fatalities are identified as not wearing helmet, driving under influence, driving in dark-unlighted roads, driving in curved roads and poor weather conditions (Alshatti 2016).

In summary, causes such as driving under intoxication, over-speeding and driving on curves seem to be common motorcycle accident causes across the world. Lack of conspicuity is a cause in countries where cars take up most of road space; however, this does not seem to be a problem on Indian roads where majority of motor vehicles are motorcycles. The factors mentioned by the World Health Organization (2017) such as mixed traffic systems, road infrastructure design that is not suitable for motorcycles, road surface conditions that are unsafe to motorcycles, and roadside hazards seem to be relevant on Indian roads. An effort to delineate the factors that contribute to motorcycle accidents in India is necessary.

3. Motorcycle travel safety audit vs. road safety audit

In the following paragraphs, the authors highlight the special features of a motorcycle travel safety audit, as proposed by them, when compared with a general road safety audit.

Road safety audit is concerned with the road facility in general, without much focus on safety needs specific to different motor vehicles. However, as the design vehicles tend to be cars and bigger vehicles, the safety checks performed are more suited for such vehicles. Unlike in the UK and other countries where the concept of road safety audit has originated in, motorcycles are the most frequently used vehicles on Indian roads. Furthermore, due to its two-wheel configuration, many road and operational conditions which may not pose a hazard to bigger vehicles may do so to motorcycles. Motorcycle travel safety audit examines the whether a road corridor poses any threats to motorcycle travel and recommends countermeasures.

Road safety audit, as described by IRC:SP:88-2010, is mainly done for new roads (The Indian Roads Congress 2010). Whereas, motorcycle travel safety audit in this study focuses on existing roads in an urban area because, the authors observe that motorcycle travel have become highly vulnerable in urban areas due to the abrupt changes in roadway and traffic conditions, and the large number of motorcycles used for commuting to work every day through the congested roads in urban areas.

While the road safety audit is concerned with mainly road infrastructure, the authors extended their audit to infrastructure features, traffic conditions and management, and user behavior which affect motorcycle travel.

Usually, the questions in road safety audit checklists have Yes/No type questions. They are based on earlier research on accidents and design guidelines. Since the checklist being prepared is specific for motorcycles, the authors probe the factors that contribute to motorcycle accidents in India through a literature review and a survey of motorcycle users. The checklist includes the factors identified in this probe in addition to the items that exist in the general road safety audit. Furthermore, the authors assign importance weightings to each checklist item based on the user survey responses. The checklist questions

As mentioned by IRC: SP: 88-2010, road safety audit is performed for an individual project; it is not used as a means to compare different projects and rate them (The Indian Roads Congress 2010). However, the authors form the audit such that it returns a quantitative score for each urban road corridor. This allows prioritizing a group of corridor for implementation of motorcycle safety countermeasures.

4. Methodology

The subject of the audit in this study is the motorcycle travel on an urban road corridor. The process of auditing includes a team of auditors observing the conditions along a corridor and answering a few objective questions listed in a checklist. The checklist should include all basic road design factors such as lane widths, shoulder widths, pavement and shoulder condition, sight distance availability, availability of proper signs and visibility, and all the factors that may specifically affect motorcycle travel safety. The first part above can be compiled based on urban road design guidelines and manuals available on road safety audit. The second part should be based on an investigation of factors that contribute to motorcycle accidents. In this study, the authors obtain the information on these factors by performing a survey of motorcycle riders. The following three subsections describe the survey, the checklist preparation and the auditing of three corridors in Vellore city.

Fig. 1 describes the methodology as a flow chart.

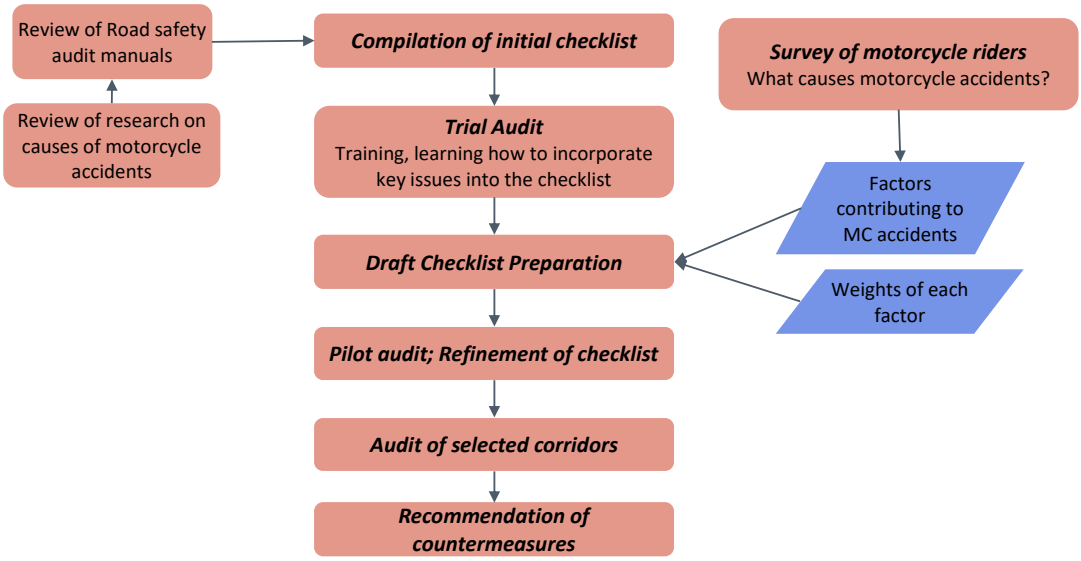

Fig. 1. Development and implementation of motorcycle travel safety audit

4.1. Survey to Identify Factors that Contribute to Motorcycle Accidents

Motorcycle accidents range from a simple "slip-and-fall down" type which may cause none or minor injury to the riders to "motorcycle-hit-by-truck" which may result in grave deaths to all riders. Many of the minor accidents go un-recorded or even un-noticed. In India, the police record the accident, usually when they are informed by the travellers. The police usually record the location of the accident, the type of vehicles involved, the details of the persons involved in accident, cause of the accident, and the number of deaths and injuries. The purpose of recording has been mainly to collect the evidence that may be needed in insurance claims and legal proceedings rather than accident analysis and prevention of accidents. So the recording of the cause of the accident has not been as detailed as necessary. The blame of the accident usually falls on the bigger vehicle perhaps so that the driver of the smaller vehicle (usually poorer) is not burdened with compensating the loss of the bigger vehicle. So the accident records from the police are not useful to find the real causes and mitigate them.

In this study, the authors first examine the data on motorcycle accidents obtained from the District Crime Records Bureau of Tamilnadu. This data does not include the exact causes of accidents. So, they decide to perform a survey of motorcycle users to obtain the information on the factors that contribute to motorcycle accidents. The following text describes the survey.

The survey is based on a google form; however, if a respondent wishes, responses are obtained through a phone call. It is divided into multiple sections, moving one section to another depending on the responses given.

As an accident is a very rare and random event, rating of the causes of accidents needs large sample of data and careful separation of causing factors. To be able to confirm whether a factor is causing an accident, attributes of motorcycle riders, vehicles and road environment conditions at the time of accident should also be noted. Some of these attributes may act as confounding factors. Descriptive analyses including frequency analysis and cross tabulation are frequently used in accident cause analysis.

First, respondent attributes such as age, gender, city of residence, education level and current occupation are obtained. This information helps in stratifying the responses based on respondent attribute. The survey initially asks whether the respondent has been involved in an accident while riding on motorcycle. If this is true, series of questions are asked to infer the causes of the accident. After that, the respondent is asked to select any four from a list of suggestions for preventing motorcycle accidents. If the answer for the prior accident is no, the survey directly goes to the suggestions. Motorcycle riders may have encountered various situations where they just avoided an accident. The authors assume that such situations may form the respondents' opinion on the suggestions.

The cause of the accident is divided into "conflict with some object (stable or moving)" or "without conflict with any object". Causes such as tyre burst, tyre slip on road, something stuck in wheel and driver lost balance of motorcycle are examined under the second type. If conflict happened, the causes of conflict are examined. In both cases, whether or not a collision happened is examined. Each question contains four to five options and "other" option where the respondent can write any cause that is not listed. The next few questions probe whether other factors such as the speeds of the vehicles, road conditions, traffic conditions and weather conditions may have contributed to the accident. At the end, an open question gives the respondent an opportunity to inform any other factors that are not covered in the questionnaire which may have caused the accident.

The authors expect that the responses to the above questions result in a large set of factors that contribute to motorcycle accidents. Each new cause mentioned by a respondent expands the above set. All the factors listed in this set may represent an item in the audit checklist. Furthermore, if the authors carefully categorize the causes, they can identify how frequently a factor occurs. This frequency may represent the importance level (weightage) of the factor in the checklist.

4.2. Development of Checklist for Auditing Motorcycle Travel Safety

The project team focuses on the following parameters while preparing the checklist:

- The questions in the checklist are customized to motorcycle travel safety audit on Indian urban roads
- The checklist should prevent observer bias in answering the questions
- The checklist should be clear and easy to respond.

The project team refers to the road safety audit checklists given in IRC:SP:88-2010 and the World Road Association manual to obtain a basic checklist. They customize it to the motorcycle travel safety audit through the means discussed below:

- To gain an on-the-ground experience of the suitability of the existing road safety audit checklists, the project team takes one of the checklists and goes on to audit a road corridor. Their observations help them to understand the inability of the checklist to capture the details of the safety problems, especially the ones related to motorcycles.
- The project team observes three other road corridors with a focus on motorcycle travel. Here, they note down all the features that may pose a hazard for motorcycle travel. Furthermore, they understand how the questions should be worded and what range of options may be shown in the response.
- The responses to the survey that is described in Section 3.1 result in a list of various factors influencing motorcycle accidents. These factors are included as checklist questions appropriately.
- The project team prepares a draft checklist and performs a pilot level audit of a few corridors in Vellore city. It revises the checklist based on the shortcomings realized in the pilot audit.
- The responses of each question in the checklist are formed as multiple options representing different levels of satisfying the checklist question. This is an improvement over just having Yes or No response. When these satisfying levels are clearly defined, the chance of two different auditors resulting in different audit for a corridor (auditor bias) is expected to decrease.
- To quantify the total audit score of the corridors, the importance weightages obtained from the survey are assigned to each item in the checklist.

4.3. Implementation of Audit

IRC: SP: 88-2010 informs that an auditor should be well trained and is able to judge the safety issues appropriately and consistently. In the current study, the project team members have trained themselves by studying the design and safety manuals and performing field visits multiple times. However, the authors realize that more training is necessary.

While auditing a corridor, as a general practice, the authors recommend that the corridor is divided into homogeneous sections. This helps in providing a consistent assessment. Assessments of all the sections may be compiled while presenting the overall assessment of the corridor. In this study, the authors have audited three small sections of corridors located in three different areas of Vellore city. This is mainly to test and refine the checklist they have prepared. The auditors first review the checklist thoroughly so that they remember what they look for while they go on observing the corridor. They have rode motorcycle and walked along the corridor sections observing various design and operational features. Their aim is to select the most suitable answer option for each checklist item.

Once the checklist responses are recorded in the field they analyse the responses to report an overall audit score for each section and corridor. Finally, they recommend the countermeasures needed in each corridor.

5. Results and discussion

5.1. Survey results

In this section, the authors summarize the responses obtained from the pilot survey of motorcycle riders. Overall, 397 responses are available, 18% from female and 82% from male respondents. Nearly half of the respondents are youth aged 25 years or below. Nearly 43% belong to age between 26 and 45 years. The group of respondents is largely educated. Nearly 72% of the respondents have a bachelor’s or master’s degree. Most of the remaining respondents are pursuing their bachelor’s degree. With respect to their occupation, nearly 40% of the respondents are students and nearly 55% are teachers or other employees of some firm. Remaining are low-paid service personnel. The survey captures the town/city where the respondent lives. Although nearly 32% of the respondents are from Vellore, Tamilnadu, they belong to all sizes of cities across India.

Among the respondents, 35% have been involved in one or more accidents while riding motorcycle. As explained in Section 3, the survey inquires the causes of accident if an accident happened. If the respondent has not been involved in an accident, the survey simply asks him/her to suggest methods to prevent accidents. Responses in both cases provide input for preparing the checklist. A summary of factors mentioned by the respondents are provided below.

Conflict or Not: Among the 139 responses which inform about the accident, 68% inform that conflict with a moving or stable object is the cause. This is a significant result because nearly one third of motorcycle accidents seem to happen due to causes such as slipping of tyre, losing of balance of motorcycle and wheel getting stuck, which do not involve other vehicles or objects.

5.1.1. Causes in the case of no-conflict

Nearly 86% of accidents that happen without conflict (27% of all accidents) are due to slipping of motorcycle or rider losing control over the vehicle. Remaining accidents in this group are found to be due to tyre puncture, wheel getting stuck or brake failure.

Slipping of tyre or puncture of tyre is caused by the factors shown in Table 1. Presence of water or soft and slippery material such as sand has caused nearly 70% of the slip cases. Stone pebbles on the road cause nearly 10% of slips. Accordingly the audit should check whether the road is free from these materials.

Table 1. Causes of no-conflict cases – Tyre slip

Tyre slip	Frequency	% Frequency	Implication for checklist
Water on the road or wet road	7	30%	Does the road have good drainage? Is it free from water flow from private properties?
Sand or other soft material on the road	9	39%	Is the road free from sand or other soft material from adjacent developments
Stone pebbles on the road	2	9%	Is the road free from stone pebbles
Oil/grease on the road	1	4%	Is the road free from oil/grease
Sand and water (combination)	1	4%	Is the road free from sand and water combination?
Tyre surface is smooth	1	4%	Is proper guidance given to riders on maintaining their tyres or vehicle?
Brake problem	1	4%	Is proper guidance given to riders on maintaining their vehicle?
Road damaged	1	4%	Are pavement damages repaired in this corridor?

There are many factors that cause motorcycle off-balance. Presence of sudden level differences such as potholes or manholes, scare created by movement of another vehicle, poor lighting, bad weather conditions and distractions such as mobile phone use are some of those factors. Table 2 shows the factors obtained in the survey responses. The checklist items corresponding to these factors are also shown.

Table 2. Causes of no-conflict cases – Motorcycle off-balance

Vehicle lost balance	Frequency	% Frequency	Implication for checklist
Sudden change in level on the road (pot hole, manhole lid, extra piece of concrete, etc.)	2	12%	Is the road free from potholes and sudden changes in level
Went off the pavement near to the corner of pavement	1	6%	Are the pavement edges properly treated? Is edge drop within the design allowance?
Saw another vehicle dangerously coming	4	24%	
Persons/load carried on motorcycle caused imbalance	2	12%	Is the number of persons or amount of load carried on motorcycle properly enforced?
Glare of light from on-coming vehicles	2	12%	Are there provisions to prevent vehicles from using bright headlights?
Using mobile while driving	1	6%	Are restrictions on mobile use while driving properly enforced? Are drivers given guidance on not using mobile phone while driving?
An issue in driving environment	1	6%	Is proper visibility maintained during night time and rainy conditions?
Driver's own mistake	2	12%	Are riders properly trained in motorcycle riding?
Driver was overtaking	1	6%	Is guidance given on safe overtaking locations?
Due to some object on the road	1	6%	Is the road clear of loose objects?

5.1.2. Causes in the case of conflict

As shown in Table 3, about 50% of the conflicts are recorded with vehicles bigger than motorcycles. This is reasonable because the area occupied by bigger vehicles is significantly larger even though motorcycles are present on road in bigger numbers. Motorcycles conflict with motorcycles in 23% of the cases. Stable objects such as median, tree, speed breaker and stone cause nearly 8% of conflicts. Significantly, animals involve in 15% of the conflicts indicating need for efforts for providing proper paths for animal movement and crossing on roads.

Table 3. Objects with which conflict is recorded

Conflicting object	Frequency	% Frequency
Motorcycle	19	23%
Other vehicle	42	50%
Pedestrian	3	4%
Median	5	6%
Animal	13	15%
Speed breaker	1	1%
Wall	1	1%

The respondents inform about various causes for conflicts. These are listed in Table 4. Vehicles stopping suddenly contribute to nearly half of the conflicts. Absence of warning sign at an intersection contributes to nearly

15%. The checklist in the audit should verify whether these types of factors are present. “Animals suddenly crossing” is a significant cause of conflict as already found in earlier paragraph.

Table 4. Causes of conflicts

Cause of conflict	Frequency	% Frequency	Implication for checklist
Causes from the list presented to the respondents			
Vehicle in front stopped suddenly/ turned suddenly	47	47%	Are the drivers warned to keep distance from vehicle in front?
No proper signal at intersection	5	5%	Are there traffic signals at intersections and are they in working condition?
No proper warning sign at a crossing/intersection	14	14%	Are appropriate warning signs present at all crossings/intersections?
Not enough width in the median for my motorcycle to stand	7	7%	Do medians have enough width at all openings to accommodate vehicles safely?
Other causes			
A hole in the under construction road	1	1%	If there is work is in progress, are there proper warning signs?
Animal suddenly crossed	7	7%	Are animals prevented from coming on to the road?
Other driver ignored my signal	1	1%	
Other driver lost control	5	5%	
No proper lighting	2	2%	Is proper lighting provided on the road?
Pedestrian crossed suddenly	2	2%	Are pedestrian crossings regulated with signals or police?
I overtook	2	2%	Is proper guidance given regarding overtaking?
Someone else overtook and came against	1	1%	
Big edge drop	1	1%	Are the pavement edges properly treated? Is edge drop within the design allowance?
Other driver made mistake	6	6%	Is proper enforcement in place to prevent driver errors? Is proper guidance provided for drivers to make decisions on the road easily?

5.1.3. Effect of road, traffic and environmental conditions

Studying the entire situation at the time of accident is necessary to understand the causes of accident accurately. Sometimes, one of these condition may be the actual cause of the accident. For example, conflict with an object on the road may seem to have caused the accident but the real cause may be the adverse weather condition; if the driver’s ability to assess the object early was not prevented by the rain, the driver could have avoided the accident. In the motorcycle rider survey, the authors ask a set of questions where the effect of location type, traffic condition, weather condition, driver behavior and other issues on the accident. The authors summarize the responses obtained for these questions in Table 5.

Table 5. Effect of conditions during the accident

Affected by	% cases affected	Specific Issues	% cases affected
Road type	36%	Curved road	9%
		Uncontrolled intersection	12%
		Other	15%
Respondent's speed	17%	High speed	12%
		Other	5%
Traffic condition	17%	Heavy traffic	5%
		Heavy vehicles	3.6%
		Other	8.4%
Wrong-way vehicles	27%		
Weather	8%	Rainy	4.3%
		Other	3.7%
Pavement condition	11%	Very rough	6.5%
		Somewhat rough	2.9%
Obstructions to vision	11%		
Distraction	11.5%	Use of mobile phone	1%
		Hoardings and signs	1%
		Movement of other vehicles	4.3%
		Other	5%

Note: The questions in the survey included three options – Not affected, Definitely affected and Somewhat affected. The results shown here correspond to only "Definitely affected". There are many respondents who chose "Somewhat affected", in some issues, more than those who chose "Definitely affected".

5.1.4. Countermeasures suggested by the respondents

As shown in Table 6, maintaining proper road surface and imposing speed limits are the top two countermeasures chosen among the list of suggestions presented. Proper design of road, providing visibility to drivers, enforcement of traffic rules, proper warning through signs and maintaining traffic signals at intersections at working condition are selected as the next important ones. Respondents suggest some other countermeasures such as imposing stricter punishments to people who do not follow the rules and enforcing them, stricter road rules with higher pun and enforcing them, entrusting traffic management to engineers rather than the police, noise control or roads and providing for proper driver education. Table 6 also shows how the checklist items can be formed based on these suggestions.

Table 6. Suggestions for preventing motorcycle accidents

Countermeasure	% Frequency	Implication for checklist
Suggestions from the list presented to the respondents		
Proper road marking	8%	Does the road has proper marking
Proper design of road	11%	Is the design according to guidelines (Includes dimensions of cross sectional elements, sight distance, super-elevation etc.)
Maintaining proper road surface	13%	Is road surface well maintained
Maintaining proper visibility along the road	11%	Does the road have proper visibility at all times
Proper warning through sign boards	9%	Are all the sign boards properly placed?
Traffic signals at intersections in working condition	11%	Are all traffic signals in working condition?
Proper enforcement of traffic rules by police	11%	Are the traffic rules properly enforced?
Imposing limits on speed	12%	Are the speed limits placed and enforced?
Making all major roads as one-way roads (dividers in the middle)	8%	If the road is a major thoroughfare, is the opposing traffic separated?
Keeping police surveillance of traffic movement	6%	Is the traffic movement under police surveillance?
Other suggestions		
Imposing strict roads rules and serious punishment in case of not following rules as in the case of other developed countries		Are stricter penalties imposed in this city?
Giving away traffic management to engineers rather than to police. Should have learnt from foreign countries		Is traffic operations managed by engineers rather than police?
Noise control on roads		Is special provisions made to control noise on road?
Alertness		Is the road free of driver distractions?
Driver education		Are there signs and messages on the road to educate drivers on traffic rules and sense?
Driver self-discipline and control		Is the road free of rash and undisciplined drivers?

The authors learn from the pilot survey that the causes of accidents can be more reliably collected by personal interviews of the persons involved in accidents. A database of accidents from local police authorities and hospitals may be used to identify the contact information of the accident victims.

5.2. Checklist

The checklist prepared by the authors contains nearly 60 questions covering design and condition of the roadway elements, traffic control devices, traffic and environmental conditions, driver/passenger behavioural issues, and

enforcement and interventions. Table 7 presents some example questions. Most of the questions are in positive tone, i.e., if the answer is NO, it indicates that there is a safety hazard. Answer is divided into a few options which represent increasing level of hazard from top to bottom. This uniformity is maintained so that the audit can be presented using an overall deficiency score.

Table 7. Summary of checklist

Characteristics	**Categories**
Design and condition of roadway elements	1.pavement
	2.other design elements
Examples	
1. Is edge drop within the design allowance? a) Yes. All along the length b) contains larger edge drops intermittently c) contains larger edge drops most of the length.	
2. Is the road free from potholes and sudden changes in level a) Yes. All along the length b) contains potholes or sudden changes in level rarely c) contains frequently	
3. Is the road surface free of sand and other soft materials? a) Yes. All along the length b) material seen rarely c) material seen frequently	
Traffic control devices	1.markings
	2.signals
	3.signs
Examples	
1. Are appropriate warning signs present at all crossings/intersections? a) Yes. They are. b) Rarely they are not present. c) Frequently they are not present.	
2. Are motorcycle specific signs and pavement markings available? a) Yes. They are. b) No. They are not.	

Table 7 (contd..)

Traffic and environmental conditions	1. traffic conditions
	2. drainage
	3. Roadside elements
Examples	
1. Are there sudden changes in traffic volume? a) None b) Rarely c) Frequently	
2. Is drainage uncovered/leaking on to the road? a) No where b) Rarely c) Frequently	
3. Is the drive free of noise from vehicle horns? a) Yes. More or less free. b) No. Noise is present.	
Driver/passenger behaviour issues	1. Speed related 2. Other
Examples	
1. Are the drivers moving without over-speeding? a) Over-speeding is not present b) Rarely present c) Frequently present	
2. Is the road free of wrong-way movements? a) Yes. There are no wrong-way movements b) Rarely present c) Frequently present	
Enforcement/ Interventions	1. enforcement
	2. interventions
Examples	
1. Do enforcement officers remove illegal parking? a) All illegal parking is cleared by the officers b) Illegal parking is rarely present c) Frequently present	
2. Are messages suggesting not using mobile phones present? a) Present b) Not present	
3. Is the number of persons or amount of load carried on motorcycle properly enforced? a) Yes b) No	

As the authors conduct the final survey with refined questionnaire, they will perform more quantitative analysis on the factors contributing motorcycle accidents and update the above checklist. The checklist may be customized to

a city, region or set of corridors based on the objectives of the audit. Once sufficient number of responses for the motorcycle traveller survey is available, comprehensive weights for the checklist criteria can be established.

5.3. Audit results

The authors audit three corridors in Vellore, Tamilnadu for their deficiencies in motorcycle travel safety. They are:

- Vellore-Chittoor road: Katpadi railway station to Titan showroom (Cor1)
- Vellore-Chittoor road: Gandhinagar junction (Cor2)
- CMC junction to National circle (Cor3)

All corridors have two lanes each way with a median barrier. Cor1 and Cor2 have more vehicular traffic while Cor3 is commercial area having significant amount of pedestrian movement and crossings. A summary of findings in this effort is presented below.

Corridor 1:

- Footpath exists but it is discontinuous. So pedestrians walk on road. There is no proper provision for pedestrian crossing at the major intersection in this section, so pedestrians cross haphazardly obstructing motorcycles.
- In this corridor there is no proper cover for drainage. The maintenance of the drainage is very poor. It may overflow on to the road making it prone to slipping of motorcycles.
- The pipes of the electric lines have come out from the ground. Construction waste is left on the road. This poses a hazard to motorcycles.
- Intersection traffic control is poor on this corridor. Except flashing Yellow signal, other signals are not functioning. Traffic police also does not exist sometime. Many conflicts are observed due to this situation.
- Due to less availability of parking, vehicles are parked on the street and affect the traffic severely.
- Pavement markings are either not present or faded in this corridor.
- Buses and other heavy vehicles frequently travel on this road section. This may affect motorcycle riders.

Corridor 2:

- Service roads are present but are not maintained properly. Due to deficient pavement and debris on these roads, motorcycle travellers face hazards.
- Construction waste is left on the street. This obstructs motorcycles and may also cause slipping.
- Roots of electric poles are protruding on the road surface causing obstruction to motorcycles.
- Signals are not working properly in this corridor. Other traffic control devices are also not seen.
- Visibility is poor as street lights are not working.
- Vehicles are parked illegally on the road at junction and in temple places causing hazard to traffic flow.
- Traffic enforcement is poor on this corridor as traffic police is not often present here.

Corridor 3:

- Among the three corridors studied, this corridor appears to pose the highest risk to motorcycle travel safety.
- Autorickshaws wait for passengers irregularly on the road at a major intersection on this corridor. These create difficulty to motorcyclists and pedestrians. Buses also stop on this corridor irregularly making it hazardous to other road users.
- Drainage is poorly maintained on this corridor. Water is seen seeping on to the road causing slippery surface for motorcycles. Restaurants and shops along the corridor are seen throwing the water on the road creating wet surface.
- Traffic signals are either not present or not in working condition at intersections on this corridor. So motorcycles face frequent conflicts with pedestrians, motorcycles and cars.
- As this corridor has a major hospital and commercial area, pedestrian movement is significant here. Pedestrians cross the road at many places causing significant hazard to motorcycles. Cyclists are seen crossing the median illegally.
- Cell phone use by drivers is frequently seen. So motorcyclists face hazard due to distraction.

Based on the above observations made in the audit, the authors present their recommendations in the next section.

6. Conclusions and future research

Rapid increase in travel by personal vehicles has increased the number of road accidents. Globally, reducing the fatalities due to road accidents has become a priority. Road safety audit has emerged as a useful tool to identify the impediments to safety on a road corridor during its development stage and suggest improvements. Since motorcycle is the mode most prominently used in Indian urban areas, and motorcycle travel is more vulnerable to road hazards, the authors focus on reducing motorcycle accidents. In this paper, they propose an audit procedure called motorcycle travel safety audit, which reviews existing urban road corridors on various factors that may contribute to motorcycle accidents and provide recommendations to the local governments regarding the accident countermeasures to be implemented. The authors first identify the factors that influence motorcycle accidents through a survey of motorcycle travelers. They develop an audit checklist that incorporates these factors. They demonstrate the procedure by auditing a set of corridors in Vellore, Tamilnadu.

Based on the limited number of responses obtained in the authors' survey, nearly one-third of accidents happen without a conflict with any other vehicle. Avoiding slippery surfaces such as water, oils, sand and other slippery material on the road is expected to prevent 48% of those motorcycle-alone accidents. Maintaining good pavement condition, providing better visibility, appropriate signs and signals, and better enforcement and road user awareness is expected to prevent another 40%. Accidents due to conflict with other vehicles can be prevented by separating different modes including pedestrians and cyclists. Preventing close following of vehicles through enforcement, driver education or better warning at intersections is expected to prevent nearly 50% of accidents.

Among the three corridors that are audited, Corridor 3 from CMC junction to National Circle should be given top priority in implementing countermeasures. Since the slippery material is a major cause of motorcycle accidents, the authors recommend that drainage facilities should be improved on Cor1 and Cor3. Construction waste should be removed from Cor1 and Cor2. To avoid rear end collisions, all intersections should be properly controlled and signals should function. Proper warning signs should be provided prior to intersections. To prevent conflicts, illegal stopping or parking should be prevented on all corridors. Proper pedestrian facilities should be provided to prevent pedestrians entering into the traffic stream.

The next step in the authors' research is to perform the survey in a bigger scale using telephonic and personal interviews of persons involved in motorcycle accidents. The responses are to be used for refining the checklist and developing the weighting factors for all the checklist items. Future research should test the checklist in different cities in India. A software application can be built to efficiently perform the auditing.

References

Alshatti, F. (2016). *Analysis of motorcycle crashes and fatalities including the impact of distracted drivers in Texas*. The Univeristy of Texas at San Antonio.

Associates, W. S., and Ministry of Urban Development, G. of I. (2008). "Study on Traffic and Transportation Policies and Strategies in Urban Areas in India." <https://casi.sas.upenn.edu/sites/casi.sas.upenn.edu/files/iit/GOI 2008 Traffic Study.pdf>.

Dundee city council. (2005). *Dundee city council road safety audit procedures*. Dundee.

Elliott, M. A., Baughan, C. J., Broughton, J., Chinn, B., Grayson, G. B., Knowles, J., Smith, L. R., and Simpson, H. (2003). *TRL581: Motorcycle safety: a scoping study*. Transport Research Laboratory.

Huang, B., and Preston, J. (2004). *A Literature Review on Motorcycle Collisions:Final Report*. Transport Studies Unit, University of Oxford.

Manan, M. M. A., Várhelyi, A., Çelik, A. K., and Hashim, H. H. (2017). "Road characteristics and environment factors associated with motorcycle fatal crashes in Malaysia." *IATSS Research*, In Press.

PIARC Technical Committe C3.1. (2011). *Road safety audit guidelines for safety checks of new projects*. Niveau, France.

The Indian Roads Congress. (2010). *IRC: SP: 88-2010: Manual on road safety audit*. New Delhi.

Transport Research Wing Ministry of Road Transport and Highways Government of India. (2017). "Road accidents in India – 2016."

World Health Organization. (2017). *Powered two- and threewheeler safety: A road safety manual for decision-makers and practitioners*.