Road Safety Audit and a Case Study on Kaithal-Kurukshetra Road Haryana, India

Er. Mandeep Singh, Er. Sachin Dass, Dr. Dhirender Singhal

Abstract— **Road traffic accidents deaths and injuries occur worldwide. It was estimated that over 1.2 million people died each year on the world roads as a result of road traffic accidents. According to a survey by WHO, more than 3,200 people get killed and over 130 000 injured in traffic every day around the world. Also almost half of all fatal accidents involve pedestrians, cyclists and power two wheelers, collectively called vulnerable road users. A Work zones are areas of construction, maintenance, and utility areas, which creates conditions that can be hazardous to drivers and highway workers. Work zones are a necessary fact of life in our communities and can cause changes in traffic patterns, reduced speed limits, causes congestion; and an influx of construction workers and equipment on the road. Sometimes work zones are poorly marked, and warning signs are hard to see, especially at night.**

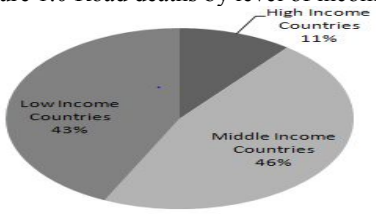
Warning signs and traffic control devices may not be related to actual work in progress or accurately portray real work zone hazards. Drivers thus disregard these warning signs with potentially tragic consequences.

Key words : Road Traffic, Safety, Accident, Highways
Sub Area : Traffic Engineering
Broad area : Transportation Engineering

I. INTRODUCTION

From figure 1.0, it can be observed that more than 85% of accident fatalities occur in low and middle income countries such as India. Though road fatality rate in high income countries has been decreasing over the last decades, even in these countries road accidents remain one the main causes of death, injury and disability

Figure 1.0 Road deaths by level of income.



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There is concerted action, the global road fatalities is expected to increase by more than 65% between year 2000 and 2020, with different trends across the different regions of the world. Fatalities are predicted to be increased by more than 80% in low and middle income countries, but be decreased by nearly 30% in high income countries, thus revealing a widening gap between the road safety in rich and the road safety poor countries.(4)

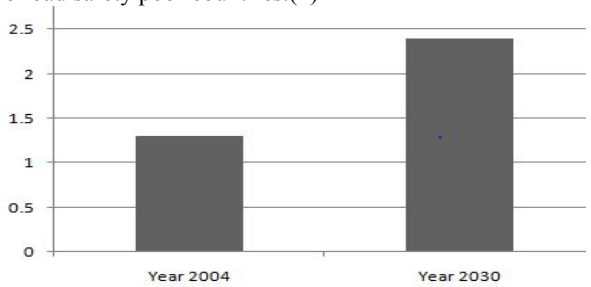

Figure 1.2 Number of road deaths per year (million) without action

From figure 1.2 above it is observed that while in many high income countries road fatality rate have stabilized or decreased, but on the other hands in the majority regions of the world such as Africa the number of people killed in road traffic accidents is constantly increasing and If the current trends allowed to continue, traffic accident related deaths may take the fifth place in the list of death causing, health disorders and injuries by the year 2030 and results in an estimated 2.4 million fatalities per year.

Statement of the Problem and Need for the Study in India

Road traffic accident occurs worldwide, but the incidence is more in developing countries such as India. The problem of road accidents in India has reached such an alarming proportion in such a way that our highways have been converted into dead zones, killing citizens daily. According to survey 7,269 peoples died, 20,752 persons sustained various degrees of injuries and 7,517 people are left permanently disabled in the year 2012 as a result of road traffic accidents across highways in India.

Sudden deaths due to road fatal accidents have continued to be source of grief in a number of homes in India. There is scarcely a week that passes without an account of a ghastly road traffic accident with many deaths being recorded. Despite the annual road safety campaigns, warning against reckless driving and road marshals on our roads, it is unfortunate that the number of traffic accidents is always on

increase leading to loss in both human and material resources through road traffic accidents.

Deaths as a result of motor vehicle accidents constitute a great economic loss to our society. Accidents have far reaching effects on families' life, on development and economic life of the country. The strained health services in the country often cannot adequately look after accident victims and there by entire families, relations, friends and collogues were suddenly swept away, which brings grief and economic hardship to the families and survivors.

Besides those that died in road traffic accidents there are many others who survived with residual disabilities of varying degrees of severity, who ends up as burden to the society. The country itself suffers by losing its talented and productive manpower often in the prime of life.

Road traffic accidents have physical, social, emotional and economic implications. The global economic cost of road traffic accidents was estimated at $518 billion per year in 2003 with $100 billion of that occurring in poor developing countries such as India.

India loses more than 80 billion annually to road traffic accidents. Of all subjects that are involved in road traffic accidents in India, 29.1 per cent suffer disability and 13.5 per cent are unable to return to work.

From all search carried out for the preparation of this thesis there was no any relevant report regarding highway safety audit in India, therefore it can be stated that road safety audit is a new practice in India, it was never carried out before and in order to save life's it is very important to introduce and carry out a road safety audit on Indian highways in order to reduce the number of persons died and severity of injuries on the roads annually

Importance of Road Safety Audit

Road safety auditing is a recognized crash prevention road safety tool worldwide that has the following importance:

a) A reduction in the likelihood of crashes on the road network,

b) A reduction in the severity of crashes on the road network,

c) An increased awareness of safe design practices among traffic engineers and road designers,

d) A reduction in the need to modify projects after they are built,

e) A reduction in the life-cycle cost of a road,

f) A more uniform road environment that is more easily understood by road users,

g) A better understanding and documentation of road safety engineering,

h) Eventual safety improvements to standards and procedures,

i) More explicit consideration of the safety needs of vulnerable road users.

Costs and benefits of Road Safety Audit

The costs of RSA can vary greatly depending on the size of the project and the phase in which the audit takes place. But the main immediate benefits of road safety audit will be accident savings.

However, there are other longer terms and more broadly based potential benefits, these include not just the immediate accident savings on the schemes subjected to the procedures, but more generally, improvements to the management of design and construction, reduced whole-life cost of road schemes, the development of good safety engineering practice, the explicit recognition of the safety needs of road users, and the improvement of design standards for safety.

The benefits of an RSA are mainly the costs saved on crashes that have been prevented by following the audit's recommendations. In addition, Gadd mentions a series of qualitative benefits after completion a diminished risk of crashes and the repair works resulting from them, a reduction of the total project costs, a greater awareness of road safety and quality in design processes, better facilities for vulnerable road users, and a contribution towards achieving road safety targets, better standards, and design guidelines.

A distinction can be made between direct and indirect costs. The direct costs are the time spent by auditors and the extra time that designers need to include the recommendations in the design. Experiences in Denmark estimate the direct costs to be an average of 1% of the total costs of a project.The indirect costs are the extra costs of construction and reconstruction activities that result from the auditors' recommendations. Estimates based on international experiences are between 1% and 2% of the total project costs. In smaller projects the direct and indirect costs of an RSA are relatively higher than in large projects.

A study in Denmark focused on 13 projects that had undergone an RSA. The number of crashes if no RSA had taken place was estimated. The savings on crash costs resulted in a cost-benefit ratio of 1:1.46.

Another study in Jordan focused on projects in which no RSA had taken place and where road safety problems occurred a short time after the projects had been completed. The study assumed that the repair works that were necessary after the crashes occurred would have been included in the initial design if an RSA had been carried out. The number of crashes that could have been prevented was estimated, resulting in a cost benefit ratio of 1:1.2.

Also a Surrey County Council in 1994 compared 38 reconstruction plans half of which had been subjected to an RSA and the other half had not. The annual average numbers of casualties saved declined by 1.25, from 2.08 to 0.83 on the reconstructed roads where an RSA had been carried out. On roads where no RSA had been carried out, the annual average number of casualties declined by 0.26, from 2.60 to 2.34.

However, it is by no means clear if the large decline on roads where an RSA was carried out was exclusively attributable to the RSA, the reconstruction activities on roads with an RSA and those on roads without an RSA were not really comparable.

Another study that is being carried out in Great Britain compared before and after crash statistics for a sample of audited schemes and non audited schemes, the study found that audited schemes achieved an average casualty saving per year of 1.25, compared to a saving of 0.26 for non-audited schemes.

From the above studies carried out in different parts of the world by different road safety auditors it can be seen that road safety audit is a very essential tool to be employed in order to reduce the cost and number of traffic accidents globally.

Objectives of Road Safety Audit

The main objective of any road safety audit is to ensure that all new and existing highway schemes operate as safely as is practicable. This means that safety should be considered throughout the whole preparation, construction and after construction of any project but more specific objectives are:

a. To help produce designs and roads that reduce the number and severity of crashes
b. To ensure that road elements with an increased risk potential are removed or that measures are identified to reduce the risk thereof
c. To Reduce likelihoods of accidents
d. To minimize the severity and crash risk of road traffic crashes that may be Influenced by the road facility or adjacent environment;
e. To minimize the need for remedial measures after the opening of a new road Project
f. To identify and report on the crash potential and safety problems of a road Project
g. To avoid the possibility of the scheme giving rise to accidents elsewhere in the road network.

Actions for Improving Road Safety on Highways

By planning more efforts for increasing highway safety, some transportation agencies have introduced safety programs specifically designed to study and improve some important geometric elements contributing to highway accidents.

At the same time, engineering design has greatly been improved in terms of increasing safety into road structure and environment. In earlier years, engineers designed and built highways, which provides a minor of protection to vehicles colliding with infrastructure or roadside elements outside travel lanes.

In 1960s and 1970s, engineers have started to build more "forgiving highways" which incorporated critical design elements that mitigated the consequence of colliding with elements beyond the travel lanes. More recently, engineers have begun to develop "caring highways" by emphasizing the need to prevent (rather than mitigate) collisions.

Although it is in practiced for nearly two decades, the concept of Road Safety Audits has only recently gained acceptance in North America. Originally developed in the United Kingdom in the 1980s as part of Accident Investigation and Prevention techniques, they have evolved to the point where they are now an integral component of the road safety process. Road safety audits help to ensure that issues associated with road safety are specifically addressed and are given equal importance as the other factors in a design project.

On the other hand, Road Safety Impact Assessment (RSIA) is just come into the Road Authorities Agendas through the proposed applications and obligations that have been set by the European Parliament and The Council of The European Union. The Road Safety Impact Assessment' means a strategic comparative analysis of the impact of a new road or a substantial modification to the existing network on the safety performance of the road network. The Commission expressed the need to carry out safety impact assessments and road safety audits, in order to identify and improve high accident concentration sections within the Community. It also sets the target of halving the number of deaths on the roads within the European Union between 2001 and 2010.

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For the purpose of this thesis a 50 km section of Kaithal-Kurukshatra express way which is an existing roadway in India will be considered as a case study. The road is a dual carriage way which connects two cities with moderate population inHaryana India and also many towns were located along the road.

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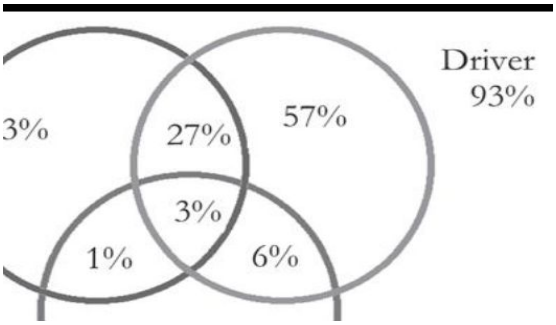

Figure 2.1 Accident contributing factors (12)

Figure 2.1 above shows that driver errors constitutes the highest percentage among the three main factors contributing to accidents followed by road condition with the second and lastly the vehicle defect or malfunction.

Considering road transportation as a system, there are things that we can directly control and things that we cannot. Drivers and environmental events like weather are hard to control and If the parts of the system that can be controlled (roads and vehicles) are designed to allow for those we cannot (road users and weather), the system as a whole will work better.

The road safety is a complex matter to understand and analyze. Because of this reason, a model preparation including all of the three elements; human, vehicle and environment is a very difficult process. These elements can be considered separately or they can be evaluated together with their relations to each other.

Increase in road safety requirements is an unavoidable consequence of rapid economic growth. Unless the road safety is maximized, the resultant economic and social costs could erode a substantial part of the benefits of economic growth. Millions of deaths and injuries, billions of dollars in medical costs, increased strain in welfare services, loss of productivity, and poverty problems are some of the consequences of slack road safety.

Hazardous Roadway Conditions

The following below are considered as the hazardous roadway conditions contributing to accidents regardless of locations on the roadway, these conditions are potentially dangerous to road users.

Roadway Departure Hazards

Roadway departure crashes occur on both straight and curved sections of roadway and often involve either rollover of a vehicle or collisions with fixed objects such as trees and utility poles. Road side hazards also include steep side slopes, drainage ditches along the roadway, and narrow shoulders not large enough to accommodate a vehicle in trouble.

Road Surface Condition

Some problems in the road surface, such as pavement edge drop-offs, potholes and reductions in surface friction due to age, wear, inadequate drainage during rain storms, and incomplete winter maintenance to remove ice or snow obviously impair vehicle stopping and maneuvering capabilities leading to fatal crashes.

Narrow Roadway and Bridges

A narrow bridge makes it difficult for drivers to safely maneuver in emergency and non emergency situations because there is simply no enough space to maneuver. Narrow bridges are particularly hazardous and collisions with bridge ends are relatively infrequent but they are often severe. Such crashes usually occur when the width of a bridge is less than that of the approaching traveling lanes and shoulders and as a result vehicles strike the end of the bridges, guardrails or curbing.

Rail Road Crossing

Rail road crossings is one of the most dangerous places along the roadway sections because trains cannot stop quickly or steer out of the way and obviously, railroad crossings are of a critical concern, and they can be incredibly hazardous, regardless of how busy they are.

Roadway Access Problems

Roadway access problems are very familiar problem and also one of the most dangerous among the hazards. Constantly growing traffic congestion, concerns over traffic safety, and the ever increasing costs of upgrading our roads have generated a new interest in managing access to our highway systems. Access management is the process that provides access to land development while simultaneously preserving the flow of traffic on surrounding roadways.

Three issues kept in the forefront of access management are safety, capacity, and speed. Fewer direct accesses, greater separation of driveways, and better driveway design and location are the basic elements to be considered for safety.

Pedestrians and Bicycle Traffic

Pedestrian and bicycle traffic must be accommodated and speeds must be controlled for them as they are vulnerable. There were high pedestrian deaths and injuries along the roads in all over the world and these numbers are expected to increase as our population increases. Therefore all highways should be design in such a way to accommodate the safety of pedestrians and bicyclist.

How to Approach Road Safety Evaluation

Evaluation of completed highway safety projects and programs are essential for safety professionals to identify the improvements that are working, the ones that are producing nominal benefit and the ones not working.

Road safety programs are prepared and are being applied to reduce the number of accidents. These programs generally have similar aim which is to reduce the number of traffic fatalities and injuries.

Once the problem or problems and their sources are identified, then the second step is the selection of the correct and adequate countermeasures to implement as there is no single counter measure that is seldom to provide a total solution to a safety problem.

Before finalizing of the treatment decision, all the cost and accident reduction factors of the different improvement scenarios should be analyzed. The most cost effective countermeasure has to be applied. The word cost effectiveness generally stands for the net resource cost of a measure per year of life saved.

The basic methods for solving safety problems can be categorized in to five stages as follows

1- Identify the type of problem and determine contributing factors

2- Select a countermeasure:

a- Which improvement offers the best results for the least cost?

b- Will a possible improvement solve the problem, or just move it down the road?

c- Will a possible improvement cause problems of its own? If so, are they worse

than the problem you are trying to solve?

3- Install the countermeasure

4- Evaluate success

5- Return to Stage 2 if necessary.

The evaluation of effectiveness of safety projects and programs can lead to continuing safety improvements at the same level, increasing resource allocations due to success achieved, or even discontinuing some safety initiatives due to their observed inability to alleviate traffic crash problems.

Counter Measure Follow-Up

To understand the effects of countermeasures, it is necessary to follow-up the application of the different countermeasures after their respective applications. For this purpose all the data and information that have been recorded before and after (follow-up) stages of the road section improvements should be saved. Again by that way follow-up can give the correct and dependable results for the future improvement applications.

Basically there are two methods for counter measure application follow up for different purposes:

The Short Term Follow-Up

Using this method, Short term effects can easily and shortly show if the road users have taken positive contribution from the improvement and usually takes place immediately after the application of countermeasure.

Planning Highway Network for Safety

Planning of roads can have a profound effect on the level of road safety, planning road networks usually contains a complex interaction of land uses and activities. Each type of land use has its own traffic characteristics and this can lead to safety problems

Road hierarchy in highway planning is to consider the functions of local roads, collectors, and arterials in terms of accessibility and mobility. Local roads mostly provide access to land, whereas arterials mostly provide mobility for through traffic. Collectors fall functionally halfway between local roads and arterials as shown in Figure 2.2 above.

Figure 2.2 above indicates that accident and fatality rates on arterial highways with full control of access are far less than

that of collectors and locals with no access control. The increase in roadside development results in an increase in at grade intersections and in business with direct access to the highway, this situation always significantly increases accidents.

Highway network planning for safety should include following three features namely road hierarchy, land use and access control. Each of the three items above is described below:

METHODOLOGY AND EXPLANATIONS OF ROAD SAFETY AUDIT

The Road Safety Audit can be applied to specific operating and maintenance activities on existing roads as well as for systematic assessment of road safety aspects on existing roads and road networks.

Some of the inputs or information's that are necessary needed for road safety audits on existing road are road function, traffic data, speed data and accident data. These data support auditors for better performing the audit of the road. By the help of these data auditors can clarify the road function, have idea about the typical accident types, volume of traffic, speed levels of different vehicles etc. After getting these data they can immediately determine the potential hazards and focus on them.

Methodology for Safety Auditing on Existing Roads

Audit on existing roads started after certain information about the road section are obtained. Highway section should be audited for both traffic directions. Nevertheless one site study is never enough to collect auditing information and its evaluation. In many cases two or more auditing studies have to be implemented and at least one survey must be conducted at night.

One of the benefits of the RSA process is the cooperative interaction created by the members of the audit team. The knowledge and experience of the team as a whole are greater than the sum of these attributes as vested in the individual members, so the process benefits from being conducted by a team. While three members in a team may be adequate for some project types, the number may not be sufficient for larger, more complex projects or those requiring specific expertise.

The best practice is to have the smallest team that brings all of the necessary knowledge and experience to the process.

All of the observations achieved during the audit are recorded on the safety audit checklists and forms prepared in a special format as illustrated on the subsequent paragraphs.

General Project Data Required for Road Safety Audit on Existing Road

In order to carry out a road safety audit on existing road, there are many important data or information's required about the particular road section selected for auditing/inspection, the basic inputs or data's are described below.

Evaluation of Improvement Projects

Techniques available used by management in evaluating highway projects in terms of project costs and safety impacts can be grouped into two broad categories 1- Using the first approach, the safety impact is represented by the monetary amount of accident cost savings called Benefit-Cost Analysis, 2- The second approach considers the cost per expected number of accidents reduced as the measure of safety effectiveness called Cost-Effectiveness Analysis.

The basic difference between the two categories is the method of measurement of safety impact.

Benefit = (Accident Cost without Improvement) - (Accident Cost with Improvement)

BCR= Benefits / Cost

Cost effectiveness= Total Cost / Expected Number of Accidents Reduced

a) After audit survey and analysis it is recognized that the most common hazards observed are fixed massive objects within the safety zone area, deficient guardrails, pavement damages, missing shoulders, non-gentle slope and improper bus stop locations

b) Also after comparison of the existing roadway cross section elements with that in AASHTO standard it is observed that majority of the roadway elements were not in accordance with AASHTO which is used as Indian standard for highway design.

c) Among all the most common hazards recorded during the survey it is observed that the most dangerous hazards are pavement damages like potholes on the roadway and pavement edge deterioration, fixed massive objects associated with road side area such as fixed massive poles and sign post that were improperly placed within the safety zone area and missing or narrow shoulder along the whole section of the roadway. All these hazards listed above contributes to the increasing number and severity of accidents along the road as some accidents were seen physically during the field survey involving fixed massive objects on the road side and some accidents associated with pavement damages.

d) Lack of adequate and proper record of accident data that covers some aspects like accident location, time of occurrence, type of vehicles involved, reasons or accident contributing factors, result of collision and many others by relevant authorities in India hinders or limits the possibility of this research to analyses the accident data and understand that either this hazards are among the accident contributing factors on this road section or not and also to know the level of contribution by each hazard on the accidents.

e) As observed during the site visit missing and narrow shoulders forces errant and vehicles that stop for emergency to park along the road section which also has ınsufficient lane width. Considering the supportive characteristic of the shoulders and their usability in emergency situations, it can be concluded that most of the present shoulders might have adverse effect to road safety.

f) Another problem which is not as dangerous as the ones listed above is improper connection of gas stations and other roadways to the main road which creates additional danger to the overall safety of the road and its environment.

g) Another significant safety problem is recorded as steep fill slopes. It is considered that slopes were not designed regarding safety standards on the fill cross sections. Guardrail application can be considered as a solution for this problem.

h) As discussed above most of the dangerous problems observed on the road section were associated with road side area, therefore it can be concluded that providing a cleared and unobstructed road side area will solve larger portion of the accident problems.

The tables below shows the most common and most dangerous hazards observed during the site visits for both directions of the road.

CONCLUSIONS AND RECOMMENDATIONS

A roadway safety is one of the items that are being brought to the forefront of the transportation industry. Road Safety Audit (RSA) is becoming a major tool for assessing the risk on existing roadways. RSA is proactive in nature and look to find safety risk before crashes occur. It has been used to improve the ability of decision makers' to assess risk on the roadways. On the other hand, transportation professionals need such a tool that can look at the complexity of the roadways.
In this thesis the real practices of road safety audit on existing roads in different countries were summarized.

Recommendations

The following recommendations can be drawn from the case study:
a. The case study methodology as a safety audit should be followed and implemented on all present rural highway networks in India and all other roadways for evaluating the overall safety of the country roads.
b. Road safety audit surveys should be done for short intervals to observe changes in the road structure and equipment as well as the road environment.
c. Road Safety Audits are being considered as more and more important and widely used tools/applications to increase the road and the road environment safety.
It is necessary to introduce course programs to teach young highway engineers in all parts of India and world in general, about these techniques as quickly as possible. The different teaching techniques such as distant learning and distant workshop facilities should be applied.
d. Problems with the lack of dependable traffic and accident common database in India have adversely influenced the road safety activities. Thus, implementing reliable and well-designed traffic safety database including road and traffic statistics and records should be accepted as the first priority action in the recent future. This common database should be open to researchers with no restrictions.
e. India should start to invest in the researches of accident reduction factors for different road safety countermeasures that are currently not available but adapted from international studies. These researches require long-term studies and should be implemented as soon as possible.

Conclusions

Many intersections are very dangerous intersections, as they are composed with confusing turn lanes, blind spots, or lack of appropriate or inadequate signage or traffic
signals. Obstructions, including vegetation, can block a driver's view of signs, signals, and other traffic control devices there by leading to high severity if accident occurs.

Roadway Design Limitations

Many local roads were not built to serve today's high-volume, high-speed traffic. Their safety is limited by hazards such as sharp curves, poor signs and pavement markings, and lack of medians to separate oncoming traffic. These limitations could present an even greater threat to highway safety because of the expected increase in the car ownership over years.
Many of these roads are now high speed commuter corridors, because of these their safety now is compromised by many hazards. Therefore, drivers must therefore be aware of roadway hazards and drive with extra care. For estimating the exact results of countermeasures it is necessary to make follow-up for minimum three years for the long-term evaluations. On the other hand, all changes in the road and its environment have to be observed, because these changes could affect the road safety and also affect the countermeasure efficiency.

REFERENCES

1. IRC CODE -37
2. IRC CODE -64
3. IRC CODE -67
4. IRC CODE -73
5. IRC CODE -84
6. Dr. L.R.Katiyal, "Traffic Engineering & Transportation planning"