FRAME WORKING ROAD SAFETY BY SAFE SYSTEM APPROACH ON SHS AND NHS IN INDIA AND ASSESSMENT WITH IRAP

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ABSTRACT

India leads in road accident deaths over the countries of the world, which is second to China in total length of roads. According to MoRTH, road deaths in National Highways and State Highways in India account for nearly 65% of the total deaths but shares only 5% of the total roads. Examining past 10 year's accident severity index it can be seen an increase from 21.6 to 29.1. This shows that the infrastructure which are designed are not capable to cushion the accidents occurring in it, which is leading to serious injuries and deaths. So there is a need to provide a Safe System which ensures that the forces in collisions do not exceed the limits of human tolerance and reduces the fatalities thus preventing from serious injuries and deaths. Therefore a safe system approach which ensures these vision, strategy, plan, and program execution must be in acted upon. For this relying on the traditional approach of Road Safety Auditing, in which only a few of the very worst roads are audited and which works better only after the accidents had occurred cannot be attributed. To counteract this assessment of high risk roads can be studied by International Road Assessment Programme (iRAP), which comes with Star Ratings and Safer Roads Investment Plans that can be used as part of a systematic approach to road infrastructure risk assessment and it also produce countermeasures as a mitigative measure. The night time accident in India is about 39 % in which most victims are the vulnerable road users. Most of the accidents are due to lack of visibility. To enhance night time visibility, provision of sufficient street lighting is requisite mainly at junctions. So in this paper meta-analysis study of various research works have been done to conclude with a better precise result for developing risk factors for street lighting which may lessen the night time accidents.

KEY WORDS: accident severity, safe system, iRAP, night time accidents, street light risk factor

INTRODUCTION – GENERAL OVERVIEW

Road traffic fatalities are a major concern which is neglected as a public health challenge that requires intensive efforts for its effective and sustainable prevention. People underestimate the road accident deaths as compared to other unnatural deaths which has a high death count. The main reason behind this is that people appear to underestimate the likelihood of a familiar accident and overestimate the frequency of unfamiliar accidents. More fatalities in a single incident registers much deeper in people's brain than such equivalently small incidents over the system. This is because these differential incidents occurs over the wide system which affect them less or they are not concerned about it happening elsewhere. So it's high time to have an

integral approach towards the road accident deaths and its causes. Below **Table 1** *(1)* gives the last 5 years road accidents data in India and the Accident Severity Index.

TABLE 1 Number of Road Accidents and Number of Persons affected in India for 2011-2015

Year	Number of Accidents		Number of Persons		Accident Severity *
	Total	Fatal	Killed	Injured	
2011	4,97,686	1,21,618 (24.4)	1,42,485	5,11,394	28.6
2012	4,90,383	1,23,093 (25.1)	1,38,258	5,09,667	28.2
2013	4,86,476	1,22,589(25.2)	1,37,572	4,94,893	28.3
2014	4,89,400	1,25,828(25.7)	1,39,671	4,93,474	28.5
2015	5,01,423	1,31,726(26.3)	1,46,133	5,00,279	29.1

[Source: MoRTH's Annual Report TRW, India]

***** Accident Severity: Number of persons killed per 100 accident

The accident severity index for India is very high as compared to developed countries, but is given less priority. The hidden danger is that the system or the infrastructure are not capable to handle the accidents occurring in it. For what the system are designed to, it doesn't deliver the required. The road accidents are resulting into death or serious injury which is a consequence of errors on the road. So these errors must be eliminated so as the infrastructure must be improved which accommodate these accidents ensuring a Safe System in which the vehicle collision forces do not exceed the limits of the human body which can tolerate it. According to road wise classification of accidents in India, The National Highways which share only 1.58 % of total road length accounts for highest road accident deaths 35.0 %. State Highways having the share of 3.38 % of total road length and have reported 28.0 % of road accident deaths in the country. **Figure 1** shows the share of various vehicle categories in total road accidents for 2015. Amongst the vehicle categories, two-wheelers accounted for the highest share in total road accidents (32 per cent) followed by cars, jeeps and taxis (17 percent).

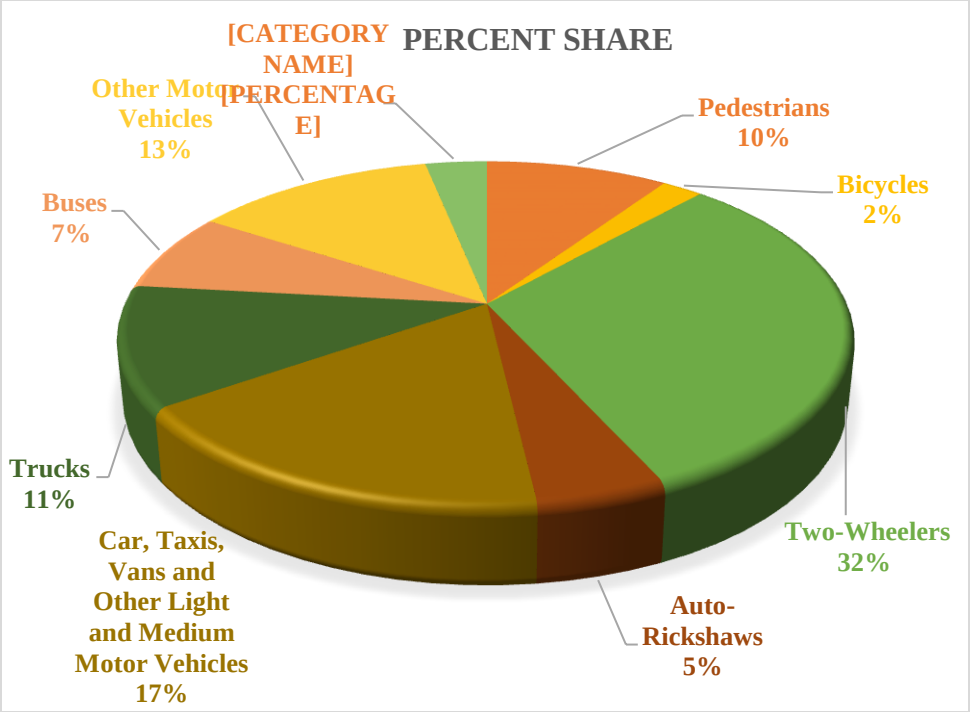

FIGURE 1 Percent share of various vehicle categories

Need for Road Safety Policies

Road crashes are preventable. Significant number of road deaths and injuries are not a fundamental law of nature or an inevitable result of motorization. Adoption of an appropriate road safety policy is the main driving force for achieving such a major goal. The recognition of an appropriate road safety policy is one such essential element of a well-balanced overall transport policy and a public health policy. Some developing countries are also now demonstrating that significant reductions can be achieved via implementation of appropriate policies.

Road Safety Initiatives by the Government of India

The Government of India has approved a National Road Safety Policy. This Policy outlines various measures such as promoting awareness, establishing road safety information data base, encouraging safer road infrastructure including application of intelligent transport, enforcement of safety laws etc. The Government has constituted the National Road Safety Council as the apex body to take policy decisions mattering road safety. The Ministry has formulated a multi-pronged strategy to address the issue of road safety based on 4 ‘E’s viz. Education, Engineering (both of roads and vehicles), Enforcement and Emergency Care. Road safety has been made an integral part of road design at planning stage. Road Safety Audit of selected stretches of National Highways has been taken up.

Problem Statement

The Road safety measures must be aimed at the benefits of people, vehicles, the road, and its environment and in the analysis process, all these elements should be considered. For the analysis an ethical and philosophical approach must be considered which will gain a prominent

place in transport policy and decision-making processes. A vision that is practical and easy to use at regional and local level must impended upon. Like in Sweden they adopted 'Vision Zero' to imply a widespread commitment from the society to give priority to prevent the worst consequences of road accidents. In Netherlands they adopted 'Sustainable Road Safety' and it has led to the creation of new design principles. Similarly in Australia and New Zealand the guiding principles for road safety is based on safe system approach. But in India, till date, it does not have a proper and formal national integrated road safety strategy despite the fact that it tops the world as far as the total number of road fatalities is concerned. So in India it's high time that an integrated plan to mitigate road crash fatalities must be implemented which has a specific planning strategy.

Safe System approach

Safe System *(2)* principles have been acknowledged in successive national road safety strategies in Australia and New Zealand and in their action plans since 2003 as the guiding principles measures for road safety programs. The approach recognises that humans, as road users, are fallible and will always continue to make mistakes which will result in crashes. This points to that road infrastructure be designed to take account of these errors and vulnerabilities to reduce the risk of serious injury.

Safe System Treatments

This paper focuses in developing a framework for the selection of infrastructure solutions to achieve a Safe System. An important part of this framework will be to advise on treatment selection, and to ensure it is the best application for the situation to move towards safe system objectives. Best fitted methodology is Assessment of roads with International Road Assessment Programme (iRAP) *(3)* which caters the safe system approach.

Treatment with help of iRAP in India

In conventional method, while Auditing roads which are identified as black spots, it only tackles a few of the very worst roads and best works after the accidents had occurred, whereas iRAP analysis is based on the current road condition and even it can assess roads in the design stage itself.

iRAP had developed four globally-consistent protocols to assess and improve the safety of roads. They are:

Risk Maps use detailed crash data to illustrate the actual number of deaths and injuries on a road network.

Star Ratings provide a simple and objective measure of the level of safety provided by a road design.

Safer Roads Investment Plans draw on approximately 90 proven road improvement options to generate affordable and economically sound infrastructure options for saving lives.

Performance Tracking enables the use of Star Ratings and Risk Maps to track road safety performance and establish policy positions.

iRAP risk map and star rating result

iRAP Star Ratings *(4)* are based on road infrastructure features and the degree to which they impact the likelihood and severity of road crashes. The focus is on the road features which

influence the most common and severe types of crash that occur for the roads users that is, motor vehicles, motorcyclists, pedestrians and bicyclists. They provide a simple and objective measure of the relative level of risk associated with road infrastructure for an individual road user. The Star Ratings are based on Star Rating Scores (SRS), shown in **Table 2**. The iRAP models are used to calculate an SRS for every 100 metre intervals for each of the four road user types, based on relative risk factors. The scores are developed by combining relative risk factors using a multiplicative model.

TABLE 2 Star Rating Bands for Different Road Users

Star Rating	Star Rating Score		
	Vehicle occupants & motorcyclists	Pedestrians	Bicyclists
5	0 to < 2.5	0 to < 5	0 to < 5
4	2.5 to < 5	5 to < 10	5 to < 10
3	5 to < 12.5	15 to < 40	10 to < 30
2	12.5 to < 22.5	40 to < 100	30 to < 60
1	22.5 +	100 +	60 +

Safer Roads Investment Plan

iRAP considers more than 90 road improvement options to generate affordable and economically sound Safer Road Investment Plans (SRIP) *(4)* that will save lives. Road improvement options range from low-cost road markings and pedestrian refuges to higher-cost intersection upgrades and full highway duplication.

Risk Factor

Accidents occurs due to several factors which are invariably a chain of events leading to loss of control of a vehicle, a failure to correct and subsequent impacts with other vehicles, road-users or objects. The severity of injury resulting from the crash depends on the kinetic energy involved in the impact. Accident investigation must be done by identifying the likelihood of a crash which will occur.

Even where a crash may be inevitable, the severity can be reduced with improved infrastructure facilities that protect road users by reducing the kinetic energy of the crash to a tolerable level. iRAP has developed a series of factors that relate road design categories with the relative likelihood of crashes and their severity. These factors are then incorporated as variables and converted to SRS.

Below discusses the advantages and disadvantages of iRAP over conventional road safety auditing:

Advantages of iRAP

- Can assess more roads as compared to road safety Auditing for a time frame
- Comparison of road with international level of standard

- Easy storage and access of data in one platform
- Uniformity in assessing the road with unique attributes for road sections
- Countermeasure production

Disadvantages of iRAP

- Not suitable for urban conditions as road attributes change frequently
- Night time road influencing factors are not considered
- Night time accidents scenario assumed as overall accidents

This paper also focuses in improving the assessment methodology with meta-analysis of night time accidents and other influencing factors which have not been accounted for generating the risk factors in iRAP. Study of various research paper have been conducted and recommends risk factors for generating Star Rating Score. Below sections discusses in detail the aforementioned.

META-ANALYSIS OF CONTRIBUTING RISK FACTORS

Road accidents occurs in different way of which the common types are Run-off, Head-on, side-front at intersections etc. The causes for these accidents may be due to one or more of the reasons. The severity of these accidents increases at night mainly due to increase in speed and lack of visibility. This section explores various contributing factors which are the reasons for increase in number of night accidents as compared to day accidents and its severity.

Factors influencing Night time accidents are:

- Road Type
- Road Marking
- Reflective materials
- Illuminance Level
- Road curvature
- Reflective Pavement Markers (Road Studs)
- Pavement Condition
- Annual Rainfall index
- Operating Speed
- Vulnerable road users
- Land use pattern
- Pedestrian facilities
- Width of edge line
- Presence of Junction
- Vegetation near road side

With the scope of the paper limited below section discusses some of the critical factors which affect the Night time accidents and recommends its probable risk factors.

Illuminance Level

Street Lighting plays a vital role as it transform outdoor night time environment over large areas, modifying natural cycles of light. This has widespread benefits and costs to humankind, impacting on health and wellbeing, vehicle accidents, crime, energy consumption and carbon emissions, aesthetics, wildlife, ecosystems etc.

Below **Table 3** shows the distribution of accident according to time of occurrence. During 2015 high rate of accidents occurred between 15:00 hours to 18:00 hours followed by 18:00 hours to 21:00 hours.

TABLE 3 Road Accidents as per the Time of Occurrence for 2015

Sl No.	Time	Number of Accidents	Per cent Share in total Accidents
1	06:00 - 09:00 hrs (Day)	55,518	11.1
2	09:00 - 12:00 hrs (Day)	81,964	16.3
3	12:00 - 15:00 hrs (Day)	79,616	15.9
4	15:00 - 18:00 hrs (Day)	87,819	17.5
5	18:00 - 21:00 hrs (Night)	86,836	17.3
6	21:00 - 24:00 hrs (Night)	51,425	10.3
7	00:00 - 03:00 hrs (Night)	27,954	5.6
8	03:00 - 06:00 hrs (Night)	30,291	6
	Total 24 hrs	**5,01,423**	**100**

[Source: MoRTH's Annual Report TRW India]

Elvik, et al. (1995) *(5)* conducted a meta-analysis of 37 published studies, reported from 1948 to 1989 in 11 different countries, which evaluated the safety effects of lighting. Analysis of the different studies indicates roughly a 65% reduction in night time fatal accidents, 30% reduction in injury accidents, and 15% reduction in property damage accidents for both intersections and roadway segments on rural, urban, and freeway facilities when lighting was installed. The effect of installing lighting was greater at intersections than non-intersections and similar results were found for rural, urban, and freeway environments.

More recently, Green, et al. (2003) *(6)* completed a before-and-after study in Kentucky that analysed the safety benefits associated with roadway lighting. A high percentage of the night time crashes had one or more of the following characteristics: occurred on a weekend, involved one vehicle, took place on a curve, or occurred in snow and ice conditions. As part of the research, a procedure was developed to identify locations in Kentucky that have a high number or rate of night time crashes. A significant number of the locations were identified as rural; however, urban sites were also included. The researchers conducted analysis of 9 intersections before and after the installation of lighting and found that night time crashes were reduced by 45%.

Below **Table 4** gives the suggested risk factor for the road attribute Illuminance Level for different road users.

TABLE 4 Risk factors by road attribute category, road user type and crash type

Illuminance Level	Vehicle occupant		Motorcyclist		Bicyclist		Pedestrian	
	Run-off	Head-on LOC	Run-off	Head-on LOC	Along	Run-off	Along	Crossing
Adequate	1	1	1	1	1	1	1	1
Low	1.5	1.5	1.5	1.5	1.5	1.5	3	3
Nil	2	2	2	2	3	3	6	6

Recommendation

The minimum street light must be checked while rating the roads. Intersection accidents are comparatively high during night time and the most vulnerable are the pedestrians. This is mainly due to lack of visibility. The pedestrians are not seen by the vehicle drivers during night and also at rural highway, negligence of the drivers that pedestrians will be least is also a factor for increase in intersection accidents. Below **Figure 2** *(7)* show the minimum recommended Illuminance level for Night to Day Crash Rate Ratio.

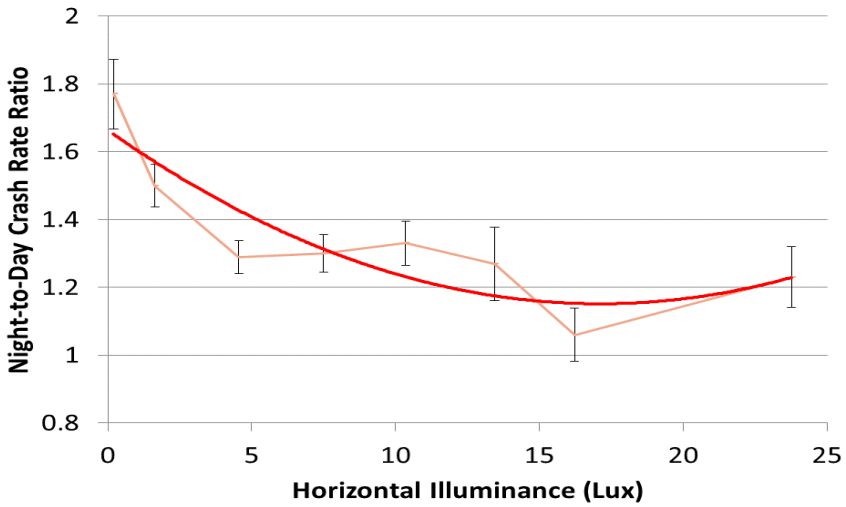

FIGURE 2 Relationship between mean horizontal illuminance level and weighted night-to-day crash rate ratio. Best fit line R2 = 0.7944

Road Marking

Road markings plays vital a role in reduction of crash at night in the absence of street lighting. Most of the drivers find road marking as useful for identifying the road edge during night. More over crash types that are most likely affected by added markings or enhanced markings (added width or more retro-reflectivity) are run-off-road and opposite-direction crashes that occur at night, occur on curves, and involve drivers with reduced visual or cognitive capabilities (e.g., older drivers or impaired drivers). Also the width/ thickness of the road marking play a key role in assessing the road edge for drivers.

Elvik et al and Vaa et al (2004) *(8)* suggest improvements to road markings and channelization at junctions can reduce accidents by 15%.

Annual Rainfall index

Sitti Asmah Hassan et al *(9)* found that rainfall intensity had a significant impact on headway data on a road section. Another impact of rainfall intensity on the traffic data is it reduces the traffic flow rate as rainfall intensity increases. When the flow rate decreases, the distance between vehicles to vehicle is larger, thus contributing to the increase of headway value. But it is observed from studies that for light rains and drizzles the accident rate increases. Below **Table 5** shows the study finding conducted by Sitti Asmah Hassan et al.

TABLE 5 Descriptive Analysis of Vehicle Headway for Various Rainfall Intensities at Night

	Dry	**Light Rain**	**Moderate rain**	**Heavy Rain**
Number of vehicles	122445	4402	927	181
Min. Headway (s)	0	0	0	0
Max. Headway (s)	943.2	185.9	135	121.1
Range (s)	943.2	185.9	135	121.1
Mean Headway (s)	8.84	9.14	10.3	12.98
Median (s)	2.7	2.6	2.7	4.2
Mode (s)	1.1	1.4	1.3	1.4
Standard Deviation	15.37	14.9	17.94	17.7
Flow Rate (/min)	6.8	6.57	5.79	4.53

Above table clearly shows that with increase in rainfall intensity the mean headway decreases which ultimately reduces the operating speed.

Below **Table 6** gives the suggested risk factor for the road attribute Rainfall intensity. The annual mean rainfall data can be correlated and the average hourly precipitation can be found.

TABLE 6 Risk factors by road attribute category, road user type and crash type

Rainfall intensity	**Vehicle occupant**		**Motorcyclist**		**Bicyclist**		**Pedestrian**	
	Run-off	**Head-on LOC**	**Run-off**	**Head-on LOC**	**Along**	**Run-off**	**Along**	**Crossing**
Light Rain, > 2.5 mm/hour	1	1	1	1	1	1	1	1
Moderate rain, 2.5-10 mm/hour	1.5	1.5	1	1	1.5	1.5	1.5	1.5
Heavy rain, 10-50 mm/hour	1.8	1.8	2	2	3	3	3	3
Very heavy rain, >50 mm/hour	2	2	3	3	3	3	3	3

CONCLUSION

- The severity of road accidents, measured in terms of persons killed per 100 accidents has also increased from 21.6 in 2005 to 29.1 in 2015.
- Road deaths in National Highways and State Highways account for nearly 65% of the total deaths but shares only 5% of the total road lengths.
- Amending Road Safety Policy in India with integration of iRAP in auditing the roads
- Assessment of night time accident need to be incorporated for the analysis while generating risk factor iRAP methodology considering various contributing factors.
- Provision of adequate street lighting must conform to the recommended minimum illuminance level.
- Extending research work in developing risk factors for Indian conditions.

REFERENCES

National Crime Records Bureau (NCRB), (2015), *Road Accidents in India,* G. O. I Ministry of Road Transport & Highways Transport Research Wing, 2015

Austroads, *Guide to Road Safety Part 1 : Road Safety Overview*, Guide to Road Safety Manual, 2013

iRAP, *Star rating Road for Safety: The iRAP Methodology,* 2014

iRAP, *Star Rating and Investment Plans :* Road Survey and Coding Specification, Manual, 2014

Elvik Rune, *Meta-Analysis of Evaluations of Public Lighting as Accident Countermeasure.* Report 1485. Transportation Research Record, 1995.

Green, Eric R., Kenneth R. Agent, Monica L. Barrett, and Jerry G. Pigman. *Roadway Lighting and Driver Safety (KTC-03-12/SPR247-02-IF).* Kentucky Transportation Center, University of Kentucky; USDOT, Federal Highway Administration, May 2003.

Design Criteria for Adaptive Roadway Lighting, FHWA-HRT-14-051, Federal Highway Administration

Elvik Rune and Vaa T (2004), *The Handbook of Road Safety Measures*, Elsevier 2004

Sitti Asmah Hassan, Teoh Hao Xuan and Nordiana Mashros, C*haracteristics of vehicle headway during rainfall at night in Pontian, Johor,* Department of Geotechnics and Transportation, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia, p69-p70.