USING IRAP STAR RATINGS AND SAFER ROADS INVESTMENT PLANS FOR IMPROVEMENT OF REGIONAL ROAD NETWORK IN INDIA

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ABSTRACT

The Government of India has invested heavily in road building programmes in recent years to improve mobility and reduce journey times. However, with a continued rise in reported road deaths it is of paramount importance that every opportunity be taken to ensure that these new roads and rehabilitation projects focus on the need for safe road infrastructure for all road users. Since 2010 several State Road Authorities in India have been using the star rating system, developed by the International Road Assessment Programme (iRAP) to measure road infrastructure risk and have been developing Safer Roads Investment Plans to identify cost-effective treatments for inclusion in planned upgrades that have made the roads safer and more forgiving.

The methodology involves assessment of road features that influence risk for vehicle occupants, motorcyclists, pedestrians and bicyclists and assigns a safety rating from 1 to 5 stars. To date in India, more than 10,000km of roads have been assessed across 10 states with more than 75% of the length assessed rated just 1 or 2-stars for safety. It is estimated that more than 75,000 deaths and serious injuries are occurring every year on the roads assessed and the investment plans are helping to ensure that safety of road designs is optimized.

This paper explains the methodology and discusses the benefits of adopting this systematic and proactive approach and looks at how the star rating of road designs is helping to make sure that safety is built-in to the process at the planning and design stage.

1. INTRODUCTION

It is recognised that investment in transport networks play an important role in a country's economic development and poverty reduction. To this end, the Government of India has invested heavily in road building programmes in recent years in order to improve mobility and reduce journey times. However, it is of paramount importance that every opportunity be taken to ensure that these new roads and rehabilitation projects focus on the need for safe road infrastructure for all road users, particularly the young and vulnerable.

Road crashes in India result in exceptionally high levels of death and serious injury. The latest official figures show that 146,133 people were reported killed and 500,279 were seriously injured in road crashes in India in 2015 (*1*). The number of reported road deaths is the highest on record and despite a commitment to reduce the number of road crashes and fatalities by 50% by 2020 (2010 baseline) the trend continues to rise.

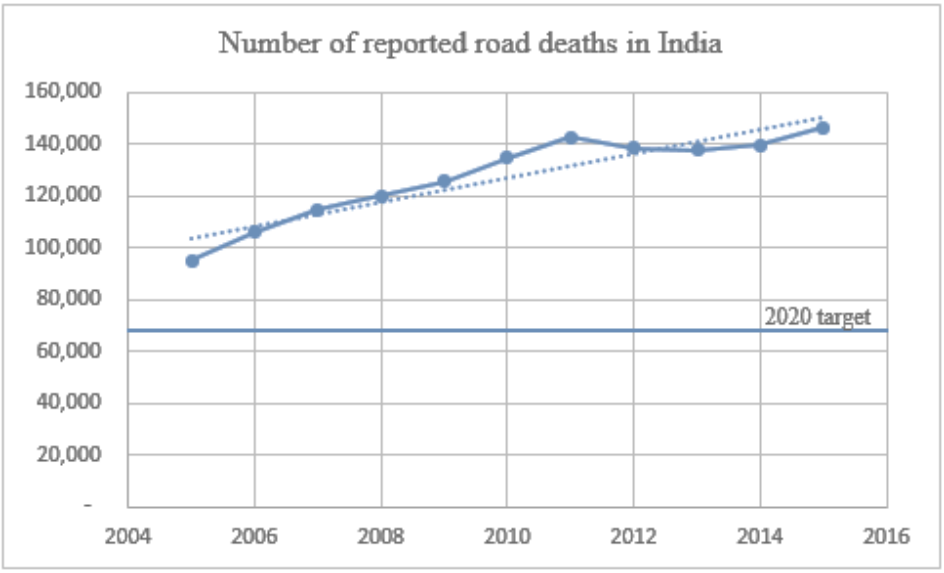

FIGURE 1 Chart showing reported road deaths in India 2005-2015 and 2020 target

Despite government efforts to reduce the numbers of road deaths and injuries through various initiatives that include identifying hazardous locations (black spots), introducing a road safety audit programme, strengthening legislation and attempting to influence road user behavior through social media and education, the number of deaths reported on India's roads continues to rise. Based on the national annual figures achieving any reduction in road fatalities appears to be a real challenge and reaching the ambitious 50% reduction target by 2020 extremely difficult unless major changes are made to the way the problem is tackled.

State Road Authorities in India have started to understand the benefits that safe road infrastructure can provide in reducing both the likelihood of a crash occurring and also the severity of a crash when one does occur. By systematically assessing their road networks and those corridors earmarked for upgrade the Public Works Departments (PWDs) have been able to identify where the road conditions and design is known to be high risk based on good quality road safety research from around the world (*2*).

Road safety research shows that highway design features can have a significant and lasting impact on the numbers of fatal and serious injury crashes that occur on the world's roads. Although it is widely accepted that India has many country-specific issues that add to the complexity of the road safety problem, solutions identified in one country are likely to reduce risk in another. For example, a divided road with a physical median such as a safety barrier will likely reduce head-on crashes regardless of location around the world. Removing or protecting roadside hazards such as rigid structures on high speed roads will reduce the severity of single vehicle run-off road type crashes. Roundabouts ensure lower vehicle speeds through the intersection and a reduced angle of impact when compared with a 3 or 4-leg priority junction. Providing good quality footpaths and pedestrian crossings improves safety and mobility for vulnerable road users.

1.1. Road Safety Assessments in India

In 2010 iRAP was invited by the Global Road Safety Facility (GRSF), funded with support from Bloomberg Philanthropies, to undertake the risk assessment of selected road network in four

states. The project was designed to assist the state governments of Andhra Pradesh, Assam, Gujarat and Karnataka, to assess road infrastructure-related risk on 3,000km of high-risk roads and identify economically viable road safety countermeasures for implementation under the World Bank financed upgrades (*3*).

Subsequently, GRSF invited iRAP to undertake road safety assessments across five states in year 2013. The Ministry of Road Transport and Highways (MoRTH) and State Public Works Departments (PWDs) of Andhra Pradesh, Gujarat, Karnataka, Kerala and Rajasthan have used the results to assist in the preparation of several road developments and upgrade projects to identify high-risk corridors and prioritise cost effective road safety countermeasures. Furthermore, Star Ratings for close to 2,000km of designs have also been produced and analysed as part of this project. Following the success of previous iRAP projects in India, a further 4,000km was identified for assessment across two new states with the Public Works Departments (PWDs) of Uttar Pradesh and Tamil Nadu preparing road improvement projects to be financed by World Bank loans, the results being used to help ensure that proven and cost effective road safety measures are implemented as part of these infrastructure upgrades.

Thus, more than 10,000 kms of roads and 2,000 kms of road designs have been star rated in 10 States of India till date. Through star rating of the proposed road designs, the road authorities were able to assess the potential risk to road users prior to construction and amend the designs to include the recommended engineering intervention.

2. THE METHODOLOGY

The International Road Assessment Programme (iRAP) is a registered charity with vision of "a world free of high risk roads". iRAP works with governments and non-government organisations to assess the road user risk based on infrastructure by inspecting the roads and developing Star Ratings and Safer Roads Investment Plans (SRIP). Star Ratings are simple and objective measure of the level of safety provided by road infrastructure. A star rating is assigned to each segment of the surveyed network with 1-star being the least safe or highest risk and 5-star being the most safe or lowest risk. The Star Rating risk assessment model is developed by world-leading road safety research agencies and its use is free-to-air.

The risk assessment models used today are the result of more than a decade of development work, which began in 1999 with EuroRAP and subsequently AusRAP. The current risk models were first derived in 2006 from the EuroRAP and AusRAP models to enable risk assessment of roads in low and middle income countries, where more than 90% of road fatalities occur (*4*). The research behind development of iRAP model was by leading researchers at TRL (United Kingdom), ARRB Group (Australia) and MRI Global (United States) with technical support from the World Bank GRSF (*5*).

The production of Star Ratings and SRIP involve a number of data collection, survey and analysis processes. The process begins with inspection of road infrastructure elements that are known to have an impact on the likelihood of a crash and its severity. Between 1 and 5-stars are awarded depending on the level of safety which is 'built-in' to the road. The safest roads (4- and 5-star) have road safety elements that are appropriate for the prevailing traffic speeds. The least safe roads (1- and 2-star) do not have road safety elements that are appropriate for the prevailing traffic speeds. The iRAP assessments make use of road attribute data for more than 50 variables at 100 metre intervals along a road. This data is collected and compiled through road survey

vehicle that collects digital images of the road using multi-view high-resolution cameras. After the images are collected, they are viewed so that road attributes are recorded at 100m intervals.

2.1. Risk Factors

The risk model assigns risk factors, also known as crash modification factors, to each road attribute category. The risk factors are used to calculate a Star Rating Score (SRS). The risk of road crash death or injury can be mitigated by reducing the likelihood that a crash will occur. For example, the likelihood of serious run-off road crashes occurring at curves, especially those with inadequate delineation, is higher than on straight sections of road. Hence, the likelihood of such crashes can be reduced by replacing such curves with straight sections of road. Research shows that rate of road crashes at curved road sections are 1.5 to 4 times higher than straight or gently curved road sections (*6*). The risk factors for the road attribute 'curvature' related to likelihood of run-off crash of vehicle occupant is given in Table 1 (*7*).

TABLE 1 Risk factors related to curvature

Curvature	Risk factors for Vehicle Occupant (run-off likelihood)
Straight or gently curving	1.0
Moderate curvature	1.8
Sharp curve	3.5
Very sharp	6.0

In the event of a run-off road crash at such a curve, its severity can be reduced by provision of safety barriers. The safety barrier reduces the severity of risk by absorbing impact energy and containing and redirecting such errant vehicle. The risk factors for roadside objects affecting the severity in case of vehicle run-off are shown in Table 2 (*8*).

TABLE 2 Risk factors related to roadside objects

Roadside object	Risk factors for Vehicle Occupant (run-off severity)
Tree (>=10cm diameter)	60
Downwards slope	45
Safety barrier - metal	12
Safety barrier – wire rope	9

Based on several researches carried out worldwide the risk factors affecting likelihood and severity of road crashes are being adopted for each of the road attributes. Using these risk factors for the road attributes recorded for each 100m road segment, the SRS is calculated.

2.2. Star Rating Score (SRS)

The SRS is a function of likelihood, severity, operating speed of vehicles, external flow influence factors, and median traversability for each road user type. It is produced for each road user and for each crash type as shown in Table 3 (*9*). At the end of the process, SRS for all crash types are summed up to arrive at SRS for each road user type. The SRS is a unit-less measurement and is calculated for each road user for each 100 metre segment of road length. A high star rating score equates with a high level of risk, and a low score equates with a low level

of risk. SRS is calculated based on an assessment of the road infrastructure elements that influence the main types of crashes. Separate SRS and star ratings are produced for four types of users that account for the majority of road users, (i) car occupants (ii) motorcyclists (iii) bicyclists and (iv) pedestrians. For each of these road user types, the SRS is produced for main types of crashes as shown in Table 3.

TABLE 3 Crash type for each road use for which SRS is produced

Type of road user involved in crash				
Crash type	**Vehicle Occupants**	**Motorcyclists**	**Bicyclists**	**Pedestrians**
	Run-off road	Run-off road	Travelling along road	Walking along road
	Head-on	Head-on	Intersection	Crossing road
	Intersection and access points	Intersection and accesses	Run-off road	
		Moving along the road		

The structure for equation of SRS for vehicle occupants is shown in Figure 2 (*10*)

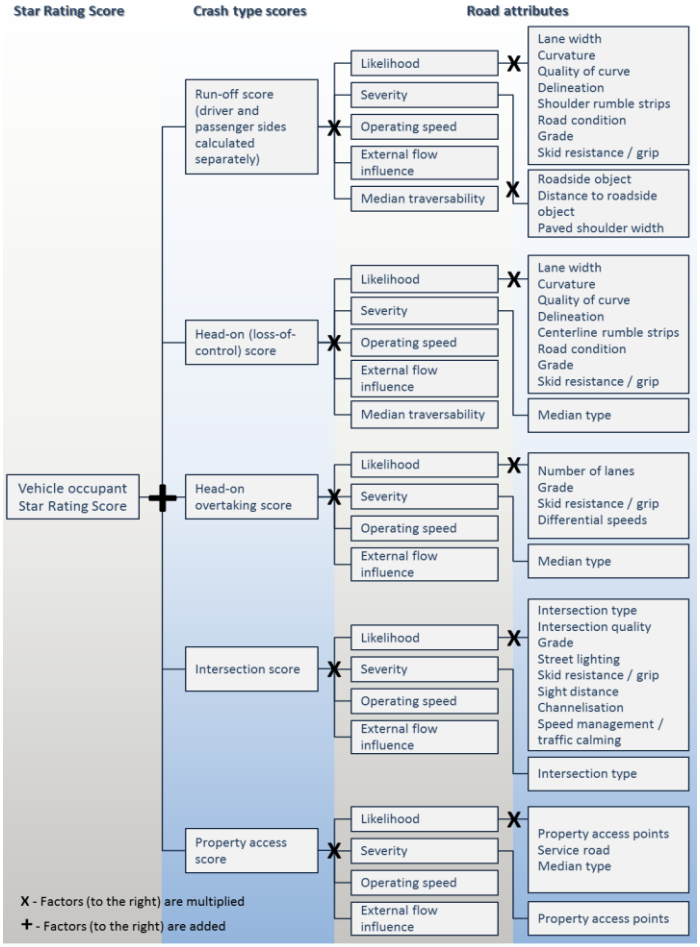

FIGURE 2 Structure of the SRS Equation for Vehicle Occupants

2.3. Star Rating Bands

Based on the SRS, each road segment of 100m is assigned Star Rating as per the bands shown in Table 4 (*11*). Separate bands are used for motorised road users (vehicle occupants and motorcyclists), bicyclists and pedestrians because their scores are calculated using different SRS equations. The Star Rating bands are uniformly adopted across the globe, so that the road infrastructure elements of two different roads in different countries/places with same Star Ratings can be compared with each other.

TABLE 4 Star Rating bands

Star Ratings	Range of Star Rating Scores (SRS)		
	Vehicle occupants and motorcyclists	**Pedestrians**	**Bicyclists**
5	0 to <2.5	0 to <5	0 to <5
4	2.5 to <5	5 to <15	5 to <15
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

2.4. Safer Roads Investment Plans (SRIP)

Based on the SRS for each 100m road segment and for each road user type, the model distributes known (or in the absence of crash data, estimated) numbers of deaths and serious injuries across the road network assessed. Using countermeasure trigger sets the model recommends countermeasure options for each 100m segment from a list of over 90 proven road safety treatments. Each countermeasure option is assessed against affordability and economic effectiveness criteria. The model recommends countermeasures based on the criteria of economic benefit. That is the estimated economic benefit from deaths and serious injuries likely to be prevented by the countermeasure should exceed the construction and maintenance cost of that countermeasure (i.e. a benefit cost ratio >1). The investment plan gives a list of affordable and economically sound road safety treatments, specifically tailored to reduce risk on the assessed road corridors. Each proposed countermeasure is supported by strong evidence that, if implemented, it will prevent deaths and serious injuries in a cost-effective way.

3. RESULTS

The risk assessment of 10,444 kms road network across 10 States in India demonstrate that there is potential to improve the safety of road design by improving road infrastructure for all the four groups of road users. It is estimated that 75,900 deaths and serious injury occur on these roads each year costing over INR 170 billion annually.

3.1. Using Star Ratings to measure risk

The risk assessment results show that 75% of the total length assessed is rated as 1-star and 2-star (out of possible 5-stars) for vehicle occupants, 82% is rated as 1-star and 2-star for motorcyclists, 85% is rated as 1-star and 2-star for pedestrians, and 72% is rated as 1-star and 2-star for bicyclists (refer Figure 3).

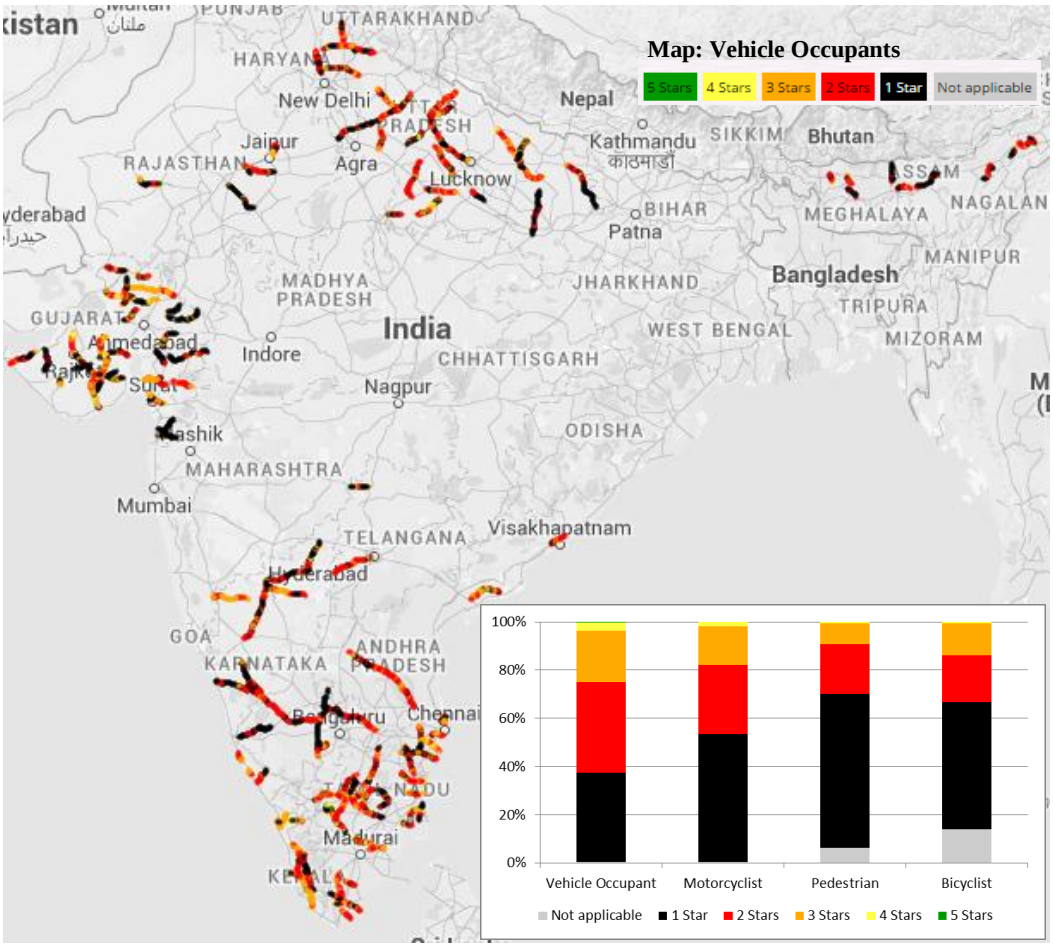

FIGURE 3 Star Ratings of roads assessed in India

Major safety hazards observed in the assessment are as below:

- 97% of road length doesn't have formal footpath, though significant pedestrians are present particularly in the urban/town areas and rural villages
- 73% of the road length has poor delineation and 93% of road length where vehicle operating speeds are 80km/h or more is single carriageway with no physical median
- 80% of road length has hazardous road side objects near the road edge (within 5m) without any protection to the flow of traffic
- More than 17,900 intersections were recorded (an average of 1.7 per km). 93% of these are unsignalised 3-leg or 4-leg intersections with no protected turn lanes
- Although bicyclists and non-motorized vehicle users are present across much of the network, there are no bicycle facilities and 68% of the roads have no paved shoulder
- Despite a high proportion of motorcycles and other powered two- and 3-wheelers there are no motorcycle facilities

3.2. The Investment Plan

The investment plan shows a list of affordable and economically sound road safety treatments, specifically tailored to reduce risk on the corridors assessed in 10 states of India. Each

countermeasure proposed in the SRIP is supported by strong evidence that, if implemented, it will prevent deaths and serious injuries in a cost-effective way. The benefits of implementing the safety treatments were calculated by estimating the number of deaths and serious injuries likely to be prevented. The cost of implementing safety treatments were derived from the engineering design cost estimates. The economic analysis was carried out for 20 years analysis period and for estimating the Net Present Costs and Benefits, a discount rate of 12% was used.

The economic cost of a death and serious injury

The economic cost of a death for this study was adopted as 70 times per capita GDP of the country and that of a serious injury was adopted as 25% of cost of a death (*12*). On this basis:

- the economic cost of a death is estimated to be 70 x INR 89,329 = INR 6,253,030
- the economic cost of a serious injury is estimated to be: 0.25 x INR 6,253,030 = INR 1,563,258

Based on the recorded road deaths per year on the entire road network assessed in India the economic cost of road deaths and serious injuries is a staggering INR170 billion per year.

Countermeasure costs

The construction and maintenance costs for each of the 93 countermeasures, considered in the development of the investment plan, were based on estimates calculated by road design consultants who were then working with the various state road authorities. The estimated costs were categorised by area type (urban and rural) and costs (low, medium and high), based on the extent to which the surrounding land use and physical environment impacts upon the construction cost of major works.

Safety treatments and economic analysis

The investment plan (summarized in Table 5) shows that a 20 year investment of INR 260 billion (US$ 4 billion), in implementing over 70 safety treatments, has the potential to prevent over 875,000 fatalities and serious injuries (FSIs) over a 20 year period, or over 43,000 FSIs each and every year. Using the estimated economic cost of road deaths and serious injuries, the total present value of the safety benefits in terms of crash costs prevented is calculated to be INR 700 billion (US$ 11 billion), giving a benefit to cost ratio of 2.7.

TABLE 5 Summary of investment plan (20yrs) for road network surveyed in India

Total FSIs Saved	Total PV of Safety Benefits	Estimated Cost	Cost per FSI saved	Program BCR
878,000	INR 700 billion	INR 260 billion	INR 315,000	2.7
	US$ 11 billion	US$ 4 billion	US$ 4,850	

The detailed list of safety treatments shown in the investment plan suggest that significant safety improvements can be made to the surveyed road network through the implementation of several key route safety and mass action treatments. Where traffic volumes are highest, treatments such as carriageway duplication (the construction of additional lanes to create a dual carriageway), 2+1 arrangements and overtaking lanes with some form of physical median to prevent head-on collisions are estimated to prevent 223,500 FSIs over a 20 year period. Provision of footpath and crossing facilities for pedestrian is likely to prevent 82,000 FSIs over a 20 year period. Details of top 8 safety treatments by FSIs likely to be saved are shown in Figure 4.

FIGURE 4 Investment Plan - recommended treatments and economic details

Full details of each recommended countermeasure, including location description, geo-reference data and economics is freely available within ViDA, the iRAP online software, so that the state road authorities, design consultants and other stakeholders can access and utilize the results to improve the safety features included in planned upgrades. The database and results of risk assessment is helping to improve safety at the planning and design stages to ensure that no more high risk roads are being built.

3.3. Star Rating of Road Designs

There is a growing international agreement on the need to provide roads that are more forgiving of user error and that provide greater protection when mistakes are made. The Commission for Global Road Safety has recommended that 'desired design speeds for new roads should be subject to achieving minimum safety ratings' and the UN Secretary General has recently called for appropriate star rating targets for the highest volume 10% of roads in each country and the adoption of minimum 3-star standard and road safety audits for all new road construction (*13*).

Star Ratings can objectively quantify the level of risk associated with new road designs and provide a platform to make evidence-based improvements during preliminary and detailed design stage (*14*). The state road authorities of Assam, Gujarat, Kerala, Uttar Pradesh, and

Karnataka have all used the star rating risk model at design stage to help make informed, evidence-based decisions on design options. By star rating the proposed designs, the state road authorities could assess the potential risk to road users prior to construction and amend the designs to include recommended treatments that are proven to reduce the likelihood and severity of road crashes. Under this process the preliminary designs prepared by the road design consultants were star rated and more safety features, that were economically viable, were included in the final version of design. The process involved updating baseline road attributes to reflect the design features and processing the data to generate projected star ratings and identify additional safety treatments which could be included in the design. An illustrative risk worm produced for vehicle occupants on Mehsana-Himmatnagar State Highway in Gujarat is shown in Figure 5 below comparing the baseline star rating score for the existing road with the projected star ratings based on the proposed design.

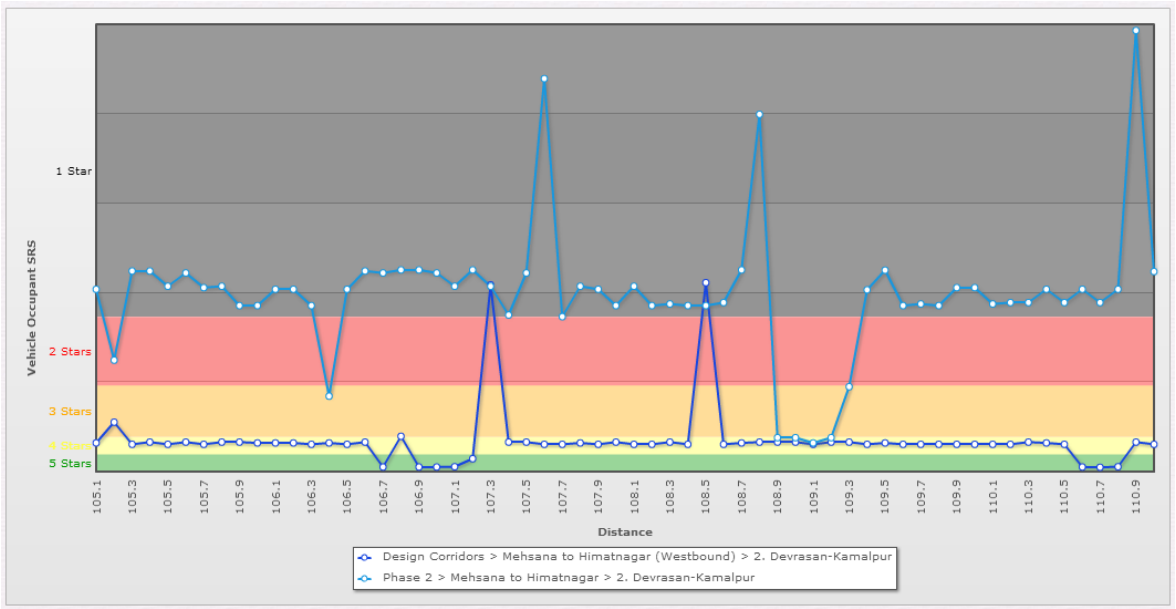

FIGURE 5 Risk worm showing SRS comparison of the baseline (light blue) and proposed design (dark blue) on Mehsana-Himmatnagar State Highway, Gujarat

4. ASSESSMENT OF GQ AND ESTABLISHMENT OF INDIARAP

The Golden Quadrilateral (GQ) – a series of national highways totaling 5,846 km connecting Mumbai, Delhi, Chennai, and Kolkata – is the most strategic set of corridors in India in terms of linking major cities, ports, and industries. The GQ is in the final stages of being upgraded to six lanes on all four legs. In anticipation of the road safety implications, the World Bank and the iRAP are assessing the existing conditions of two legs – an effort that will produce star ratings and recommendations for enhancing infrastructure. Based on the anticipated success of the partnership, the Ministry of Road Transport and Highways is planning to establish a systematic approach to improve safety infrastructure provisions across the entire national highway network. A locally established road assessment program, IndiaRAP, will play an important role alongside all the pillars of road safety to drive policy, investment and action and ultimately save lives. IndiaRAP will involve research and educational institutes to further develop the iRAP model for local Indian conditions.

5. CONCLUSION

The road assessment program in India covering over 10,000km of State and National Highways across 10 States, has demonstrated that there is potential to improve the safety by providing safe road infrastructure for all the four groups of road users. The safe road treatments, suitable to local conditions, recommended under this program suggest a potential saving of more than 40,000 deaths and serious injuries each year which would result in crash cost savings of close to INR 100 billion each year. Star Rating the design of roads being taken up under various state road improvement program is helping the state road authorities and design consultants to assess the potential risk to road users prior to construction and amend the designs to include recommended treatments that are proven to reduce the likelihood and severity of road crashes. States like Karnataka and Gujarat have adopted safe corridor demonstration projects under World Bank funding which includes setting a policy level target of designing the road with minimum 3-star ratings for all road users. Construction is underway to upgrade and rehabilitate many of the roads with an estimated 58% reduction in fatal and serious injuries form infrastructure improvements alone. Combined with a coordinated effort to improve police enforcement of road rules; improving road user behavior such as speed limit compliance, seat belt and helmet wearing rates and reducing alcohol use; improving the safety of the vehicle fleet; the systematic assessment and investment in road safety countermeasures across the country will contribute greatly to reducing the death toll on India's roads and will help to meet future road safety targets.

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