ROAD SAFETY RISK MAPPING USING STRUCTURED DATA

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ABSTRACT

Risk is a function of potential hazards identified by audit or elaborate safety assessment using standard RAP (Road Assessment Programme) used around the world. With detailed crash and traffic data, risk map can give objective assessment of the fatal and serious injury accidents in the network, which actually captures the combined risk of the interaction of all road users with the road environment. Therefore, emphasis of risk mapping is on identifying the high-risk routes/segments in the network, which can be treated proactively with enhanced safety measures to minimize/eliminate the risks. Thus, preparation of risk maps requires data-led investigation and analysis to identify blackspots or stretches with repeated occurrence of crashes, and their patterns. Such risk mapping leads to recommendations of engineering interventions. In developing countries the detailed crash data are seldom available and detailed assessment of the infrastructure is often used as an alternative to identify potential risks. Star Rating of roads for safety, based on iRAP methodology, is one such tool to measure infrastructure related risk for road users, which is now-a-days being used also in developing countries. This paper addresses different techniques for risk mapping with examples.

INTRODUCTION

Risk mapping is the process of identifying, quantifying and prioritizing the risks that may interfere with the achievement of objectives of any project. The aim of risk mapping is to arrive at a clear set of action plans that improve risk management controls, in areas where these are necessary and help the management of resources to eliminate or reduce the impact of these risks. Such mapping based on structured data, in case of road projects, depicts where road users are likely to be killed or seriously injured on a road network and where their risk of potential crash is high. The traditional approach of mapping the risk for a road network (or a section of road) is to analyze the historic crash data and relate the pattern of crashes to road features. Lately the road safety experts around the world have developed procedures to measure or assess the road infrastructure risk, where crashes are likely to occur rather than depending on the past crash pattern.

RISK MAPPING BASED ON HISTORIC CRASH DATA

The process involves collection of crash data, analyzing the data to identify the pattern of crashes and correlating it with the ground features. A detailed list of the crash data, which is necessary to establish a pattern and thereby to identify blackspots, is given below.

1. Crash Data
   I. Crash identification (a unique number-based system)
   II. Time and location of crash
   III. Crash type and vehicles involved
   IV. Crash consequences (fatalities within 24 hours/30days, injuries, property damage, etc.)
2. Road and Traffic Data
   I. Geometric details of crash site
   II. Road surface condition and delineation at the site
   III. Roadside hazards
   IV. Visibility and weather conditions
   V. Traffic control at the site
   VI. Position of crash – travel direction/location - traffic lane, shoulder, roadside, etc.
   VII. Main cause(s) of crash – speeding, overtaking, right of way, etc.
3. Additional Data
   I. Driver details
   II. Impairment and condition of the driver
   III. Use of restraint devices
   IV. Road use behavior of the persons/drivers involved in crash
   V. Vehicle license plate number
   VI. Vehicle operator (private, commercial, public transport, etc.)
   VII. Emergency service involvement

The crash data for minimum past 3 years is analyzed to identify frequent occurrence spots of crashes or blackspots. This is followed by detailed observation or safety audit of the blackspots and the correlation of observed pattern of crashes with the ground features. The process is depicted in the form of flowchart below.

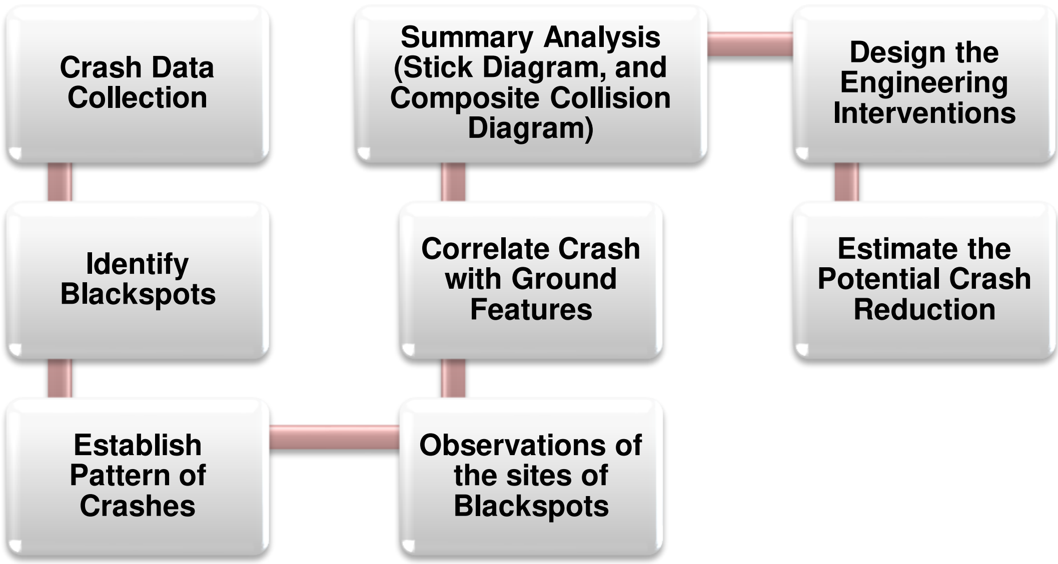


Figure 1: The process of risk mapping based on historic crash data

<u>Case study – Blackspot Improvement in the Hill State of Himachal Pradesh, India</u>

Each year more than 1000 people get killed on roads in the State of Himachal Pradesh. Most of the roads are hill roads in this State and lack in minimum safety infrastructure, e.g. delineation, crash barriers on the valley side of road, and traffic calming devices. The State road authority had identified 500+ frequent crash sites based on past data and wanted to take up engineering measures on sites where most frequent crashes were occurring.

The crash sites were screened based on severity index. The severity index for each site were worked out by assigning 10 points to each fatal crash, 6 points to each crash involving grievous injury, and 3 points for minor injury crash. Each site was assigned points based on the above criteria and top 50 sites are chosen for further prioritization by verifying the sites. Using the detailed data of road geometry of the 50 sites, and considering the strategic importance of the routes a quantitative framework was developed for prioritization in a structured manner. The indices for quantitative assessment of these 50 sites with their scale of score are given below.

Table 1: Indices and their scores adopted for prioritization of blackspots

(A) Scope of Improvement		**(B) Route Weightage Index**	
Scope of Improvement	Score	Road Classification	Score
High	30	National Highway	20
Medium	20	State Highway	15
Low	10	Major District Road	10
NIL	0	Village Road	5
(C) Severity Index			
Crash Classification		Score	
Fatal crash		10	
Grievous injury crash		6	
Minor injury crash		3	

With the above indices the 50 sites were ranked and top 20 were chosen for detailed design of engineering measures to reduce number of crashes. For rest of the 30 sites safety countermeasures were suggested which may be taken up at later stage for detailed engineering and implementation. Fig. 2 shows the 50 sites and prioritized 20 sites.

<u>Limitations of Risk Mapping based on Crash Data</u>

This approach of risk mapping requires detailed crash data which may turn up to be a limitation on its application as developing nations do not have system in place for collection of comprehensive crash data. A study conducted in New Zealand revealed that more than half of fatal chases occurred at locations where no other crashes had occurred in the previous five years *(Blair T. and Roper P.).* The study also revealed that, in Australia only 2/3rd of all serious injury crashes are recorded in the crash database. Thus, it is evidential that the aim of any such exercise should be the assessment of infrastructure risk rather than only treating blackspots.

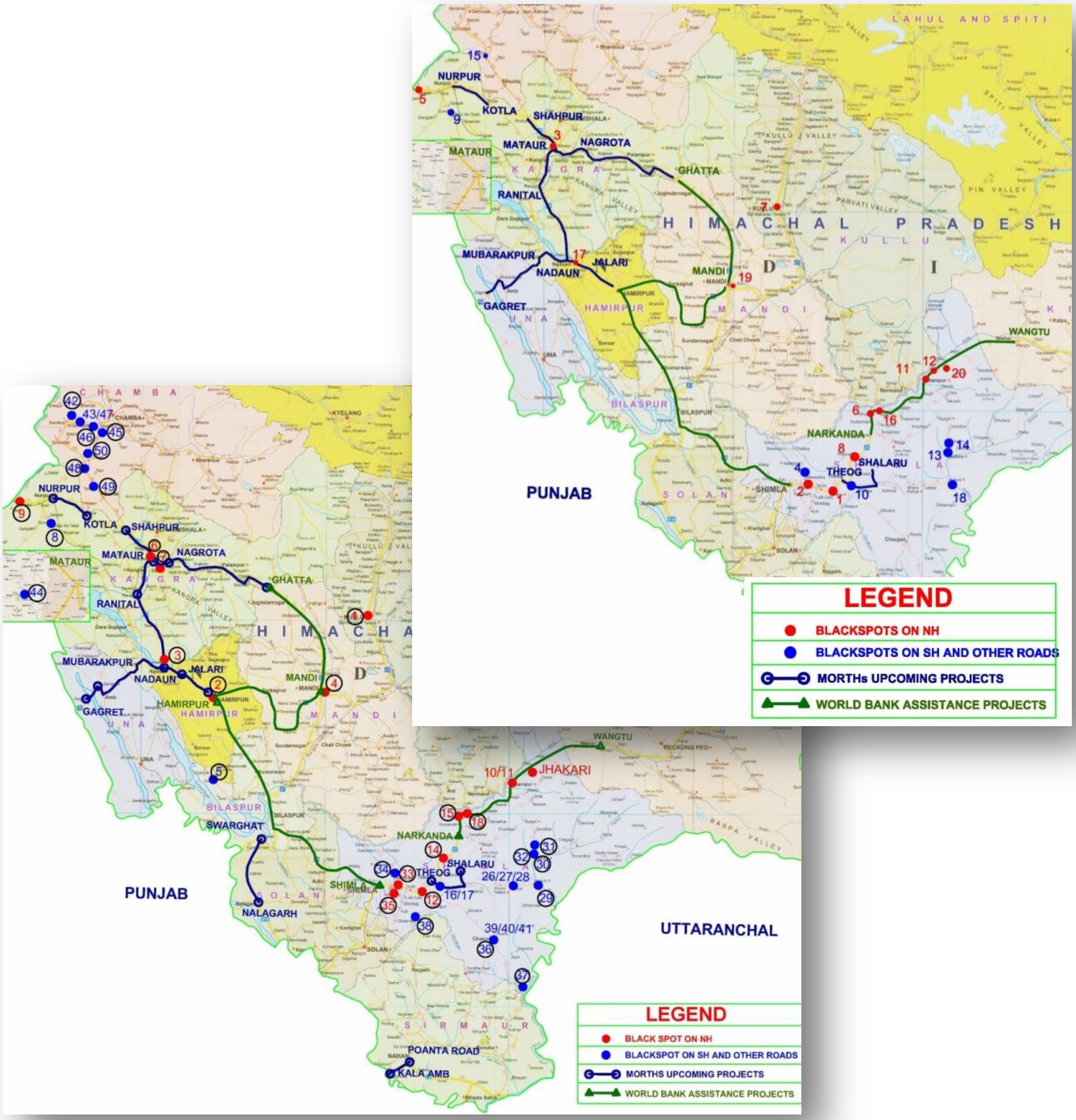


Figure 2: Blackspots on the roads in Himachal Pradesh. (a) 50 sites with frequent crashes, and (b) 20 major blackspots

RISK MAPPING BASED ON AUDIT OR ASSESSMENT OF INFRASTRUCTURE

Road safety audit (RSA) is a formal examination of an existing or a new road or a traffic project, which is yet another way of risk mapping. With detailed observation and assessment of the existing or planned road infrastructure, the crash potential and safety performance are measured. Thus, the RSA is also an important input to the design process. In RSA the following road infrastructure parameters are assessed by visual inspection and critical sites are identified where crash risk is high.

- Geometric Design

- Operational Characteristics
- Road Signs, Markings and Delineation
- Road Furniture and Appurtenances
- Provisions for VRUs
- Traffic Management, both in day and night
- Road Works and Maintenance

The assessment of road features combined with past crash data (if available) puts each site or stretch of road assessed in the appropriate cell of the risk matrix as shown in Fig. 3 to prioritize the treatment action.

Frequency / Severity	Frequent	Probable	Occasional	Improbable
Catastrophic	Intolerable	Intolerable	Intolerable	High
Serious	Intolerable	Intolerable	High	Medium
Minor	Intolerable	High	Medium	Low
Limited	High	Medium	Low	Low

Figure 3: The risk matrix

Case study: Road Safety Audit of SH-24 Odisha, India

The map showing risk assessment of SH-24 which passes through hill and built-up area in the plain is shown in Fig. 4 with the summary of risk assessment.

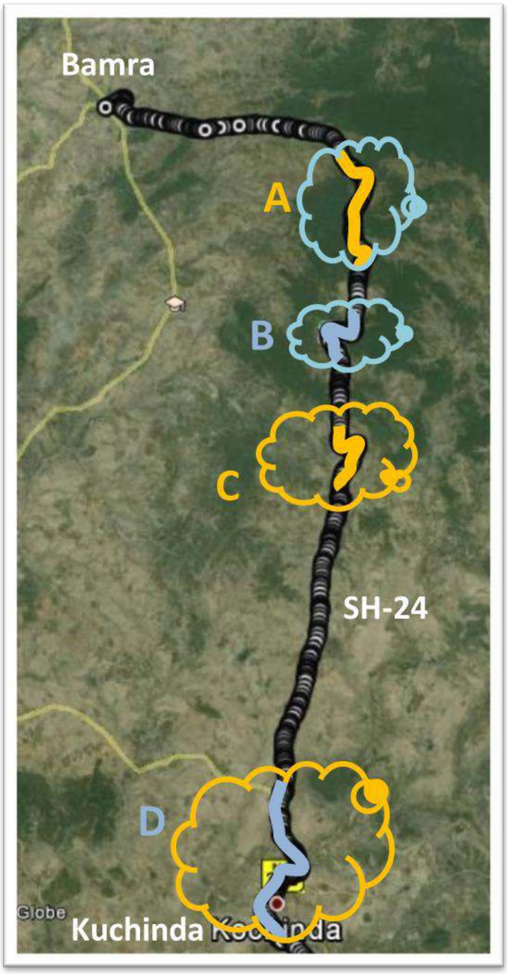


Figure 4: Risk assessment of SH-24

Hill road in forest area

- Series of sharp horizontal curves and bends
- **A:**
  - No delineation and edge protection
  - Risk of fatal and major injury to vehicle occupants high
- **B:**
  - Delineation, but no edge protection
  - Risk of fatal and major injury to vehicle occupants medium

Built-up Area

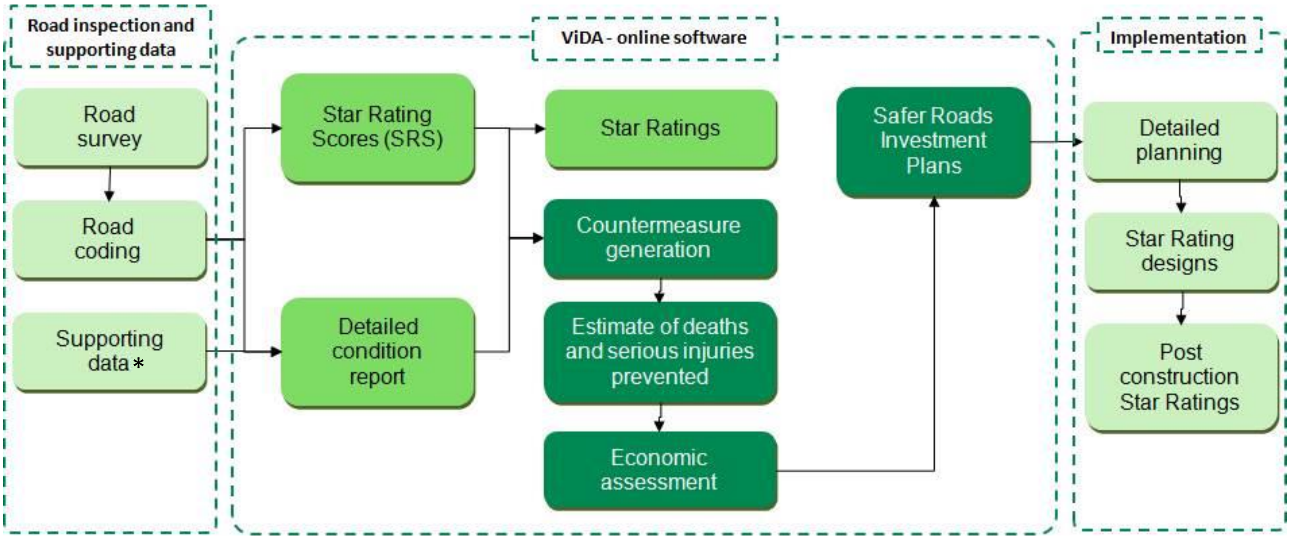
- **C:**
  - No facilities for VRUs
  - High speed traffic, no traffic calming measures
  - Risk of fatal and major injury to pedestrian and bicycles high
- **D:**
  - Footpaths, but no crossing facility for pedestrian
  - Medium speed traffic, traffic calming measures at few places
  - Risk of fatal and major injury to pedestrian and bicycles medium

ROAD ASSESSMENT PROGRAMS, RAP (CONDUCTED BY IRAP[1])

Road Assessment Program (RAP) Star Rates the roads based on the measured infrastructure related risks. iRAP (International Road Assessment Program) does the assessment in low and middle income countries, generates Star Ratings and Safer Roads Investment Plans (SRIP) suggesting countermeasures to reduce number of deaths. The high income countries like USA and Australia are also extensively using RAP for managing the risks for their road networks. The overall methodology of producing Star Ratings and SRIP is shown in Figure 5. This involves a systematic data collection surveys and analysis processes. The iRAP assessments make use of road attribute data for more than 50 variables at 100 meter intervals along a road. Thus, the data collection task is significant. This data is compiled through road surveys that collect digital images of the road using multi-view high-resolution cameras as driven along the road. After the images are collected, they are viewed by trained coders using specialized software in the office to record the road attributes.

[1] International Road Assessment Program is a registered charity dedicated to saving lives through safer roads. For more information visit www.irap.org

The coded road data is processed using globally consistent models to produce Star Rating and SRIP. Each road segment of 100m is allocated to one of the five Star Rating bands separately for vehicle occupant, motorcyclist, pedestrian and bicyclist. The system reflects typical international practice of recognizing the best performing category as 5-star and the worst as 1-star. When plotted on a map the color coded star rating of road depicts the infrastructure related risk and likelihood of crash.



Source: Star Rating Roads for Safety, the iRAP Methodology
**Traffic Volumes (AADT), Operational Speed, Number of reported Road Crash Deaths in a year, and Construction cost of engineering treatments.*

Figure 5: The iRAP road survey, coding, Star Rating and Safer Roads Investment Plan process

Case study: Star Rating of Delhi Border – Panipat Section NH-1 in the State of Haryana, India [2]

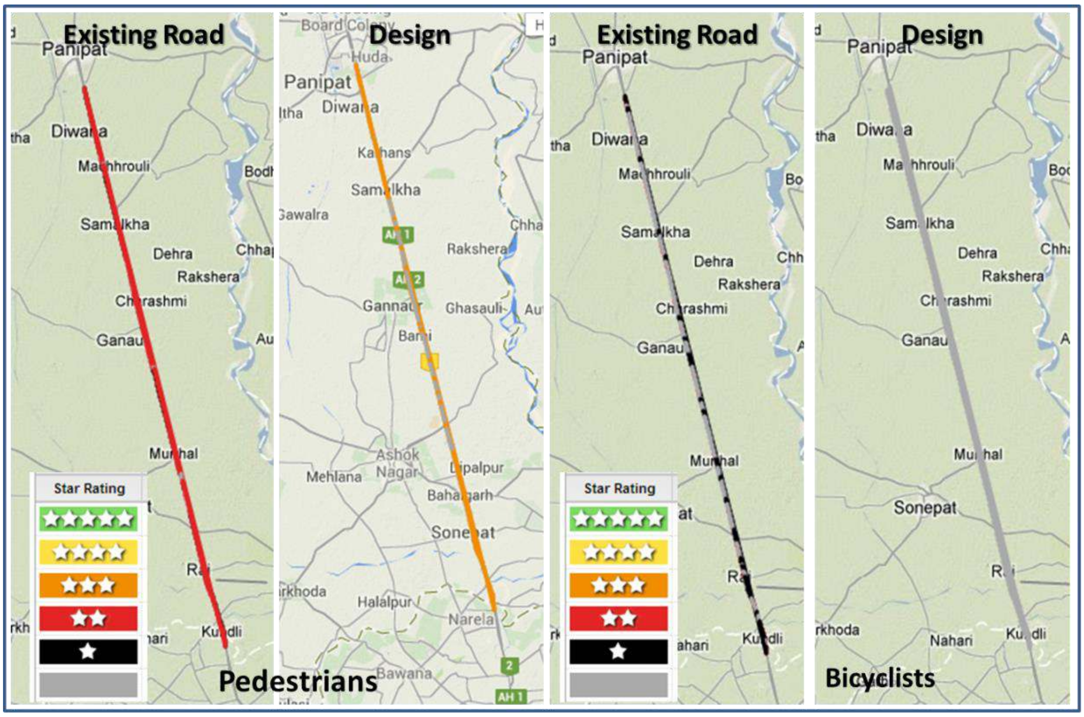
As part of efforts to prevent road deaths and serious injuries, the National Highway Authority of India (NHAI) and the World Bank created the 'Safer-Greener Highways Pilot', to develop a 'model road' (of 56 km length) that has safety standards that are comparable to those in high-income countries. iRAP Road Protection Scores and Star Ratings based on a detailed inspection and assessment done for this road section indicate that the road is constructed reasonably well for vehicle occupants, with a significant proportion of the road rating as 4-stars for vehicle occupants. However, the road does not cater well for vulnerable road users, especially pedestrians and bicyclists, and much of its length rates within the 1 and 2-star category for these vulnerable road users. Based on the countermeasures suggested by SRIP to reduce number of deaths and serious injuries on NH-1, a detailed study was conducted to design the engineering treatments. The design study identified additional treatments based on detailed investigations of traffic conditions, existing and potential land use developments in the vicinity of the road, and extensive public consultations. The countermeasures included improved delineation of the entire road stretch, construction of grade separated intersections, better crossing facilities for

[2] Safer Greener Highways Pilot, October 2010 and Detailed Project Report (DPR) for Safer-Greener Highway on NH-1, May 2013

pedestrians including foot-over bridges, footpaths with fences, and service roads in urban sections. The Star Ratings and Star Rating Maps for both the baseline and recommended design of countermeasures are given in Table 2 and Figure 6 respectively.

Table 2: Star Rating of NH-1, comparison of Baseline vs. Design

Star Ratings	Vehicle Occupant		Motorcycle		Bicycle		Pedestrian	
	Baseline	Design	Baseline	Design	Baseline	Design	Baseline	Design
5 Stars	0%	1%	0%	3%	0%	0%	0%	0%
4 Stars	60%	71%	23%	75%	0%	0%	0%	0%
3 Stars	24%	27%	49%	22%	0%	0%	0%	63%
2 Stars	15%	1%	25%	0%	14%	0%	49%	0%
1 Star	2%	0%	3%	0%	14%	0%	44%	0%
Not applicable[3]	0%	0%	0%	0%	72%	100%	7%	37%



[3] Star Ratings are not produced for sections where road user type is not present or no risk involved – risk assessment is not done in such road sections – but risk may be involved

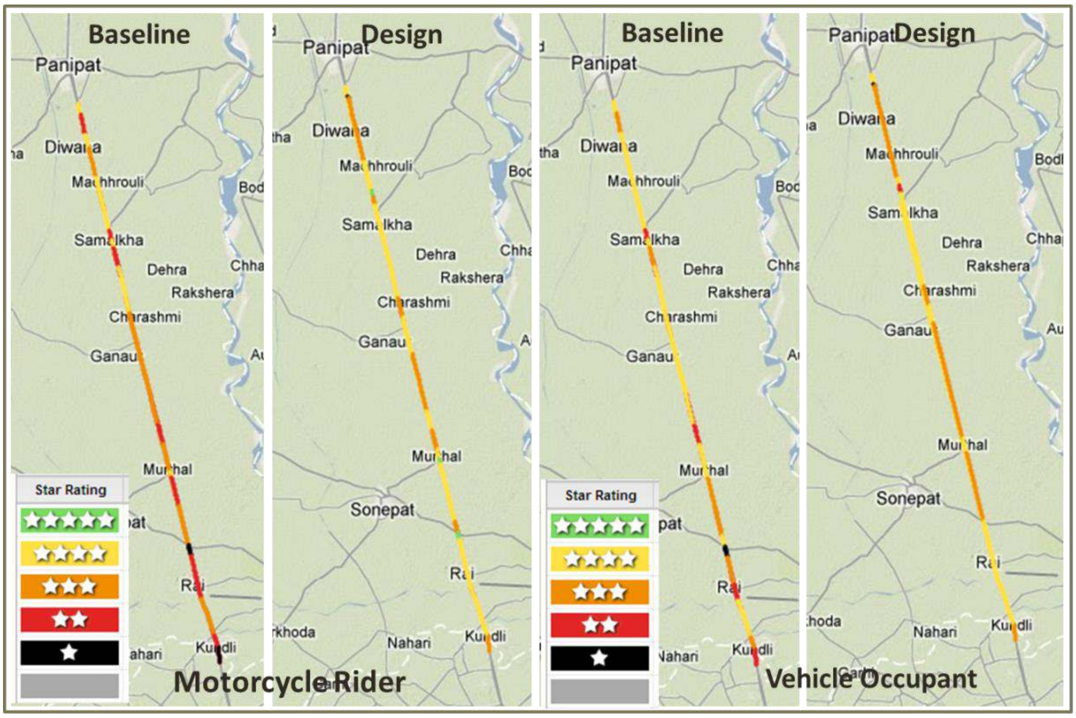


Figure 6 Star Rating Maps of NH-1, Comparison of Baseline vs. Design

Implementation of the countermeasures recommended by SRIP and detailed design study together are likely to reduce the existing number of deaths from 213 to 109 in a year and similarly in serious injuries, resulting into a huge economic benefit.

CRASH DATA IN DEVELOPING COUNTRIES

The crash data in developing countries is collected by police officers as an adjudication record. Vital information on exact crash location, road geometry and condition, etc. is missing from the data and thus incomplete, for any scientific crash investigation. Also, the management and mechanism to share the available data with other stakeholders is also missing. Further, any of the three methods described in this paper for risk mapping, when applied to the road network of developing or developed countries alike, need the comprehensive crash data for calibration and validation of the method. Also, the crash modification factor is estimated based on the KSI (killed and serious injury) crashes saved by a designed countermeasure, which is not possible without systematic crash data collection.

A tablet based application tool **(RADaR – Road Accident Data Recorder)** to record comprehensive crash data, including the GPS coordinates of crash location and other vital information, has been developed by IRF. It is a user friendly software application loaded on to tablet computer working on ANDROID operating system. It facilitates recording of the crash data through drop-down menus using touch screen mode and also facilitates taking photographs or video of crash scene. RADaR also provides cloud-based central server facility for storing the crash database. The data for each Police Station can be recorded through RADaR, managed and maintained separately, so as to provide access to the different users hierarchically for their jurisdictions – from a Police Station or even at the highest level of the country as a whole. It also provides a reporting tool to generate cross classified tables, graphics and maps for further analysis using the database, such as,

- Road type
- Road surface condition
- Weather condition
- Gender Distribution
- Age distribution
- Vehicle type
- Crash location
- Crash time
- Collision type
- Severity type
- Many others

CONCLUSIONS

Whereas, risk mapping based on crash data gives an opportunity to identify blackspots and spot remedial measures to avert more such crashes at these sites, mapping of infrastructure related risk gives an opportunity to identify sites with potential risks, where crashes are likely to occur. Due to lack of comprehensive or location based crash data in developing countries, it is not possible to relate or validate the risk assessment models in these countries. With help of RADaR the creation of comprehensive crash database will surely open an era of road crash research in developing world.

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