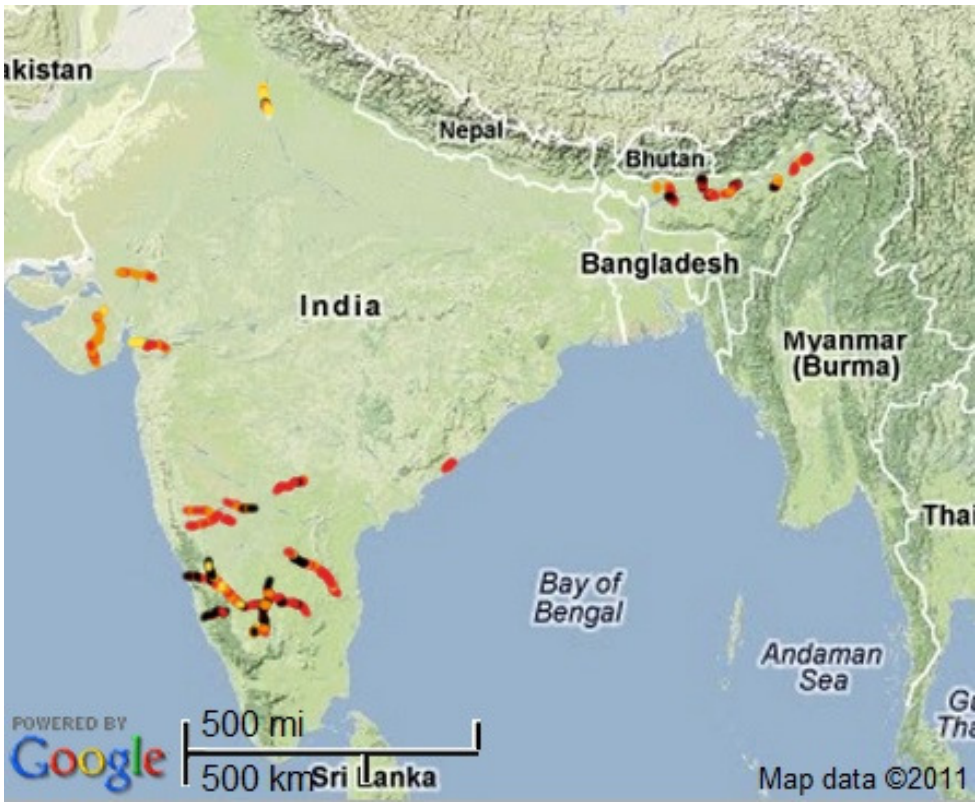
iRAP
INTERNATIONAL ROAD ASSESSMENT PROGRAMME

International Road Assessment Programme

A WORLD FREE OF HIGH RISK ROADS

iRAP India Four States Road Safety Report



सत्यमेव जयते

India Fast Facts	
Population	1,189,172,906
GDP per Capita	Rs 70,220
Road Network	3320410km
Fatalities (2009)	125660
Serious Injuries (2009)	515458
Est. Crash Cost	Rs 322,186,309,712
Traffic Mix	Cars and utility 12%, Trucks and buses 5%, Motorcycles 82%, 3-wheelers (auto's) 2%

iRAP India Four States Project
Technical Report

Bloomberg Philanthropies

GRSF
Global Road Safety Facility

About iRAP

The International Road Assessment Programme (iRAP) is a registered charity dedicated to saving lives through safer roads.

iRAP works in partnership with government and non-government organisations to:

- inspect high-risk roads and develop Star Ratings and Safer Roads Investment Plans
- provide training, technology and support that will build and sustain national, regional and local capability
- track road safety performance so that funding agencies can assess the benefits of their investments.

Road Assessment Programmes (RAP) are now active in more than 70 countries throughout Europe; North, Central and South America; Africa and the Asia Pacific region.

The International Road Assessment Programme (iRAP) has drawn upon the extensive knowledge base of established Road Assessment Programmes (EuroRAP, AusRAP and usRAP), with the generous support of the FIA Foundation, Global Road Safety Facility and the Road Safety Fund, to target high-risk roads where large numbers of people are killed and seriously injured and inspect them to identify where affordable programmes of safety engineering can reduce death and injury.

Regional development banks, national governments, automobile clubs and associations, charities, the motor industry and institutions such as the European Commission also support RAPs and encourage the transfer of research and technology to iRAP. In addition, many individuals donate their time and expertise to support iRAP.

For more information

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To find out more about the programme, visit www.irap.org. You can also subscribe to 'WrapUp', the iRAP e-newsletter, by sending a message to icanhelp@irap.org.

iRAP502.15: 19 December 2011

Document Version History

Version	Date	Description
iRAP502.15	19 December 2011	Document created.
iRAP502.15v2	29 March 2012	Updated to include Star Rating maps, reference to the KSHIP Star Rating Road Designs Report, JP Research Baseline Data Report and other minor amendments.
iRAP502.15v3	18 April 2012	Amended to include a list of acknowledgements.

1 Executive Summary

In a reflection of the significant social and economic impact of road crashes worldwide, the United Nations has declared 2011-2020 the Decade of Action for Road Safety. It is expected that during the decade, significant efforts will be made to stabilise and then reduce the death toll through systematic improvements in road infrastructure, road user behaviour and vehicle safety.

Globally 2-3% of GDP is lost through crashes, with road deaths and serious injuries costing the Indian economy an estimated US$65.4 billion per year.[1] The latest figures show that 125,660 people lost their lives on India's roads in 2009, however some estimates suggest that the death toll could be closer to 200,000 per year – an average of 550 lives lost every single day.[2] India accounts for 15% of the world's road fatalities, although it has just 1% of the world's motor vehicles.

To help reduce the risk of death and serious injury on the Indian road network, iRAP was invited by the Global Road Safety Facility (GRSF), funded with support from Bloomberg Philanthropies, to undertake what has become known as the iRAP India Four States Project. The project was designed to assist the governments of four Indian states: 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.

This report provides an overview of the project, including details on data collection, the methodology used and a summary of the results. It is accompanied by a series of short reports which provide additional details on road corridors in the states. The focus of the project was on national and state highways, which account for two-thirds of road deaths in India but represent just 10% of the nation's 3.3 million kilometre road network.

The infrastructure-related risk assessment involved detailed surveys and coding of 50 road attributes at 100 metre intervals along the network and creation of Star Ratings, which provide a simple and objective measure showing the level of risk on the road network. The assessment found that 72% of the 3,000km surveyed is rated 1- or 2-stars (out of a possible 5-stars) for vehicle occupants; 88% is rated 1- or 2-stars for motorcyclists; 55% is rated 1- or 2-stars for bicyclists; and 81% is rated 1- or 2-stars for pedestrians. None of the network achieved a 5-star rating and less than 10% achieved a 4-star rating for vehicle occupants and motorcyclists.

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[1] Calculation uses Indian road deaths (point estimate) from World Health Organisation, *Global Status Report on Road Safety. Time for Action*, 2009 and methodology as explained in K. McMahon and S. Dahdah, *The True Cost of Road Crashes: Valuing life and the cost of a serious injury*, iRAP, 2008.

[2] Point estimate of 196,445 road deaths in India (2007), World Health Organisation, *Global Status Report on Road Safety. Time for Action*, 2009, p.243.

Star Ratings by road user

Road user	5 Star	4 Star	3 Star	2 Star	1 Star	Not rated
Vehicle occupants	0%	7%	21%	51%	21%	0%
Motorcyclists	0%	4%	8%	40%	48%	0%
Bicyclists *	0%	0%	1%	35%	20%	44%
Pedestrians*	0%	0%	1%	81%	0%	18%

* Star Ratings are not produced for sections of road where there is no road user activity recorded.

The road attribute data shows that the majority of the survey was conducted along a two-lane, single carriageway rural network, with very little physical separation between opposing flows. Roadside hazards are numerous, with most of the survey length having hazardous objects within 5m of the running lane and limited road side protection. Provision for vulnerable road users is poor with no motorcycle or bicycle facilities present and insufficient footpath provision and crossing facilities where pedestrian numbers are high.

The project also involved the creation of Safer Roads Investment Plans, which draw on more than 70 proven road safety treatments, ranging from low cost road markings and pedestrian refuges to higher cost intersection upgrades and full highway duplication. The analysis found that a combined investment for the four states of 27 billion rupees would prevent almost 125,000 deaths and serious injuries and save close to 120 billion rupees in crash costs avoided. This represents a 40% reduction in deaths and serious injuries based on current estimates.

Safer Roads Investment Plan summary

India Four States Project	Indian Rupee	US$*
Road length	3,020km	
Investment	27,000,000,000	513,000,000
Economic benefit (20 years)	119,500,000,000	2,270,000,000
Benefit cost ratio (bcr)	4.4	
Deaths (per year)		
Before countermeasures	1,419	
After countermeasures	854	
Prevented	565	
Deaths and serious injuries (20 years)		
Before countermeasures	312,077	
After countermeasures	187,879	
Prevented	124,198	
Reduction	40%	
Cost per death and serious injury prevented	217,500	4,130

*Conversion rate used: 1 INR = 0.019 USD (19.12.2011)

The provision of training and technical support for road authority staff in each of the four participating states was delivered to maximise the potential benefits of the iRAP results, to build road safety capacity within each road authority and to ensure that the recommended treatments were included in the planned rehabilitation works where appropriate. The setting of minimum Star Rating targets and the Star Rating of new road designs were key features of the project and should be considered for inclusion in future road assessments.

Acknowledgments

The iRAP India Four States project would not have been possible without the direct support of numerous people and organisations. These include:

- Premchand Reddy, Andhra Pradesh Transport Commissioner
- Mr Reddy, Chief Engineer, Andhra Pradesh Road Development Corporation
- Phanindra Prasad, Andhra Pradesh Road Development Corporation
- K.C.Hazarika, Chief Engineer, PWD, Assam
- Diganta Goswami, Asst.Executive Engineer, PWD, Assam
- Nayan Jyoti Barman, Niren Baruah and Mr Chaudhary, PWD, Assam
- R.K.Chauhan, Chief Engineer, Roads & Buildings Dept., Gujarat
- Samir Raval, Dy. Executive Engineer Roads & Buildings Dept., Gujarat
- Mr Rohit, BJ Bhatt & Ms Chitra, Gujarat Engineering Research Institute (GERI)
- B.Naganjaneyulu, Deputy General Manager (Highways), LEA Associates South Asia Pvt. Ltd.
- K.B.Kulkarni, Deputy Secretary to Government, Govt. of Karnataka
- B.H.Anil Kumar, Managing Director, Karnataka Road Development Corporation Ltd. (KRDCL)
- H.S.Prakash Kumar, Project Director, Karnataka State Highway Improvement Project (KSHIP)
- K.R.Devika, Engineer, Karnataka State Highway Improvement Project (KSHIP)
- M.D.Nadaf & S.Kinni, Executive Engineers, Karnataka State Highway Improvement Project (KSHIP)
- K.S.Krishna Reddy, Chief Engineer, National Highway Zone, PWD, Govt. of Karnataka
- Prakash G.S. & Bartesh K.Jakkannvar, Scott Wilson India Pvt. Ltd.
- Ravishankar Rajaraman & Swastik Narayan, Safety Group, JP Research India Pvt. Ltd.
- Gopalakrishna Parasuraman & Abhishek Tiwari, Indian Road Survey & Management Pvt. Ltd. (IRSM)
- Said Dahdah, World Bank Global Road Safety Facility
- Arnab Bandyopadhyay, Senior Transport Engineer, South Asia Region World Bank
- Richard Wix, Principal Technical Advisor, Systems, Australia Roads Research Board (ARRB)
- Van Hoang, Team Leader - Rating Team, Data Collection, Australia Roads Research Board (ARRB)
- Greg Smith, Asia Pacific Regional Director, iRAP

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Contents

2 Introduction

Deaths and injuries from road traffic crashes are a major and growing public health epidemic. Each year 1.3 million people die and a further 50 million are injured or permanently disabled in road crashes. Road crashes are now the leading cause of death for children and young people aged between 15 and 29. The burden of road crashes is comparable with malaria and tuberculosis and costs between 1% and 3% of the world's GDP.[3]

In low and middle income countries, road crashes represent a major health concern. More than 85% of the global death toll and serious injuries occur in developing countries like India. Over the next ten years road deaths are expected to fall in high-income countries, whereas they are likely to increase by more than 80% in the rest of the world unless decisive action is taken.

In a reflection of the significant social and economic impact of road crashes worldwide, the United Nations has declared 2011-2020 the Decade of Action for Road Safety. It is expected that during the decade, significant efforts will be made to stabilise and then reduce the death toll through systematic improvements in road infrastructure, road user behaviour and vehicle safety.

To help reduce the risk of death and serious injury on the Indian road network, iRAP was invited by the Global Road Safety Facility (GRSF), funded with support from Bloomberg Philanthropies, to undertake the iRAP India Four States Project. The project was designed to assist the governments of four Indian states: 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.

This report provides an overview of the project, including details on data collection and the methodology used along with a summary of results. It is accompanied by a series of short reports which provide additional details on road corridors in each of the states. The focus of the project was on national and state highways, which account for two-thirds of road deaths in India but represent just 10% of the nation's 3.3 million kilometre road network.

2.1 Road safety in India

India has experienced a period of rapid development and economic expansion during the last decade, with Gross Domestic Product (GDP) growing by 7.6% per annum for the period 2002 – 2007.[4] Despite the current global economic downturn India's growth continues at a rapid pace with

[3] World Health Organisation, *Global Plan for the Decade of Action for Road Safety 2011-2020*, 2011.

[4] Socio-Economic Review – Gujarat 2007-2008, Directorate of Economics and Statistics, Government of Gujarat, 2008.

current annual GDP growth projections at 8% for the current fiscal year ending March 2012.[5] Both the nation's road network and its vehicle fleet are increasing year on year, with average car sales up 16% and motorcycles 9% per annum in the five years to 2009.[6] As the road network continues to grow and vehicle ownership increases, so India's road deaths continue to rise.

India accounts for 15% of the world's road fatalities, although it has just 1% of the world's motor vehicles. The latest official figures show that 125,660 people lost their lives on India's roads in 2009.[7] However, some estimates suggest that total could be closer to 200,000 per year, with a further 3 million seriously injured, costing the Indian economy an estimated US$65.4 billion per year. These figures are set to rise unless significant investment is made to improve the safety of India's road infrastructure.

2.2 iRAP India Four States Project

The Global Road Safety Facility, funded with support from the Bloomberg Philanthropies Global Road Safety Project (RS-10 project) financed the International Road Assessment Programme (iRAP) in India covering four states. The Ministry of Shipping, Road Transport and Highways (MoSRTH) and State Public Works Departments (PWDs) of Andhra Pradesh, Gujarat, Karnataka and Assam identified a network of 3,000 km consisting of several high-risk sections for inclusion in the project.

MoSRTH and the four states are preparing road improvement projects to be financed by World Bank loans, and this iRAP assessment will be used as a tool to ensure that proven and cost effective road safety measures are implemented as part of these infrastructure upgrades.

The Andhra Pradesh project began ahead of the other states with the road survey completed in June 2010 and technical report published in February 2011. iRAP provided implementation support throughout 2011 whilst projects in the remaining three states were initiated.

Due to the nature of the project, with multiple stakeholders and different Public Works Departments and state governments being responsible for their individual networks, the project was undertaken with separate analyses, results, recommendations and reports being provided to each road authority within each of the states.

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[5] The World Bank, India Country Overview - September 2011. http://www.worldbank.org.in/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/INDIAEXTN/0,,contentMDK:20195738~menuPK:295591~pagePK:141137~piPK:141127~theSitePK:295584,00.html

[6] Mohan,D. et al., *Road Safety in India: Challenges and Opportunities*, UMTRI, 2009.

[7] MoRTH, Government of India, *Status paper on Road Safety in India*, 2011.

Therefore this report can be regarded as an overview, bringing together and summarising the key findings from all four states. A series of supplementary stand-alone reports have been produced for each of the individual projects that collectively make up the iRAP India Four States Project and are shown in the table below.

Table 1 iRAP reports

World Bank Project	iRAP reports	Document Ref.
Andhra Pradesh Road Sector Project	• Andhra Pradesh Technical Report	• 502.15.1
Assam State Road Project	• Assam Summary Report • SH3 Summary Report	• 502.15.2 • 502.15.3
Second Gujarat State Highway Project	• Gujarat Star Rating Report • Gujarat Summary Report (SRIP)	• 502.15.4 • 502.15.5
Second Karnataka State Highway Improvement Project (annuity roads)	• Malavalli to Pavagada Prelim KSHIP Results • Mudhol to Nippani Prelim KSHIP Results • Shikaripura to Anandapuram Prelim KSHIP Results • Managuli to Devapura Prelim KSHIP Results • KSHIP Annuity Roads: Analysis of proposed design • Star Rating Road Designs: Performance Indicators for Roads in India	• 502.15.6 • 502.15.7 • 502.15.8 • 502.15.9 • 502.15.10 • 502.15.17
Second Karnataka State Highway Improvement Project (Safe Corridor Demonstration Project)	• SH17 SCDP Summary Report • SH20 SCDP Summary Report	• 502.15.11 • 502.15.12
First National Highway Interconnectivity Improvement Project	• Karnataka National Highways Summary Report • NH234 (Madhugiri to AP border) Summary Report • NH234 (Mangalore to Belur) Summary Report • NH206 Summary Report	• 502.15.13 • 502.15.14 • 502.15.15 • 502.15.16

Each report provides details of the Star Rating results for each road user type, a summary of the road attributes recorded and a list of recommended countermeasures. See Appendix A for the Investment Plan Summary and details of the top 5 road safety countermeasures for each project.

Two additional reports by JP Research India Pvt. Ltd. describing the findings of the traffic surveys and crash investigation studies conducted on several sample corridors in Gujarat and Karnataka are available on request. As reliable traffic survey and crash data was not widely available, the

collection of additional supporting (baseline) data was required to calibrate the model to local conditions and was used in the generation of the iRAP Star Ratings and Safer Roads Investment Plans. The use of supporting data in calibrating the model is described in section 5 of this report.

The table below shows a list of all roads included within the iRAP analysis along with the road survey length and survey completion date.

Table 2 Roads included in the project

Project	Road name	Surveyed length (km)	Survey date
Andhra Pradesh Road Sector Project	SH4: Hyderabad to Karnataka border road	124.8	June 2010
	SH31: Renigunta to Rayalachervu road	259	June 2010
	SH38: Anakapalli to Anandapuram road	47.2	June 2010
Assam State Road Project	Baihata Goreswar Road	51.7	March 2011
	Bonaigaon to Abhayapuri	31.8	March 2011
	Jorhat to Barhalla	50.2	March 2011
	SH26 Jaipur to Tengakhat	22.9	March 2011
	SH27 Nazira to Naharkatiya	79.8	March 2011
	SH3 Narengi to Naltoli	124.6	March 2011
	SH31 Jorhat to Mariani	18.5	March 2011
	SH46 Dudhnoi to Goalpara	42.3	March 2011
	SH5 Bilasipara to Sherfanguri	24.1	March 2011
Second Gujarat State Highway Project	Rajula to Surendranagar	260.1	Feb' 2011
	Sagbara to Dahej	208.9	Feb' 2011
	Shamlaji to Patan	141.5	March 2011
KSHIP II (annuity roads)	Malavalli to Pavagada	175.5	Feb' 2011
	Managuli to Devapura	110.2	Feb' 2011
	Mudhol to Nippani	108.5	Feb' 2011
	Shimoga to Hangal (122.5km) inc. Shikaripura to Anandapuram (32.4km)	154.9	Feb' 2011
KSHIP II (Safe Corridor Demonstration Project)	SH17: Maddur to Mysore	108	Feb' 2011
	SH20: Belgaum to Hungund	176.1	Feb' 2011
First National Highway Interconnectivity Improvement Project	NH234: Madhugiri to AP border	180.6	Jan' 2011
	NH234: Mangalore to Belur	128.2	Jan' 2011
	NH206: Honavar to Tumkur	390.6	Jan' 2011
Total (km)		3,020	

2.2.1 Project delivery

The project objective was to prepare iRAP Safer Roads Investment Plans for potential inclusion in World Bank transport projects across the surveyed network. The project consisted of the following stages and activities:

- Collection of road safety background data and analysis of crash, speed, traffic flow and economic data
- Development of draft Star Ratings and Safer Roads Investment Plans

- Provision of training and technical assistance to staff of each of the PWDs in undertaking the Star Rating analysis using iRAP online software and development of Safer Roads Investment Plans
- Development of a full technical report and summary on the Safer Roads Investment Plans for approval by each of the Public Works Departments' senior management and implementation of the iRAP results as required.

This Road Assessment Programme was comprised of several fundamental components involving numerous partners. The table below shows the significant contributions made by each organisation at key stages of the project in each of the four states.

Table 3 Delivery of project components

RAP component	A.Pradesh	Assam	Gujarat	Karnataka
Procure survey	iRAP	World Bank	World Bank	World Bank
Road survey	IRSM	IRSM	IRSM	IRSM
Collection of supporting data	iRAP & APRDC	iRAP & PWD	iRAP, ARRB, PWD & JP Research	iRAP, ARRB, PWD & JP Research
Coder training and supervision	ARRB & iRAP	IRSM & iRAP	ARRB & iRAP	ARRB & iRAP
Coding	IRSM	PWD	GERI	PWD
Coding QA	ARRB & iRAP	IRSM & iRAP	ARRB, iRAP & R.Dziub	ARRB, iRAP & R.Dziub
Training and technical assistance	iRAP	IRSM & iRAP	iRAP	iRAP
Data processing and analysis	iRAP	iRAP	iRAP	iRAP
Star Rating new road designs	Not applicable	iRAP & PWD	Not applicable	iRAP, KSHIP & Scott Wilson India
Reporting	iRAP	iRAP	iRAP	iRAP

2.2.2 Andhra Pradesh

Among the states of India, Andhra Pradesh experiences the largest number of road deaths each year.[8] In 2009, 14,792 people were reportedly killed and a further 59,506 were injured.[9] This equates to a rate of 19 deaths per 100,000 population, which is significantly higher than the best performing jurisdictions around the world. With economic activity in Andhra Pradesh growing at around 10% per annum, there is a very serious risk that road trauma will increase unless commensurate road safety efforts are made.

[8] D. Mohan et al., *Road Safety in India: Challenges and Opportunities*, UMTRI, 2009.

[9] State Crime Records Bureau 2010, cited in *Road accidents on a rise in Andhra Pradesh.* PTI, Wednesday 19 May 2010, http://www.dnaindia.com/india/report_road-accidents-on-a-rise-in-andhra-pradesh_1384961.

In 2009, the Government of Andhra Pradesh (GoAP) took the decision to implement a Road Safety Action Plan; establish an Empowered Committee to oversee the Plan and consisting of Secretaries and Heads of a number of departments; and establish a Road Safety Cell within the office of the Transport Commissioner to support the implementation of the Plan. As part of the Plan, the GoAP identified three demonstration corridors for road safety improvements. These roads represent less than 1% of the total State Highways in Andhra Pradesh, but account for approximately 4% of the state's road deaths. Further details on the results and analysis can be found in the *Andhra Pradesh Technical Report*.

2.2.3 Assam

A large part of the 69,000km road network in the north-eastern state of Assam has suffered from a lack of investment in recent years and is in need of significant resources in order to improve capacity, quality and safety. The Assam State Road Project (ASRP), set up within the Public Works Department (PWD) is working to upgrade 500km of State Highways (including several bridge structures) and to develop an asset management system and build road safety capacity within the PWD funded by a World Bank loan.

As part of the road safety element, iRAP is supporting the PWD to incorporate recommended countermeasures from the iRAP Assam analysis and to Star Rate design plans in order to minimise risk for road users. A summary report containing the Star Ratings and the Safer Roads Investment Plan for 446km (*Assam Summary Report*) has been delivered along with a separate analysis for the road safety demonstration corridor, State Highway 3 from Narengi to Naltoli (*SH3 Assam Summary Report*).

2.2.4 Gujarat

Situated on the Kathiawar peninsula, on India's northwest coastline, Gujarat is one of the more industrialised and prosperous states in India. With its continued economic growth, infrastructure improvement remains a key focus of the Government of Gujarat.

Through the Roads and Buildings Department (R&BD) the state government is responsible for 74,000km of road of which 18,590km is State Highway, with 20,811km of Major District Roads. R&BD also maintains 3233km of the National Highway network under contract with the Ministry of Shipping, Road Transport and Highways.

In 1997 the Government of Gujarat initiated a major programme of road improvements on the State Highway network. As such the R&BD undertook a World Bank financed road improvement project, the Gujarat State Highway Project (GSHP-I), which led to the rehabilitation and upgrade of some 1800km of road. In order to build on the success of that project, the Gujarat State Highway Project

II has been developed which will see the upgrade of a further 1600km at a cost of US$ 0.5billion.[10] iRAP has been invited to survey 610km, provide an assessment of infrastructure risk for road users (iRAP Star Ratings), a programme of cost effective road safety countermeasures (iRAP Safer Roads Investment Plan) and to assist the R&BD and the Gujarat Engineering Research Institute (GERI) with the implementation of these recommendations.

Further details on the results and analysis can be found in the *iRAP India Four States Gujarat Star Rating Report* and *Road Safety Summary Report: Gujarat India*.

2.2.5 Karnataka

Located in south-west India, Karnataka is the country's eighth largest state by area with a population of 61 million (2011). The total road network length of 144,130 km is comprised of 3,973 km of National Highways (NH), 17,222 km of State Highways (SH), 30,975 km of Major District Roads with the remaining made up of other district and village roads. The state PWD is responsible for a total of 52,170 km. As of 2005 there were 5.43 million registered vehicles in Karnataka, 72.8% of which were motorcycles. Recent figures show a 10-15% annual rise in road traffic, a trend that looks set to continue.[11]

This rapid growth in vehicular traffic has contributed to a steady increase in the numbers of reported road crashes, deaths and serious injuries. There were 40,317 reported collisions in 2005, at a rate of 10.84 per 10,000 vehicles, currently increasing at 3.42% per annum. 10.1% of India's road deaths occur in Karnataka. [12]

The iRAP analysis was divided between the Public Works Department responsible for the National Highway (NH) upgrades and the Karnataka State Highway Improvement Project (KSHIP) with responsibility for the World Bank funded State Highway upgrades.

KSHIP play a fundamental role in the Government of Karnataka's development strategy to sustain economic growth and regional development through infrastructure improvements and are working closely with iRAP to ensure that the planned engineering upgrades eliminate high risk sections of road where possible. The iRAP KSHIP project was made up of the four roads planned for upgrade under an annuity concessions agreement, referred to here as the 'Annuity Roads' and also the SH17 and SH20 which together make up the Safe Corridor Demonstration Program (SCDP), on

[10] R&BD, Gov.of Gujarat, Project Preparatory Works Consultancy Services for Gujarat State Highway Project – II, Inception Report, LEA Associates, September 2011.

[11] KSHIP Feasibility Study, Chapter 4: Traffic Study and Analysis, para.4.

[12] KSHIP Feasibility Study, Chapter 4:Traffic Study and Analysis, para.4.6.4.

which a minimum 3-star rating is to be achieved. The results of the iRAP analysis for both the Annuity Roads and the SCDP have been provided separately.

The Karnataka National Highways project consisted of 700km of the National Highway network across three separate corridors along NH206 and NH234. Further details on the results and analysis can be found in the *Karnataka National Highways Summary Report* or the individual corridor reports (see Table 1).

2.3 Methodology

iRAP uses globally consistent models to produce vehicle occupant, motorcyclist, pedestrian and bicyclist Star Ratings and Safer Roads Investment Plans. The methodology for each of these is described in:

- *Star Rating Roads for Safety: The iRAP Methodology*
- *Safer Roads Investment Plans: The iRAP Methodology*

These reports are available for download at: http://www.irap.org/library.aspx.

Other iRAP reference documents used in this project include:

- The True Cost of Road Crashes – Valuing life and the cost of a serious injury
- Vehicle Speeds and the iRAP Protocols
- Star Rating Quality Assurance Guide – Coding Edition
- A Guide to Producing iRAP Star Ratings and Safer Roads Investment Plans
- iRAP Star Rating Coding Manual – India Three States Edition

2.4 Online results

This report provides an overview of the methodology used and summarises the results produced in the project. Full results, including data tables, interactive maps and download files, as well as data underpinning the analyses, are available in the iRAP online software at www.iraptools.net. Access to the iRAP online software is password protected. Usernames and passwords have been allocated to all iRAP project supervisors in each participating state. For further information about accessing or using the software, contact Luke Rogers, Senior Road Safety Engineer, iRAP at luke.rogers@irap.org.

3 Training

The provision of training and technical support for staff in each of the four PWDs was considered a fundamental element of the project in order to maximise the potential benefits of the iRAP results and to build road safety capacity within the participating road authorities.

3.1 iRAP coder training course

iRAP coder training was hosted by the Federation of Indian Automobile Associations (FIAA) at the Automobile Association of Upper India (AAUI) training facility in New Delhi from January 24 to 28, 2011. The course was delivered by an experienced team consisting of staff from iRAP, ARRB Group and Indian Road Survey and Management (IRSM) and attended by 26 participants from PWDs of the four states.

Each attendee was provided with training materials consisting of:

- iRAP Coding Manual (India Three States Edition, Jan.2011)
- Hawkeye Processing Toolkit manual.

The course included:

- An introduction to road safety – a local perspective
- Data collection methodology
- Presentations on safe road design and the Safe System approach
- Sessions on iRAP Coding Manual and Hawkeye software
- Practice coding sessions, analysis and group discussions
- Presentation of certificates of participation

Figure 1 Participants learning the iRAP coding process

Ten computer work stations were purchased (by IRSM) for the project and were fully utilised during the training. At the completion of the training the computers were dispersed to the various states where they were used for the iRAP coding of the road survey data collected in Assam, Gujarat and Karnataka (the road survey and coding for Andhra Pradesh were completed previously, in June 2010).

The following table shows the list of participants who attended the training course and the facilitators from iRAP and ARRB.

Table 4 Attendance list, iRAP Coder Training, 24-28 Jan.2010, AAUI, New Delhi, India

Name	State / Organisation	Position
Shri Parikhit Baruah	Assam	PWD (Rds), Assam
Shri Himangshu Das	Assam	AE Guwahati State Road Authority
Shri Sanjib Lahan	Assam	AEE Johrat State Road divn
Shri S.K.Mittal	Assam	Bungayam State Road Sub-Divn II
Shr Niren Baruah	Assam	Road Research Laboratory Fatasil
Shri Nabel Deuri	Assam	AEE, Lakhimpur State Road Sub-Divn II
Shri S K Chawda	Gujarat	Joint Director (Roads), GERI, Vadodara
Shri P A Dangar	Gujarat	(I/c) Research Officer, RRD-4, GERI, Vadodara
Shri S M Raval	Gujarat	Dy. Executive Engineer, PIU Sub-division, Bharuch, R&BD
Shri B J Bhatt	Gujarat	ARO, GERI Vadodara
Shri N M Jadav	Gujarat	Assistant Engineer (PPU) G'nagar
Shri B A Patel	Gujarat	Assistant Engineer, Radhanpur (R&B) Sub Dv
Sri Sathyanarayana	Karnataka	Assistant Executive Engineer, PIU, KSHIP
Sri G Surendranath	Karnataka	Assistant Executive Engineer, PIU, KSHIP
Sri Sathyanarayana Rao T A	Karnataka	Assistant Engineer, QA Division, Bangalore
Sri N Guruprasad	Karnataka	Assistant Engineer, QA Sub Division, Mysore
Sri S M Bhaldar	Karnataka	Assistant Engineer, QA Sub Division, Belgaum
Sri V Suresh Babu	Karnataka	Junior Engineer, QA Sub Division, Bellary
Sri Shankare Gowda	Karnataka	Superintending Engineer, PPP Cell, National Highways, Bangalore
Sri Narasimha Reddy D.G.	Karnataka	Assistant Executive Engineer, National Highways Sub-Division, Kolar
Sri Ravishankar K.V.	Karnataka	Assistant Executive Engineer, National Highways Sub-Division, Tumkur

Sri Jeevan Kumar M.G.	Karnataka	Assistant Executive Engineer National Highway Special Sub-division, Shimoga
Sri. M.A. Saleem	Andhra Pradesh	E.E (R&B)(A/C), APRDC, Hyderabad
Sri. D.Prasada Rao	Andhra Pradesh	A.E.E (R&B), APRDC, Hyderabad
Sri J.Seshu Babu	Andhra Pradesh	A.E.(R&B) APRDC, Hyderabad
Sri .P.S.Phanindra Prasad	Andhra Pradesh	SE (R&B) & GM(PPP), APRDC, Hyderabad
Abhishek Tiwari	IRSM	Project Engineer, Data Collection & Processing
Said Dahdah	World Bank	Transport Specialist
Nitin Dosa	FIAA	Vice President, Projects
Richard Wix*	ARRB	Principal Technical Advisor, Systems
Van Hoang*	ARRB	Team Leader – Rating Team, Data Collection
Greg Smith*	iRAP	Regional Director
Luke Rogers*	iRAP	Senior Road Safety Engineer

*Training facilitators

Figure 2 iRAP coder training course participants, AAUI, New Delhi

3.2 Supplementary coder training

Coding teams consisting of between 6 to 12 local PWD staff and engineers were established in each of the states in order to undertake the coding process. Upon completion of the road surveys, each team received a further 5 days expert tuition from a combination of iRAP, ARRB Group and IRSM staff in the use of the Hawkeye software and iRAP coding specifications prior to the start of the coding stage. This additional training provision ensured that all members of the coding teams had a minimum of 5 full days coding experience prior to the start of the coding task.

During the coding, full-time guidance was provided by ARRB Group staff and under the supervision of team leaders who had attended the coder training course in New Delhi, the teams recorded road attributes at 100m intervals across the 3,000km network, resulting in 1.5 million data entries. In all, close to 50 PWD staff members from 4 states were trained and took part in the coding, achieving the required level of accuracy as described within the *iRAP Star Rating Quality Assurance Guide*. The process took between 3 to 5 weeks per state to complete, depending upon the size of the coding teams and the length of the surveyed network to be coded.

3.3 iRAP analysis training

In order to build road safety capacity within each of the Public Works Departments, approximately 45 senior staff, project managers, design consultants and local engineers (often those directly involved in preparing the World Bank funded projects) were provided with an understanding of the iRAP Star Rating methodology through seminars and tuition on how to use the iRAP results to identify high-risk routes and to investigate recommended countermeasures for inclusion within planned upgrades.

Sessions were held for managers, engineers and design consultants to help ensure that at all levels, safe road design is given the highest priority during both the planning and design stages. The seminars were designed to enable participants to use local results to gain a better understanding of how the recorded road attributes (the coded data) influence risk for road users and how the iRAP Safer Roads Investment Plans can help to reduce that risk.

Other sessions included instruction on how to use the reports and download files within the iRAP online software to fully analyse the results; using the Road Safety Toolkit to improve knowledge and understanding of current best practice in road safety engineering; and tuition on how to use the iRAP Demonstrator to assess individual sites and design plans.

3.4 Ongoing training and support

Each of the four states will be provided with ongoing training and support as required to ensure iRAP recommended countermeasures are investigated and considered for inclusion in the planned upgrades. The Star Rating of proposed designs is currently underway and plans for further training as part of additional iRAP work in India is being developed.

4 Road Surveys and Coding

Using a specially equipped vehicle the road network was surveyed, recording digital images at 10m intervals to enable the coding of 50 road attributes relating to the likelihood and severity of a crash.

4.1 Road Surveys

The surveys were undertaken by Indian Road Survey and Management (IRSM) between June 2010 and April 2011 using a "Hawkeye 2000" digital imaging system. The features of the inspection system were:

- Use of three high-resolution digital cameras (1280 x 960 pixels).
- Digital images collected with a 150 to 180 degree field of view (centred on the travel lane) at 10m intervals.
- Geo-reference data was collected for each digital image, including distance along road (from an established start point) plus latitude and longitude coordinates.
- The images were calibrated to enable detailed measurements of the road features.
- It had the capability to provide automated measurements of radius of curvature for horizontal curves and gradient for vertical alignment.

Pavement condition data was also collected via a digital laser based profiler beam fitted to the front of the vehicle. Each system was fully integrated and the outputs linked to both spatial (GPS) and linear references. The pavement condition data will be made available to asset management engineers in each state.

Figure 3 The IRSM survey vehicle

The road survey officially commenced in Andhra Pradesh in June 2010, followed by Karnataka and Gujarat in early 2011, finishing in Assam in April 2011.

Figure 4 Equipment demonstration at KSHIP offices, Bangalore

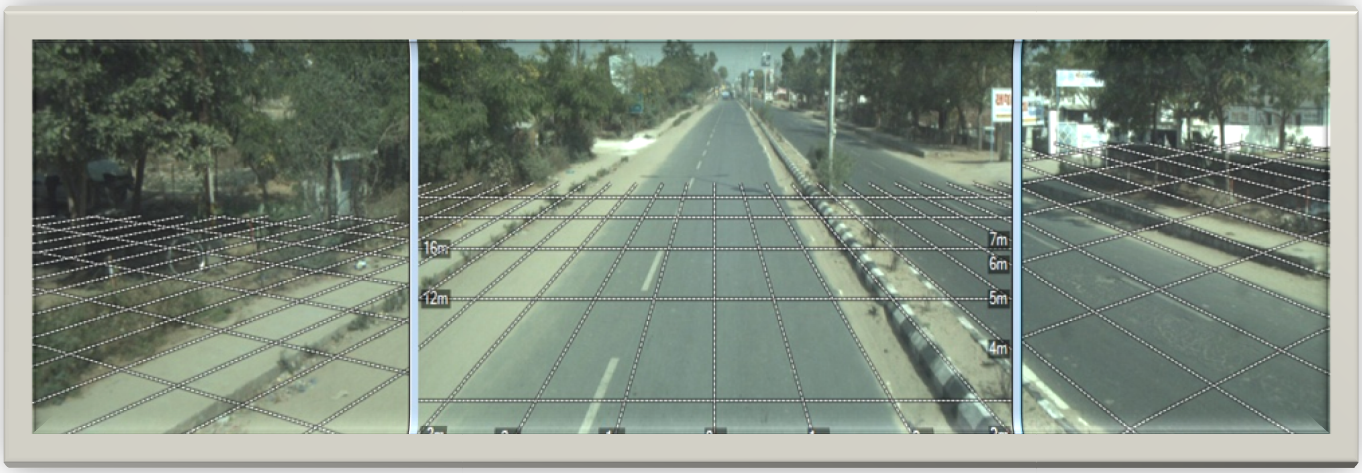
The surveys were completed with the assistance of local PWD officers who provided the necessary logistical support, reference information and to act as navigators during the survey. The project has a considerable training and capacity build focus, as such the IRSM team invited staff from the many various agencies to attend demonstration events and join the data collection surveys as observers.

4.2 iRAP Coding

Upon completion of the road surveys the digital images and geo-reference data was coded by teams of engineers from each of the participating states using the Hawkeye Processing Toolkit software, in accordance with the iRAP Coding Manual (India Three States Edition, Jan.2011) and under the supervision of experienced staff from ARRB Group, Australia. Several members of each coding team had previously attended the iRAP coder training course in early 2011, at the AAUI training facilities in New Delhi.

The coded data was subject to quality assurance checks in accordance with *iRAP's Rating Quality Assurance Guide,* prior to any analysis occurring.

Figure 5 The Shamlaji to Patan corridor, Gujarat, being viewed and coded using the Hawkeye software



4.3 Road attributes

A summary table of the recorded road attributes for each study within the India Four States Project is provided in each of the summary reports and can be accessed using the iRAP online software (www.iraptools.net). A full data set of the coded attributes is also available as a downloadable file. As an example, the table below shows the recorded road attributes for 549km of State Highway in Karnataka, India, part of the Second Karnataka State Highway Improvement Project (annuity roads).

Table 5 Recorded road attributes (KSHIP annuity roads)

Vehicles per day	Length (km)	%
1000 - 5000	345.8 km	63
5001 - 10000	126.2 km	23
10001 - 15000	24.8 km	5
20001 - 40000	3.6 km	1

Motorcycle flow (% of traffic)	Length (km)	%
1% - 5%	323.4km	59
11% - 20%	197.5km	36
21% - 40%	24.6km	4
61% - 80%	3.6km	1

Bicycle flow	Length (km)	%
Not recorded / none	150.7km	27
Low	353.6km	64
Medium	34.6km	6
High	10.2km	2

Pedestrian flow across the road	Length (km)	%
Not recorded / none	402.9km	73
Low	100.9km	18
Medium	38.3km	7
High	7km	1

Pedestrian flow along the road	Length (km)	%
Low	510.5km	93
Medium	8.3km	2
High	30.3km	6

Area type	Length (km)	%
Rural	509.4km	93
Semi-urban	30.3km	6
Urban	9.4km	2

Number of lanes for use by through traffic	Length (km)	%
One	546.9km	100
Two	2.2km	0

One way / two way flow	Length (km)	%
Two way traffic	549.1km	100

Road condition	Length (km)	%
Good	42.4km	8
Medium	149.9km	27
Poor	356.8km	65

Land use - left	Length (km)	%
Undeveloped areas	438.8km	80
Development other than residential or commercial	9.4km	2
Residential	59.4km	11
Commercial	41.5km	8

Land use - right	Length (km)	%
Undeveloped areas	445.6km	81
Development other than residential or commercial	6.8km	1
Residential	54.3km	10
Commercial	42.4km	8

Side friction	Length (km)	%
Low	474km	86
Medium	46.2km	8
High	28.9km	5

Shoulder rumble strips	Length (km)	%
No	549.1km	100

Pedestrian crossing facilities	Sites
Unsignalised marked crossing without refuge	2 sites
No facility	5489 sites

Pedestrian crossing quality	Sites
Adequate	2 sites
Not applicable	5489 sites

Bicycle facilities	Length (km)	%
None	549.1km	100

Motorcycle facilities	Length (km)	%
None	549.1km	100

Table 5 continued

Speed	Length (km)	%
50km/h	39.7km	7
80km/h	509.4km	93

Motorcycle facilities - speed	Length (km)	%
<= 40km/h	549.1km	100

Lane width for lanes serving through traffic	Length (km)	%
Wide (> 3.25m)	147.3km	27
Medium (2.75m <= to <= 3.25m)	120.8km	22
Narrow (0.0m to < 2.75m)	281km	51

Paved shoulder width	Length (km)	%
Wide (>= 2.4m)	2.1km	0
Medium (1.0m < to < 2.4m)	5.7km	1
Narrow (0.0m < to <= 1.0m)	2.8km	1
None	538.5km	98

Unpaved shoulder width	Length (km)	%
Wide (>= 2.4m)	33.3km	6
Medium (1.0m < to < 2.4m)	349.6km	64
Narrow (0.0m < to <= 1.0m)	160.9km	29
None	5.3km	1

Curvature	Length (km)	%
Straight or gently curving	426km	78
Moderate	87.4km	16
Sharp	32.5km	6
Very sharp	3.2km	1

Quality of curve	Length (km)	%
Adequate	426.1km	78
Poor	123km	22

Overtaking demand	Length (km)	%
None	4.2km	1
Low	0.3km	0
Medium	187km	34
High	357.6km	65

Delineation	Length (km)	%
Adequate	84.4km	15
Poor	464.7km	85

Vertical alignment variation	Length (km)	%
Flat	548.8km	100
Undulating / rolling	0.3km	0

Sidewalk provision - left	Length (km)	%
Non-physical separation > 1.0m <= 3.0m	0.3km	0
Adjacent to traffic	3.6km	1
None	545.2km	99

Minor access point density	Length (km)	%
Low	39.7km	7
Not applicable	509.4km	93

Roadside severity - left	Length (km)	%
Safety barrier	1.8km	0
Cut	0.4km	0
Deep drainage ditches	2.3km	0
Steep fill embankment slopes	9.9km	2
Distance to object 0.0m - 5.0m	207.9km	38
Distance to object 5.0m - 10.0m	135.7km	25
Distance to object > 10.0m	191.1km	35

Roadside severity - right	Length (km)	%
Safety barrier	1.8km	0
Cut	0.7km	0
Deep drainage ditches	3.4km	1
Steep fill embankment slopes	11.7km	2
Distance to object 0.0m - 5.0m	219.7km	40
Distance to object 5.0m - 10.0m	113.1km	21
Distance to object > 10.0m	198.7km	36

Bicycle facilities - roadside severity	Length (km)	%
Not recorded	549.1km	100

Motorcycle facilities - roadside severity	Length (km)	%
Not recorded	549.1km	100

Major intersection type	Sites
Merge lane	3 sites
Roundabout	2 sites
3-leg (unsignalised) without cross-traffic turn lane	235 sites
3-leg (signalised) without cross-traffic turn lane	2 sites
4-leg (unsignalised) without cross-traffic turn lane	51 sites
4-leg (signalised) without cross-traffic turn lane	2 sites
Non-major junctions or driveways (rural roads only)	484 sites
None	4710 sites
Railway crossing - active (flashing lights / boom gates)	2 sites

Intersection quality	Sites
Good	11 sites
Poor	768 sites
Not applicable	4712 sites

Median Type	Length (km)	%
Physical median width 1.0m - 5.0m	0.8km	0
Physical median width up to 1.0m	3.4km	1
Centre line only	544.9km	99

Sidewalk provision - right	Length (km)	%
Non-physical separation > 1.0m <= 3.0m	0.3km	0
Adjacent to traffic	3.6km	1
None	545.2km	99

5 Supporting Data

Although the iRAP Star Ratings and Safer Roads Investment Plans use a standardised global methodology, the models are calibrated with local data to ensure that the results reflect local conditions. The following section outlines the supporting data and how it was used in the iRAP analysis.

An Indian road safety consultant, JP Research, collected supporting data in two of the participating states (Gujarat and Karnataka) to assist in the generation of iRAP Star Ratings and Safer Roads Investment Plans. The study corridors were:

1. Maddur to Mysore, Karnataka (53 km)
2. Belgaum to Hungund, Karnataka (186 km)
3. Dahej to Valia, Gujarat (78 km)

Both real-time and historic crash data was gathered along the study corridors with the assistance of the police, road authority and medical services. Traffic surveys were also conducted along the route which included the recording of traffic volumes, speeds and vehicle classification data. The data was used in the iRAP analysis and the detailed results are recorded in two separate reports available on request.

5.1 The role of speed

The issue of speed management is of paramount importance in road safety. Traffic speeds also have a significant bearing on the iRAP Star Ratings.

The risk of death or serious injury is minimised in any crash, where:

- vulnerable road users (e.g. motorcyclists, bicyclists and pedestrians) are physically separated from cars and heavier vehicles, or traffic speeds are 40km/h or less
- opposing traffic is physically separated and roadside hazards such as trees and other fixed objects (including concrete guard posts) are well managed
- traffic speeds are 70km/h or less for occupants of cars on roads where opposing traffic flows are not physically separated or where roadside hazards exist.

The safety of infrastructure is heavily influenced by the speed of traffic and without an understanding of the operating speeds it is difficult to assess the safety performance of

infrastructure at a given location. All iRAP assessments are based on vehicle operating speeds to ensure that the Star Rating is based on how the road is actively functioning, which is often above the posted speed limit.

In many countries there can be a marked difference between the posted speed limit and the actual speed of vehicles using the road. This is a function of local behaviour, local enforcement practice and whether the engineering features of the road are designed in accordance with the speed limit, for example the use of traffic calming measures to help manage speeds.

Although many of the speed limit signs recorded during the survey had shown a mandatory limit of between 30km/h to 60km/h, the results of several speed surveys conducted suggest that operating speeds are well in excess of these posted speed limits. For further details of the iRAP specifications in relation to vehicle speeds see *Vehicle Speeds and the iRAP Protocols*, which can be found on the iRAP website http://www.irap.net/library.aspx.

5.2 Speed data

Figure 6 Summary of 85th percentile traffic speeds, SH17 Karnataka, India

Traffic Speed

SITE E	SITE D	SITE C	SITE B	SITE A
M2W – 55 kmph	M2W – 67 kmph	M2W – 62 kmph	M2W – 60 kmph	M2W – 61kmph
Car – 72 kmph	Car – 99 kmph	Car – 92 kmph	Car – 80 kmph	Car – 87 kmph
Bus – 59 kmph	Bus – 68 kmph	Bus – 69 kmph	Bus – 68 kmph	Bus – 69 kmph
Truck – 57 kmph	Truck – 74 kmph	Truck – 61 kmph	Truck – 61 kmph	Truck – 62 kmph
Others – 43 kmph	Others – 48 kmph	Others – 46 kmph	Others – 46 kmph	Others – 46 kmph
All vehicles– 65 kmph	All vehicles – 87 kmph	All vehicles – 81 kmph	All vehicles – 71 kmph	All vehicles – 77 kmph

For much of the surveyed network a clearly defined speed limit was difficult to detect. Where speed limit signs were observed, vehicle speeds were often well in excess of the posted limit. The results of the speed surveys conducted by JP Research (see Figure 6) along various points of the study

corridors showed the 85th percentile speeds of motor vehicles recorded were often more than double that of the posted speed limit. On the multi-lane, divided, State Highway 17 in Karnataka for example, the average 85th percentile speed for all vehicles at two of the survey sites (Survey Sites C and D) was in excess of 80km/h despite a 30km/h posted limit. The 85th percentile speed for motor cars was 92km/h at site C and 99 km/h at site D.[13]

With vehicle fleets, road conditions, geometry, speed limits and enforcement differing from state to state it was difficult to make general assumptions regarding vehicle speeds for all roads within this project. Due to the lack of comprehensive speed data across the network an estimate of vehicle operating speeds was made. The method adopted to estimate 85th percentile operating speeds and the assumptions made are detailed below:

- vehicle operating speeds were based on the data collected by JP Research for the three corridors within that study
- elsewhere (based on the findings of the speed surveys), vehicle speeds were assumed to be 80km/h in rural areas, except where pavement condition was poor and narrow lanes were recorded, in which case 70km/h speeds were used in the analysis
- in semi-urban areas vehicle speeds were assumed to be 60km/h
- in urban areas vehicles speeds were assumed to be 50km/h or less

5.3 Traffic volumes

Total traffic flow (or volume) for all motorised vehicles is required for each road section and is used in the estimation of the distribution of the numbers of deaths and serious injuries that could be prevented on the network. The data is required to be in Annual Average Daily Traffic (AADT) format and should not be adjusted to passenger car equivalent (PCU) volumes.

The AADT for many of the road sections within this assessment has been provided by the PWDs from each of the states. However, data has not been provided for all road sections within this assessment therefore where data has not been supplied estimates have been made based on:

- observations made during the detailed road survey and coding phase
- local knowledge
- findings from study by JP Research

[13] iRAP Baseline Data Collection in India – Karnataka Phase, J.P.Research India Pvt. Ltd., 2012, p.12.

5.4 Motorcycle volumes

Detailed data on motorcycle traffic was not available for all roads included in the assessment. Where available, data from classified traffic surveys was used, for other roads estimates have been made based on other data sources such as observed flow during coding, percentage of powered two-wheelers from vehicle registry and other related traffic surveys.[14]

5.5 Pedestrian and bicycle volumes

Pedestrian and bicycle flows were recorded during the coding process. It is possible to rely solely on this data for processing, though it is not recommended. This is because pedestrian and bicycle flows can be transitory and a one-off visual inspection is unlikely to provide a strong basis for determining overall flows. As survey data was unavailable for pedestrian and bicycle flows an estimate was made based on observed volumes plus other related information such as area type, and adjacent land use. See *iRAP 310: A Guide to Producing iRAP Star Ratings and Safer Roads Investment Plans* for further information.

5.6 Number of deaths and serious injuries

As part of the iRAP model calibration, an estimate of the number of deaths and serious injuries that occur on the road was required. In order to allocate deaths and serious injuries to the network, the iRAP model requires an estimate of the distribution of deaths by road user type.

Where available, existing records of the number of road deaths occurring per year was used. For the roads included in the JP Research study, the fatality data was based on the findings of their investigations. However, detailed road crash data was not available on many of the road sections included within this analysis and therefore on these roads, estimates of the number of deaths and serious injuries were made based on typical death rates per billion vehicle kilometres travelled (vkt). Where necessary, assumptions on the number of deaths by road user type were made based on various reports and road safety studies (MoRTH Road Safety Status Report, WHO, Mohan et al).

The number of serious injuries was estimated using the standard iRAP assumption that for each death, 10 serious injuries occur.[15]

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[14] The World Health Organisation Global Status Report on Road Safety (WHO, 2009) shows 71% of India's 73 million registered vehicles to be motorised two-wheelers and the figures for the State of Gujarat show almost 74% of registered vehicles within the state to be motorcycles (Socio-Economic Review – Gujarat 2007-2008, Directorate of Economics and Statistics, Government of Gujarat, 2008).

[15] K. McMahon and S. Dahdah, *The True Cost of Road Crashes: Valuing life and the cost of a serious injury*, iRAP, 2008. http://irap.org/library.aspx.

Table 6 Traffic data and estimated casualties (KSI: Killed and serious injury)

State	Road name	Length (km)	Ave. AADT	Ave. m'cycle flow	Ave. ped flow	Ave. bicycle flow	Est. KSIs per year
A.P.	SH4	124.8	6,444	6-10%	medium	low	980*
	SH31	259	7,463	21-40%	low	low	2,509*
	SH38	47.2	7,888	11-20%	low	low	535*
Assam	Baihata Goreswar Road	51.7	6,000	41-60%	low	medium	238**
	Bonaigaon to Abhayapuri	31.8	6,000	21-40%	medium	medium	114**
	Jorhat to Barhalla	50.2	6,000	21-40%	low	low	113**
	SH26 Jaipur to Tengakhat	22.9	6,000	21-40%	low	low	55**
	SH27 Nazira to Naharkatiya	79.8	6,000	21-40%	low	low	221**
	SH3 Narengi to Naltoli	124.6	8,486	21-40%	low	medium	515**
	SH31 Jorhat to Mariani	18.5	18,371	21-40%	medium	medium	102**
	SH46 Dudhnoi to Goalpara	42.3	6,000	21-40%	medium	medium	145**
	SH5 Bilasipara to Sherfanguri	24.1	6,000	11-20%	low	medium	54**
Gujarat	Rajula to Surendranagar	260.1	6,757	21-40%	medium	low	1,493**
	Sagbara to Dahej	208.9	8,271	21-40%	medium	low	939**
	Shamlaji to Patan	141.5	5,218	21-40%	medium	low	600**
Karnataka	Malavalli to Pavagada	175.5	5,129	6-10%	low	low	1,105**
	Managuli to Devapura	110.2	4,500	1-10%	low	low	355**
	Mudhol to Nippani	108.5	7,813	6-10%	low	low	589**
	Shimoga to Hangal	154.9	3,696	6-10%	low	low	680**
	SH17: Maddur to Mysore	108	33,907	41-60%	low	low	990**
	SH20: Belgaum to Hungund	176.1	10,806	41-60%	low	low	1,095**
	NH234 Madhugiri to AP	180.6	3,636	41-60%	low	low	593*
	NH234 Mangalore to Belur	128.2	3,375	11-20%	low	low	386*
	NH206 Honavar to Tumkur	390.6	3,967	21-40%	low	low	1,161*
Total		3,020	7,902				15,569

Notes:
AADT was supplied by PWDs where available (traffic data was not available for many of the roads in Assam).
Motorcycle flow estimated from observations during coding and adjusted using traffic survey data where available.
Pedestrian and bicycle flow estimated using methodology explained in *iRAP 310: A Guide to Producing iRAP Star Ratings and Safer Roads Investment Plans.*
Source of casualty data: *PWD/Police crash data; **other (typical casualty rates estimated from other sources i.e. JP Research, MoRTH Road Safety Status Report, WHO Global Status Report on Road Safety, Mohan et al etc).

5.7 The economic cost of a death and serious injury

Safer Roads Investment Plans: The iRAP Methodology describes the process used to estimate the economic cost of a road death and a serious injury for iRAP projects. This approach is applied globally by iRAP and is based on research undertaken by McMahon and Dahdah (2008).

The key equations used are:

- the economic cost of a death is estimated to be: 70 x Gross Domestic Product (GDP) per capita (current prices)
- the economic cost of a serious injury is estimated to be: 0.25 x economic cost of a death.

On this basis:

- the economic cost of a death is estimated to be 70 x INR 70,220 = INR 4,915,400 (USD 93,400)[16]
- the economic cost of a serious injury is estimated to be: 0.25 x INR 4,915,400 = INR 1,228,850 (USD 23,350).

If the estimate of 200,000 deaths per year on India's road network is used, based on these calculations the economic cost of road deaths and serious injuries in India is a staggering US$65.4 billion per year.

To calculate Net Present Costs and Benefits, a discount rate of 4% was used.

5.8 Countermeasure costs

The iRAP model requires the input of local construction and maintenance costs for the 70 countermeasures that are considered in the development of the Safer Roads Investment Plans. The estimated costs are categorised by area type (urban, semi-urban and rural) and upper and lower 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.

The countermeasure costs used as the basis for all the studies within the Four States Project were estimated by staff at the Andhra Pradesh Road Development Corporation (APRDC). Some minor adjustments were incorporated for the Assam study based on the *Schedule of Rates for Road, Bridge & Culvert Works 2009-2010*, Government of Assam Public Works Department. Subsequent amendments to the countermeasure costs for each individual study were based on data supplied by the participating PWDs. The full data set for each study is available in the iRAP online software (www.iraptools.net).

[16] Exchange rate: 1 INR = 0.019US$ 19.12.2011

6 Star Ratings

iRAP Star Ratings are based on numerous road features and the degree to which they impact the likelihood and severity of road crashes. The focus is on the features which influence the most common and severe types of crash on roads for 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. 5-star (green) roads are the safest, while 1-star (black) roads are the least safe. Star Ratings were not assigned to roads where there was very low use by that type of road user. For example, if no bicyclists use a section of road, then a bicyclist Star Rating is not assigned to it.

The Star Ratings are based on Road Protection Scores (RPS). The iRAP models calculate an RPS at 100 metre intervals for each of the four road user types, based on relative risk factors for each of the road attributes. The scores are developed by combining relative risk factors using a multiplicative model. As an example of a risk factor, the relationship between delineation and the likelihood of vehicle occupants being killed or seriously injured in a crash is shown below. It indicates that the relative risk of death or serious injury on a rural road is 20% greater when the delineation is poor, all other things being equal.

Table 7 Vehicle occupant risk factors for the likelihood of death or serious injury on a rural road [17]

Delineation	Relative Risk
Adequate	1.00
Poor	1.20

More information on risk factors, RPS and Star Ratings is available in iRAP (2009) *Safer Roads Investment Plans: The iRAP Methodology* (see www.irap.org).

6.1 Example Star Ratings

The following images show examples of the Star Ratings and the road attributes that influence the ratings from the Gujarat State Highway study. The examples shown are based on results for pedestrians and vehicle occupants only; however similar figures can be produced for motorcyclists and bicyclists.

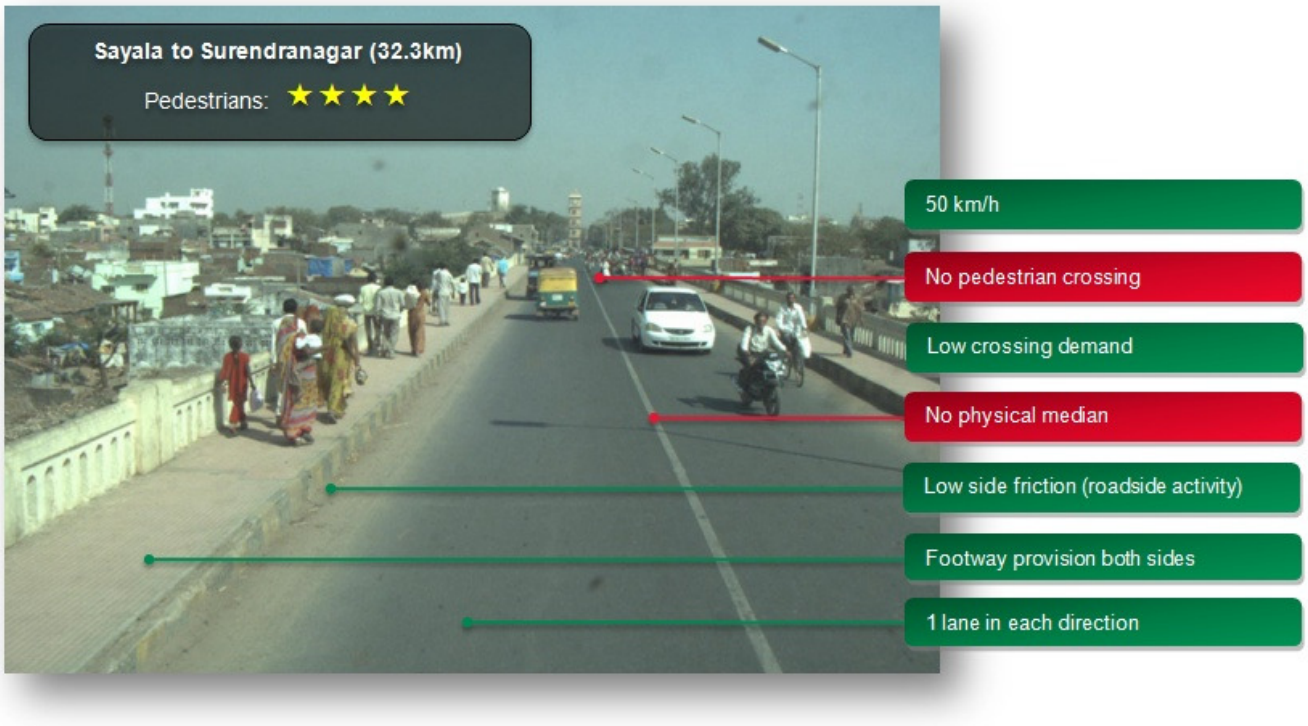
[17] The research underpinning this particular set of relationships is reflected in Austroads' Road safety engineering risk assessment project 2002-07; Elvik, R. Vaa, T. (2004) *The handbook of road safety measures*. Elsevier, The Netherlands; and Ogden, K. W. (1966) *Safer roads: a guide to road safety engineering*. Avebury Technical, Ashgate Publishing Limited, Grower House, Croft Road, Aldershot, England.

In the figures:

- Green coloured attributes are associated with a reduced level of risk
- Yellow coloured attributes are associated with an intermediate level of risk
- Red coloured attributes are associated with an increased level of risk.

The figures help to illustrate the fact that the level of risk associated with a road's infrastructure, and hence its Star Rating, is a function of numerous attributes, including travel speeds.

Figure 7 **Example of 4-star rating for pedestrians. Note, no sections achieved a 5-star rating for pedestrians and this bridge is the only 4-star example for this road user type**



Note that the Star Rating for pedestrians at this location will drop to 3-stars when vehicle operating speeds increase to 60km/h.

Figure 8 Example of 3-Star Rating for pedestrians

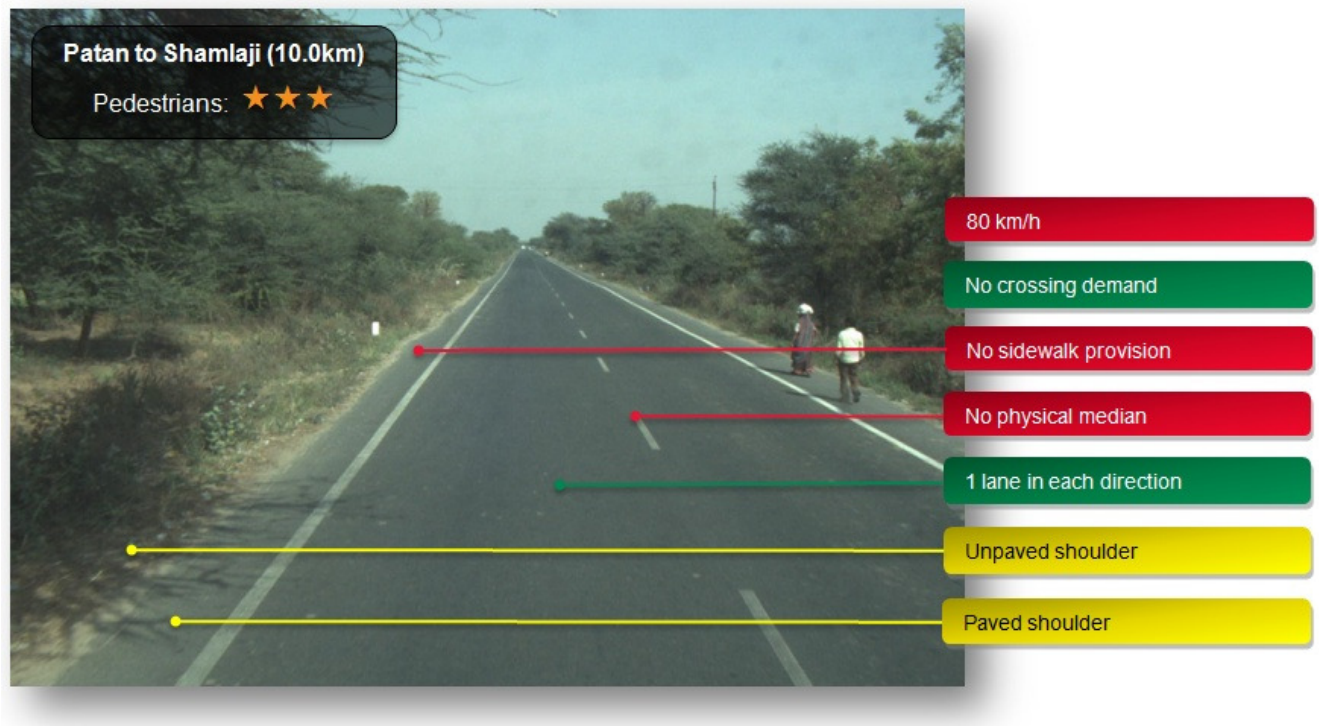


Figure 9 Example of 2-Star Rating for pedestrians

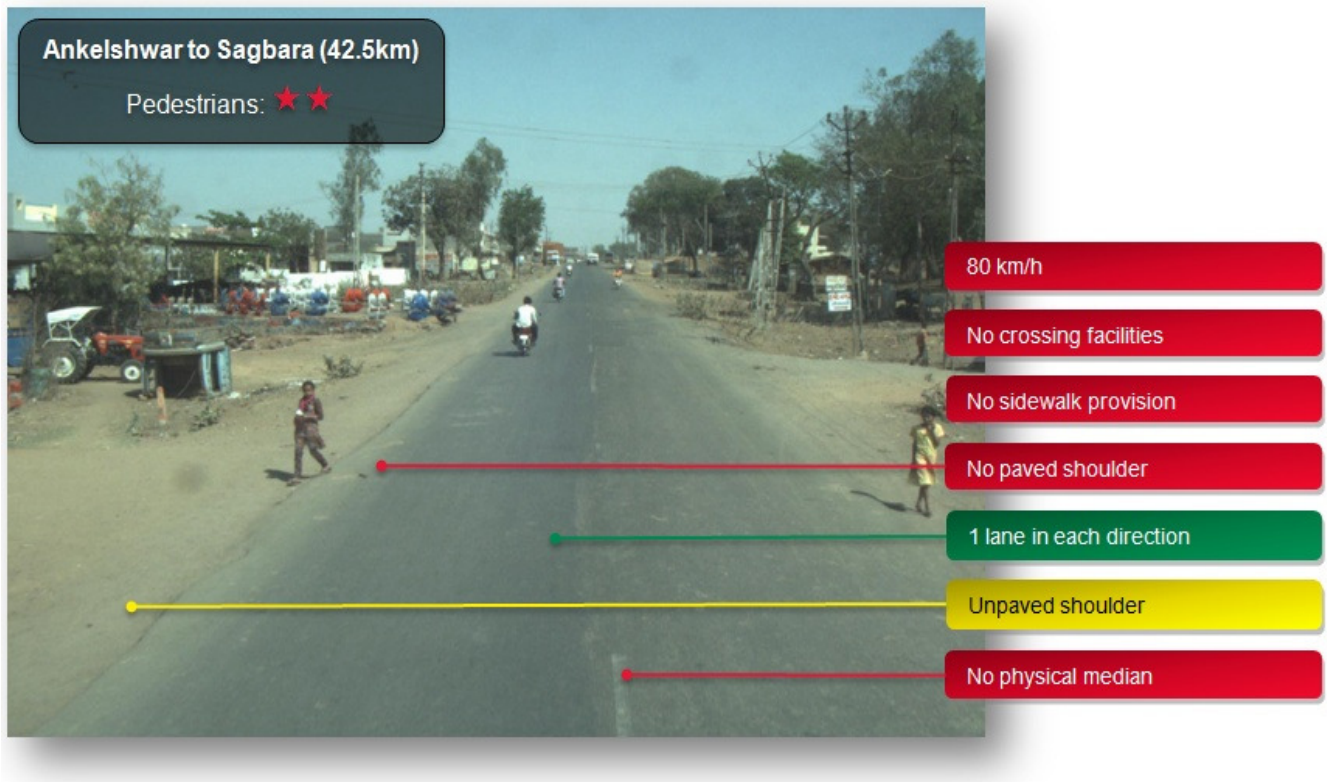


Figure 10 Example of 5-Star Rating for vehicle occupants (assuming operating speed of 60km/h)

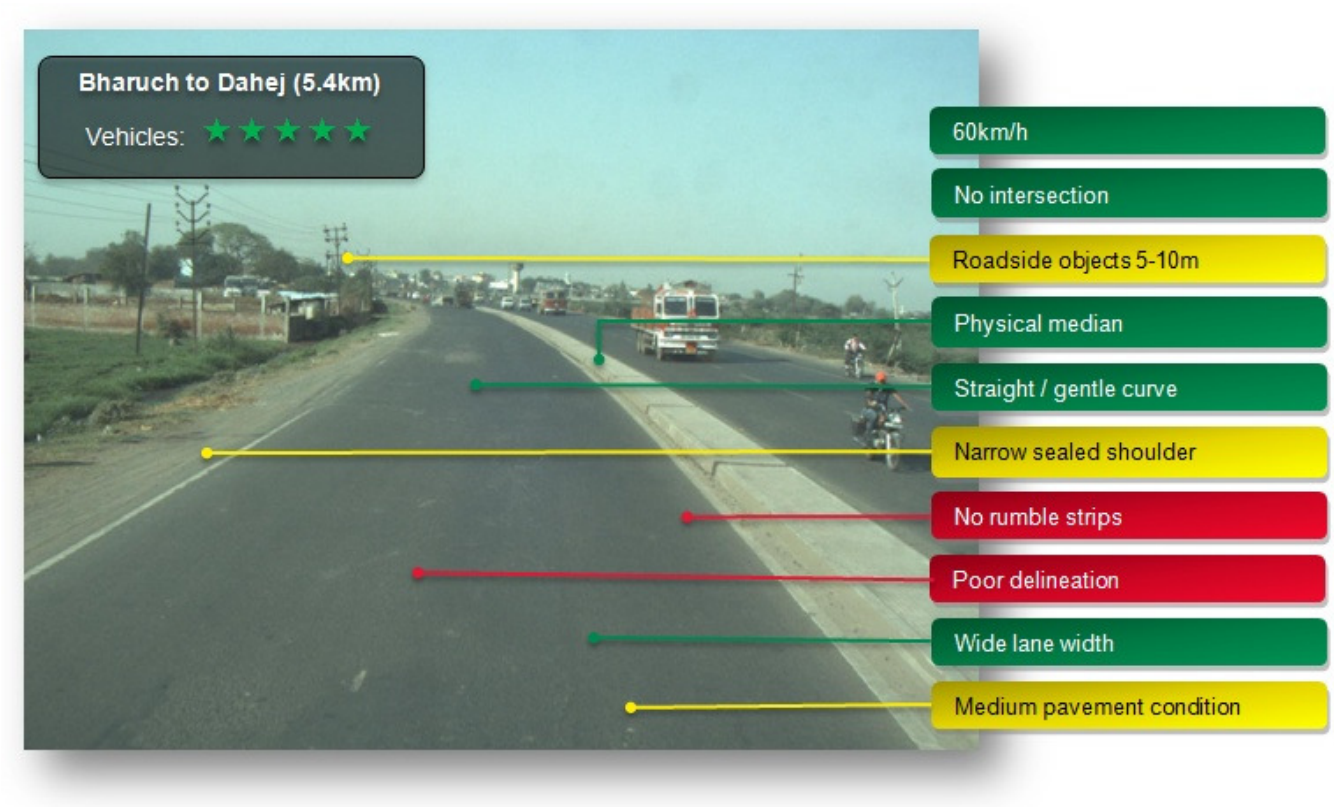


Figure 11 Example of 4-Star Rating for vehicle occupants

Figure 12 Example of 3-Star Rating for vehicle occupants

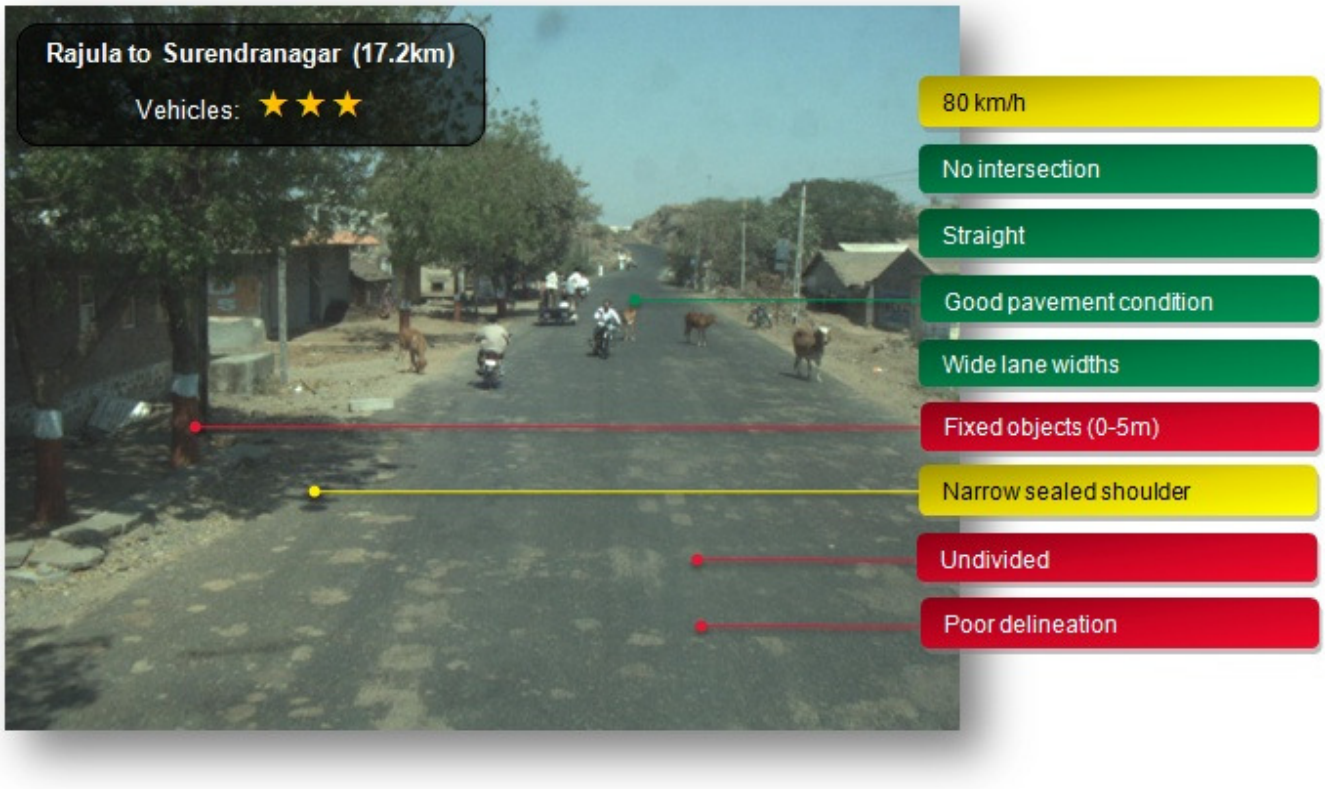


Figure 13 Example of 2-Star Rating for vehicle occupants

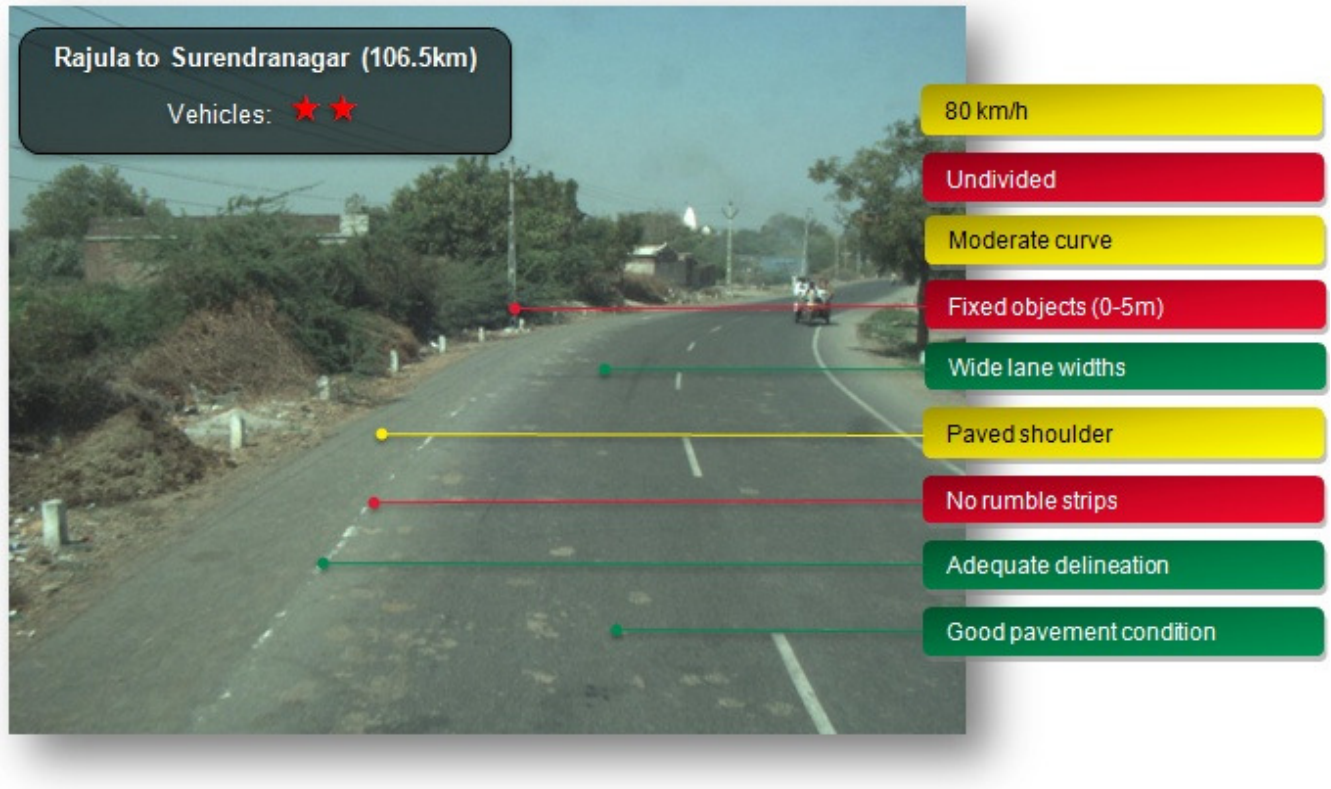
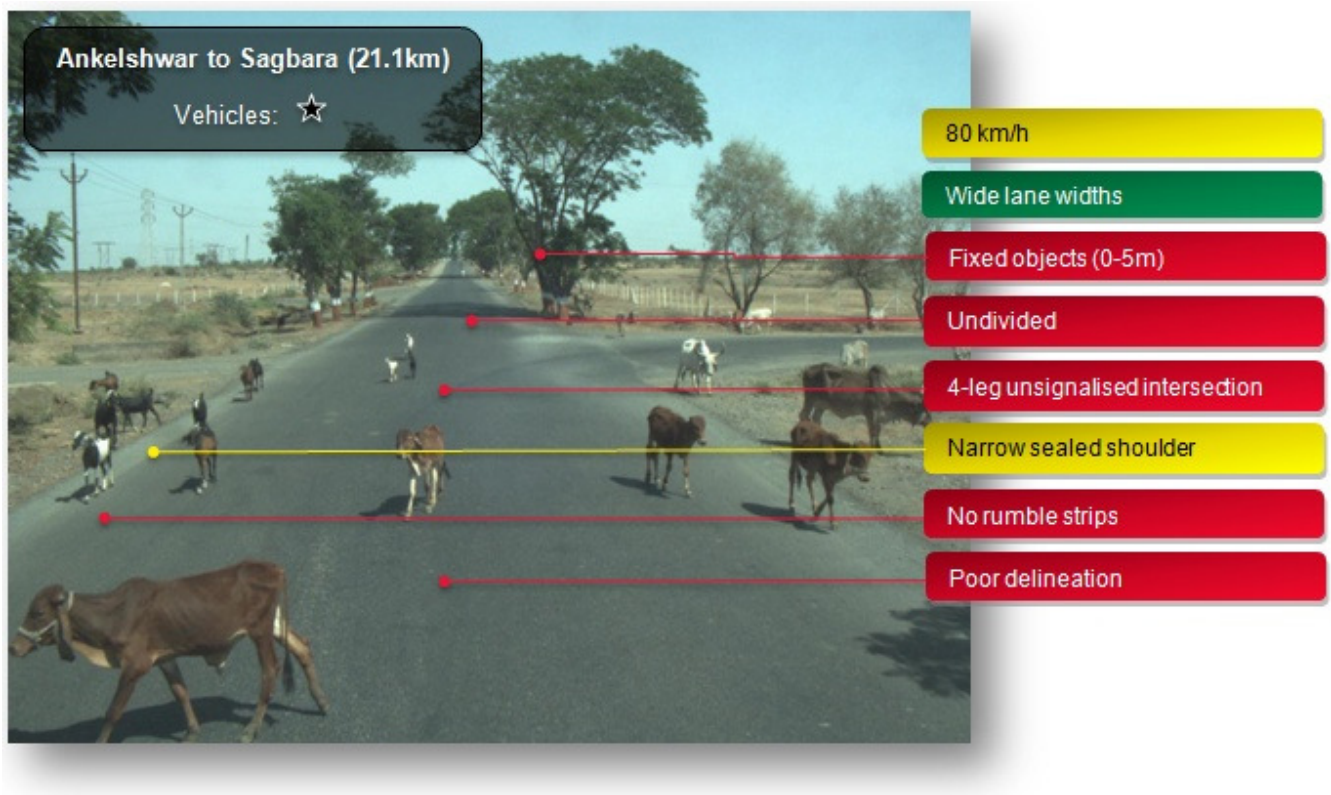


Figure 14 Example of 1-Star Rating for vehicle occupants



6.2 The Star Rating Results

The combined Star Rating results for all road sections surveyed within the iRAP India Four States Project demonstrate that there is potential to improve the safety of road infrastructure for all users. High risk roads feature significantly in the results with the majority of the surveyed network rated 2-stars or less (out of a possible of 5-stars) for vehicle occupants, motorcyclists, bicyclists and pedestrians. Almost three-quarters (72%) of the roads surveyed have been rated as high risk (1 and 2-stars) for vehicle occupants; whilst 88% was rated in the high risk categories for motorcyclists. Almost the entire network where pedestrians and bicyclists were present was rated as high risk.

Table 8 Star Ratings

Road user	5 Star	4 Star	3 Star	2 Star	1 Star	Not rated
Vehicle occupants	0%	7%	21%	51%	21%	0%
Motorcyclists	0%	4%	8%	40%	48%	0%
Bicyclists *	0%	0%	1%	35%	20%	44%
Pedestrians*	0%	0%	1%	81%	0%	18%

* Star Ratings are not produced for sections where road user type is not present.

The following images show a sample of the Star Rating results for vehicle occupants and pedestrians in each of the four states. Maps showing all the Star Ratings results for all users (including motorcyclists and bicyclists) are shown in the individual Road Safety Summary Reports (see Table 1) and are also available in the iRAP online software at www.iraptools.net.

Figure 15 Vehicle occupant Star Ratings, Assam

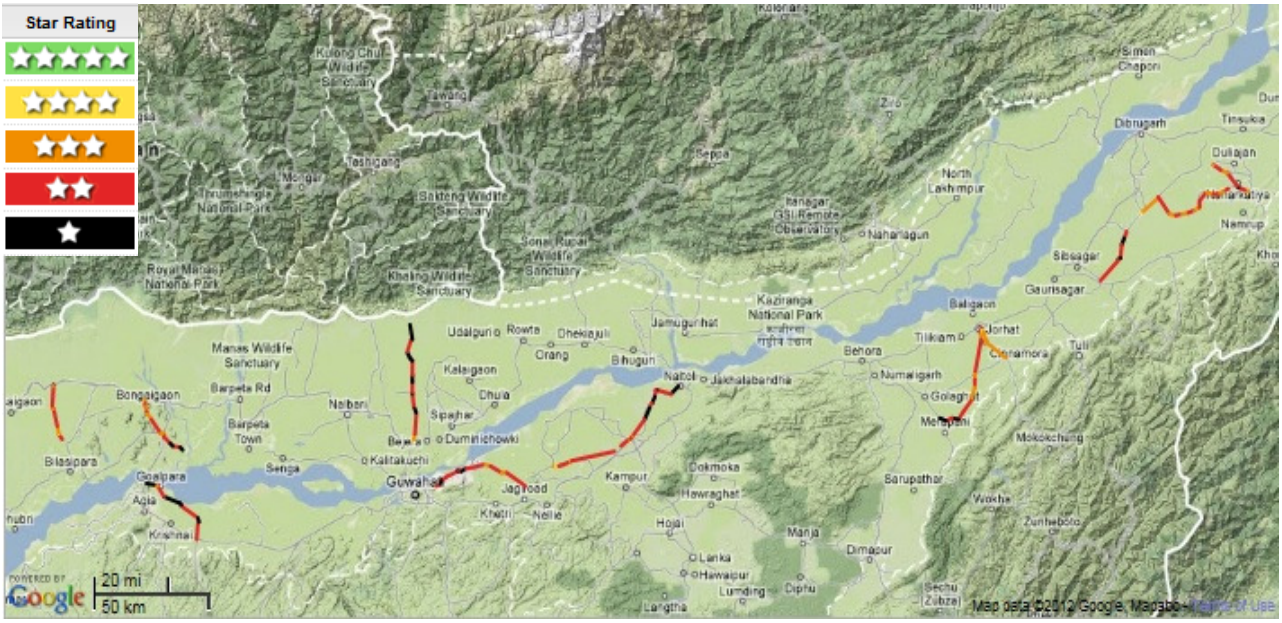


Figure 16 Pedestrian Star Ratings, Assam

Figure 17 Star Ratings for vehicle occupants, Gujarat

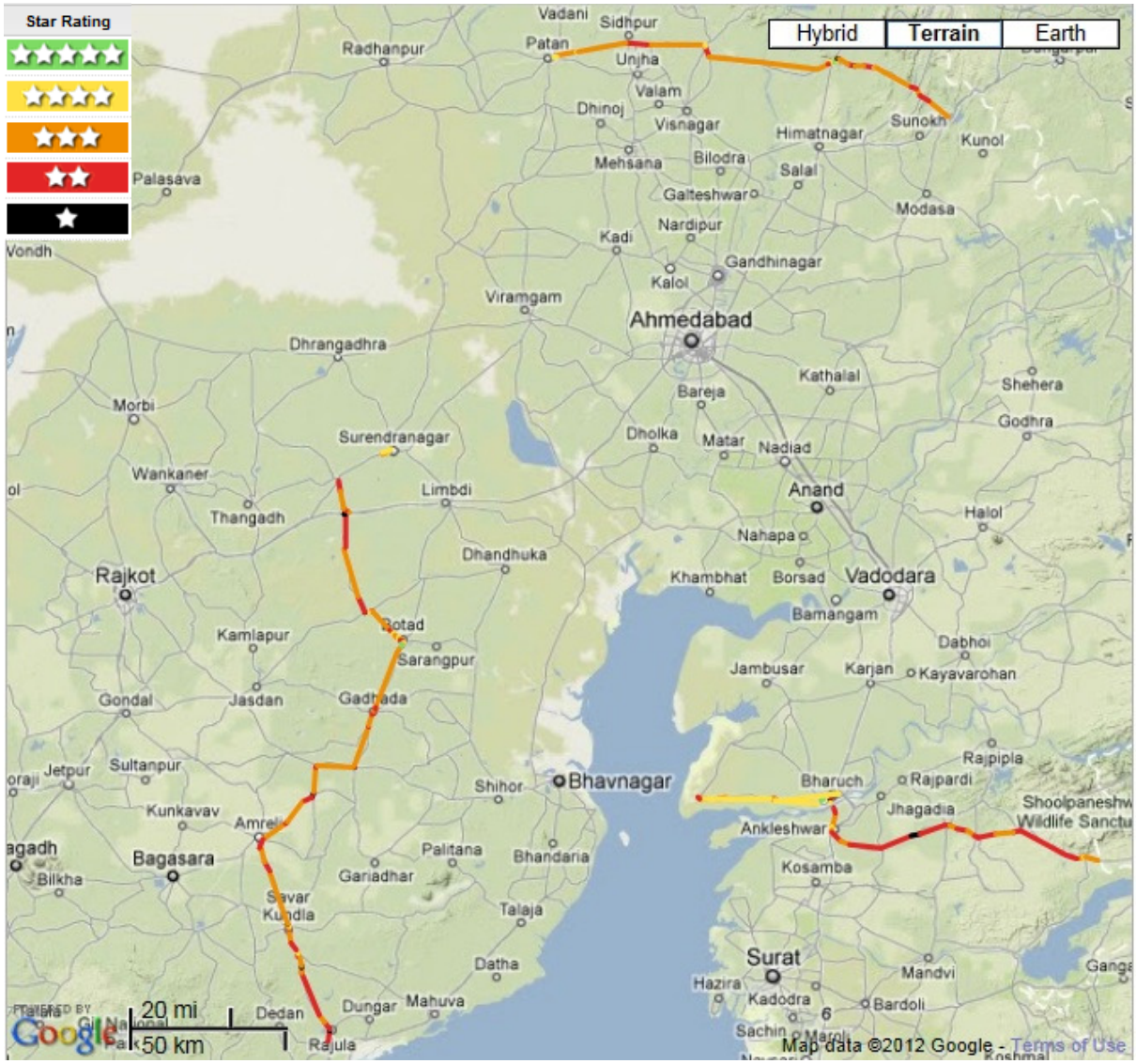


Figure 18 Star Ratings for pedestrians, Sagbara to Dahej, Gujarat

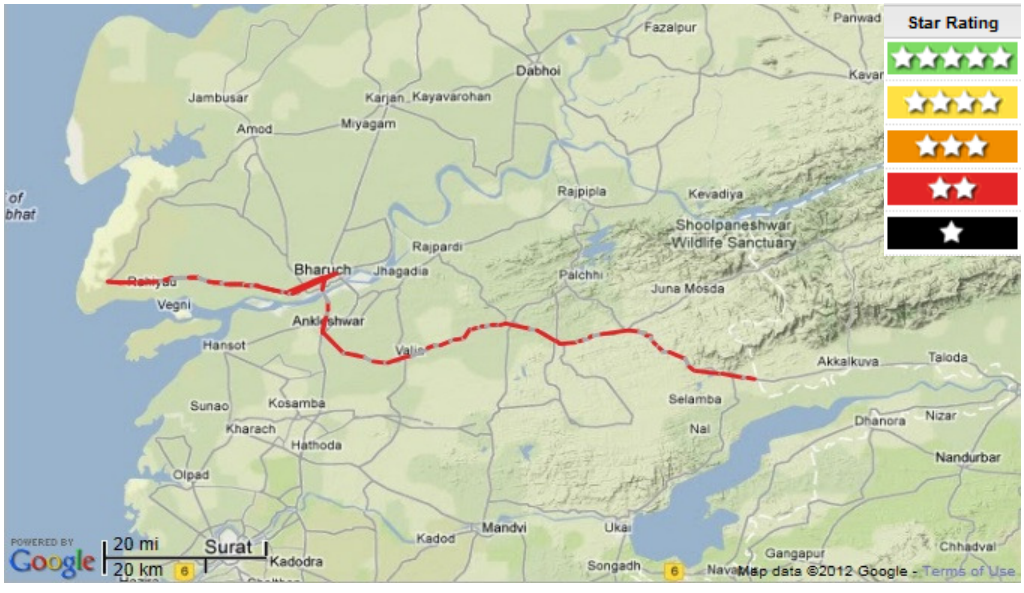


Figure 19 Star Ratings for vehicle occupants, Karnataka

Figure 20 Star Ratings for pedestrians, Karnataka

Figure 21 Star Ratings for vehicle occupants, SH31, Andhra Pradesh

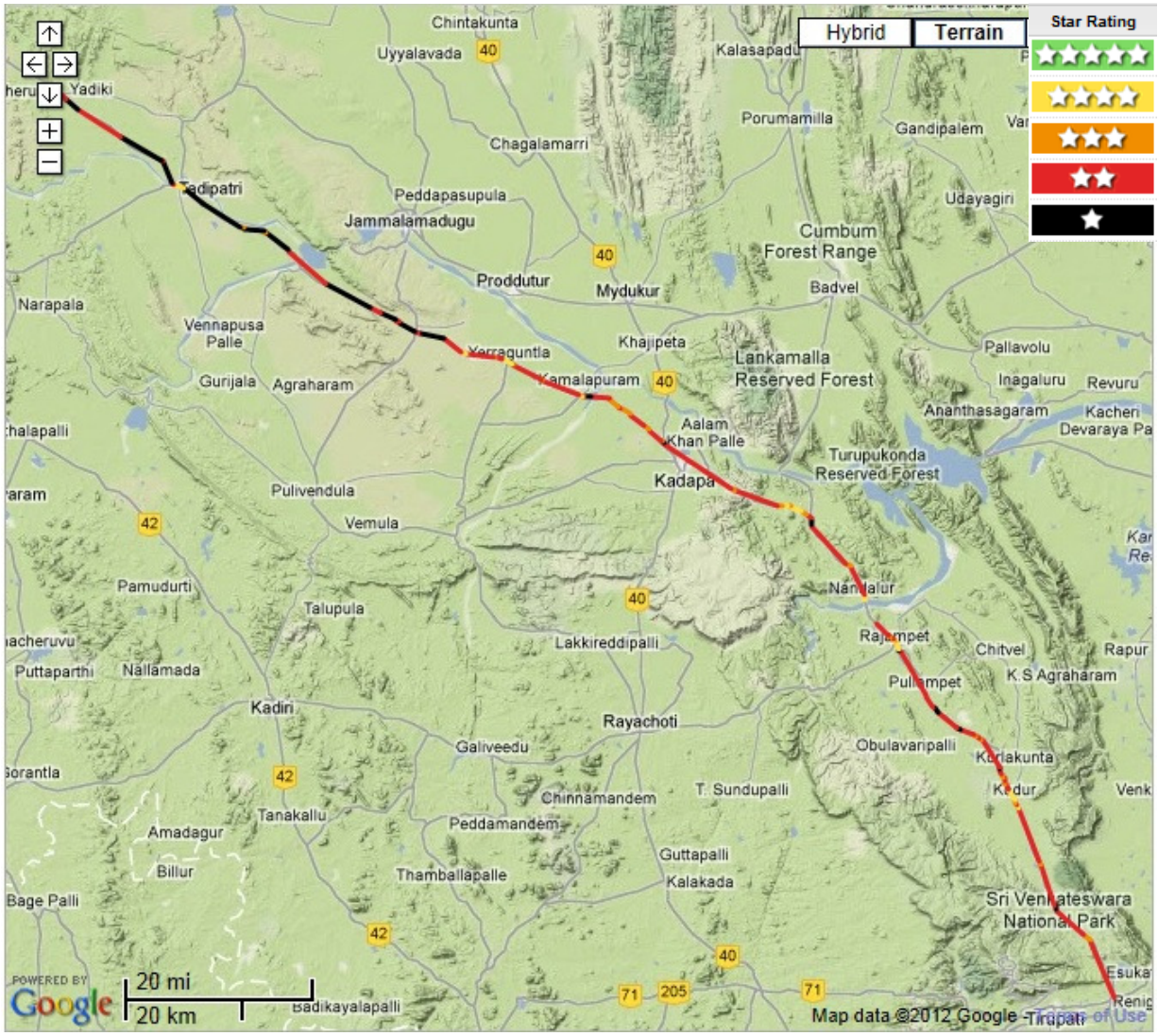


Figure 22 Star Ratings for vehicle occupants, SH4, Andhra Pradesh

7 Safer Roads Investment Plans

iRAP considers more than 70 proven road improvement options to generate affordable and economically sound Safer Road Investment Plans 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.

Plans are developed in three key steps:

1. Drawing on the Star Ratings and traffic volume data, estimated numbers of deaths and serious injuries are distributed throughout the road network.
2. For each 100 metre section of road, countermeasure options are tested for their potential to reduce deaths and injuries. For example, a section of road that has a poor pedestrian Star Rating and high pedestrian activity might be a candidate for a pedestrian refuge, pedestrian crossing or signalised pedestrian crossing.
3. Each countermeasure option is assessed against affordability and economic effectiveness criteria. The economic benefit of a countermeasure (measured in terms of the economic benefit of the deaths and serious injuries prevented) must, at a minimum, exceed the cost of its construction and maintenance (that is, it must have a benefit cost ratio (BCR) greater than one). In many circumstances, the 'threshold' BCR for a plan is lifted above one, which has the effect of reducing the overall cost of the plan. This helps to ensure that the plan is affordable while representing a positive return on investment and the responsible use of public money.

The individual Safer Roads Investment Plans for each separate study within the India Four States Project can be found within each summary report, further detailed analysis is available through the iRAP online software and the methodology underpinning this process is available in *Safer Roads Investment Plans: The iRAP Methodology* (www.irap.org/library.aspx).

Similar treatments are repeatedly recommended for investigation across the various individual studies. The most common among these include the removal of roadside hazards, paved shoulder widening, road surface upgrades, intersection upgrades and improvements to delineation. Facilities for vulnerable road users also feature regularly within the investment plans with pedestrian footpaths and crossings, bicycle lanes and motorcycle lanes being recommended as economically viable countermeasures.

When the results of the Safer Roads Investment Plans are combined the analysis shows that an investment of US$513million has the potential to save an estimated 565 lives per year across the surveyed network. With a benefit to cost ratio of 4.4 and a 40% reduction in the number of deaths and serious injuries, the programme represents a sound investment and an opportunity to prevent

almost 125,000 deaths and serious injuries over the next 20 years. A summary of the combined investment plan is shown in the table below.

Table 9 Economic analysis

India Four States Project	Indian Rupee	US$*
Investment	27,000,000,000	513,000,000
Economic benefit (20 years)	119,500,000,000	2,270,000,000
Benefit cost ratio (bcr)	4.4	
Deaths (per year)		
Before countermeasures	1,419	
After countermeasures	854	
Prevented	565	
Deaths and serious injuries (20 years)		
Before countermeasures	312,077	
After countermeasures	187,879	
Prevented	124,198	
Reduction	40%	
Cost per death and serious injury prevented	217,500	4,130

*Conversion rate used: 1 INR = 0.019 USD (19.12.2011)

8 Implementation and recommendations

The road attribute data shows that the majority of the survey was conducted along a two-lane, single carriageway rural network, with very little physical separation between opposing flows. Roadside hazards are numerous, with most of the survey length having hazardous objects within 5m of the running lane and limited road side protection. Provision for vulnerable road users is poor with no motorcycle or bicycle facilities present and insufficient footpath provision and crossing facilities where pedestrian numbers are high.

The recommendations primarily seek to improve facilities for vulnerable road users and to reduce the risk of head-on, run-off and intersection crashes for motorised users. Along with roadside safety improvements and the segregation of opposing flows, intersection upgrades also featured prominently in all Safer Roads Investment Plans (SRIPs) with roundabouts, signalisation, turn lanes and improved delineation providing good returns on investment.

iRAP is currently working alongside each of the four states to ensure that the recommendations from each of the SRIPs are considered for implementation. Every proposed countermeasure is supported by strong evidence that, if implemented, it will prevent deaths and serious injuries in a cost-effective way (a minimum threshold BCR of 1 was used). Nevertheless, each countermeasure should be subject to additional prioritisation, concept planning and detailed design before implementation.

8.1 Secured funds and implementation support needs

The iRAP recommendations provide the basis for high economic return improvements that will prevent death and serious injury. The inclusion of these life saving treatments in each of the loan packages is essential to ensure the realisation of the benefits of the iRAP assessments in each state.

The following table below shows the total loan packages available for each project and the value of the recommended iRAP Safer Roads Investment Plan in addition to the estimate of deaths and serious injuries that can be prevented over 20 years.

Table 10 Secured funds and implementation support needs

Bank Project	Loan amount ($ million)	Road Safety Component ($ million)	iRAP recommended investment on surveyed network ($ million)	Estimate of deaths and serious injuries prevented (20yrs)	Funds secured to date ($ million)	Estimate of deaths and serious injuries prevented (20yrs) based on secured funds
APRSP (Andhra Pradesh)	320	18.6	97.8	41,659	Ongoing implementation support will be required during 2012-2013 to secure leveraged funds (as per KSHIP II below). This will ensure that iRAP recommendations are included within the design bidding documents and minimum star rating targets are successfully achieved for the upgraded corridors.	
ASRP (Assam)	320	12	93	18,110		
GSHP II (Gujarat)	375	tbd*	55.6	14,471		
NHIIP I (Karnataka)	500	tbd*	94.2	15,155		
KSHIP II (Karnataka)	350	14	172	34,492	120	22,484

*tbd: to be decided

Many of the treatments can be incorporated into the primary loan package as they relate to typical cross-section design features to be included in the rehabilitation work (e.g. capacity improvements, lane and shoulder widening, road surface upgrades and pedestrian facilities). The smaller road safety component may be utilised for the targeted, site specific road safety countermeasures such as roadside hazard removal, traffic calming and intersection upgrades.

For example in the KSHIP II project, the iRAP recommended treatments for the annuity concession roads included road surface upgrades, paved shoulder widening, lane widening and improved delineation, all of which had been independently identified by the design team for inclusion in the rehabilitation works using IRC (Indian Roads Congress) standards. This meant that the road safety component could be used to include improvements such as speed reducing features in urban areas, footpaths and pedestrian crossings, dedicated motorcycle lanes and turning lanes at intersections.

Details of the funds secured to date have been shown (where implementation support activities have already begun) and an estimate of pro-rata deaths and serious injuries prevented is also provided. For the remaining projects further implementation support will be required during the 2012-2013 programme to ensure that the necessary funds are secured to include all viable cost effective road safety treatments recommended by iRAP and to ensure that minimum Star Rating targets are achieved.

8.2 Commit to a Safe System approach

The investment plans contain infrastructure improvements that can be set in place immediately. To complement those improvements, a series of additional measures need to be implemented, and a longer-term safety strategy set in place.

The Safe System approach is based on the theory that all humans make mistakes, but that a mistake made on the highway should not result in death or serious injury. It recognises that the human body is vulnerable and is unlikely to survive an uncushioned impact at speeds of 30km/h or more.

When these occasional, but inevitable mistakes occur on our busy roads, it stands to reason that collisions or crashes will result. Currently some of these collisions have fatal consequences, and others are less severe. The Safe System provides a forgiving highway infrastructure, one which recognises that mistakes will be made and attempts to minimise their occurrence, and the forces involved in a resulting crash, to reduce its severity to survivable levels.

The Safe System approach includes engineering measures such as the removal or protection of roadside hazards, the re-design of roads and roadsides to reduce risk to a minimum and the setting of speed limits according to the existing levels of infrastructure safety. The adoption of this approach is recommended.

8.3 Engage with local communities

In order to make India's road network safer for all its users, efforts that go beyond traditional engineering improvements will also be necessary. For example, research has demonstrated that it is crucial to ensure that local communities not only have the opportunity to contribute to new road designs but that they also understand the intended use of various road design features.[18]

Star Ratings can be used to effectively communicate the need for safe road design, not only within each PWD, but also to local residents and other stakeholders. Using Star Ratings will allow opportunities to celebrate success i.e. Ministers, local politicians, and/or road authorities can celebrate road safety upgrades "1-star road upgraded to 3-star standard etc."

In addition to the road safety engineering upgrades, significant benefits could also be realised through the coordinated targeting of behavioural risk factors for road users (such as speeding, seat belt wearing, the adherence to traffic regulations and alcohol use) and road vehicle safety (i.e. ABS brakes, side-impact bars and airbags). This would be consistent with taking a Safe System approach to the programme. The Road Safety Toolkit (toolkit.irap.org) and United Nations Road Safety Collaboration Good Practice Manuals provide further information on these issues.[19]

[18] BRAC Annual Report 2009 http://www.brac.net/

[19] UN Road Safety Collaboration manuals: http://www.who.int/roadsafety/projects/manuals/en/index.html

8.4 Star Rating new road designs

Star Ratings can objectively quantify the level of risk associated with new road designs and provide a platform to make evidence-based improvements. They have been used by the project implementation unit at the Karnataka State Highway Improvement Project (KSHIP) to help shape the design of 550km of road and this approach is recommended for all future projects.

By engaging consultants to Star Rate the proposed designs, KSHIP was able 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.

The approach has resulted in a reduction of the percentage of road rated 1- or 2-stars for vehicle occupants from 86% to 2%. For pedestrians, the percentage of high risk roads dropped from 100% to 12%. It is estimated that the improvements will prevent approximately 30,000 deaths and serious injuries over 20 years, with the estimated annual death toll on the corridor dropping from 248 to 111 per year, representing a 55% reduction across the surveyed network.[20]

8.5 Set policy targets

With the ever increasing death toll on India's road network it is strongly recommended that each of the participating states set policy targets to stabilise and then reduce the forecasted level of road traffic fatalities in line with the recommendations discussed in the *Global Plan for the Decade of Action for Road Safety 2011-2020*. Recommendations include:

- Set a target to eliminate high risk (1- and 2-star) roads by the end of the Decade of Action for Road Safety (2020).
- Set minimum Star Ratings for all new road designs to ensure that no more killer roads are built. For example, a road authority could set a policy stating that all new roads shall be built to a minimum 3-star standard for all road users.
- iRAP Star Rating and Investment Plans for the highest risk or highest volume 10% of roads in the country/state. For example, the Andhra Pradesh Road Development Corporation is keen to progress from pilot study to full programme with an extension of the iRAP survey. 17,000km are planned for 2012 and a further 25,000km the following year.

For further information on the setting of road safety policy targets, the development of local and national action plans and implementing sustainable road safety strategies, refer to the *Global Plan for the Decade of Action for Road Safety 2011-2020*.

[20] iRAP, *Star Rating Road Designs: Performance Indicators for Roads in India*, 2012.

9 Appendices

9.1 Appendix A: Investment Plan Summary and Top 5 Road Safety Countermeasures

The follow tables show the investment plan summary for each investment option analysed where applicable. Also included are the details of the top 5 recommended countermeasures (in terms of estimated deaths and serious injuries prevented), based on a minimum bcr of 1 for all treatments.

Andhra Pradesh (SH4, SH31 & SH38 combined)

Investment Plan Summary (US$)	Option 1	Option 2	Option 3	Option 4	Option 5
Investment (m)	82.2	18.6	6.9	2.8	1.1
Economic benefit (20 years) (m)	690.8	430.1	267.0	160.1	95.0
Benefit cost ratio	8	23	39	58	86
Deaths (per year)					
Before countermeasures	*370*	*370*	*370*	*370*	*370*
After countermeasures	*188*	*257*	*299*	*328*	*345*
Prevented	*182*	*113*	*71*	*42*	*25*
Deaths and serious injuries (20 years)					
Before countermeasures	*81,400*	*81,400*	*81,400*	*81,400*	*81,400*
After countermeasures	*41,295*	*56,443*	*65,880*	*72,121*	*75,867*
Prevented	40,105	24,957	15,520	9,279	5,533
Reduction	*49%*	*31%*	*19%*	*11%*	*7%*
Cost per death and serious injury prevented	*$2,051*	*$744*	*$446*	*$300*	*$199*

Top 5 Road Safety Countermeasures	Length / Sites	KSIs prevented (20yrs)	BCR
Shoulder sealing/widening	305km	12,253	9.81
Pedestrian footpath	202km	8,812	14.01
Roadside hazard removal	426km	6,538	8.00
Pedestrian crossing facility	220 sites	3,078	12.93
Roadside safety barriers	223km	2,989	3.57

Assam (all roads)

Investment Plan Summary (US$)	Option 1
Investment (m)	93
Economic benefit (20 years) (m)	366
Benefit cost ratio	4
Deaths (per year)	
Before countermeasures	*113*
After countermeasures	*31*
Prevented	*82*
Deaths and serious injuries (20 years)	
Before countermeasures	*24,760*
After countermeasures	*6,650*
Prevented	18,110
Reduction	73%
Cost per death and serious injury prevented	$5,100

Top 5 Road Safety Countermeasures	Length / Sites	KSIs prevented (20yrs)	BCR
Roadside hazard removal	617km	4,544	7.08
Shoulder sealing/widening	320km	3,560	3.35
Road surface upgrade	207km	2,288	6.36
Pedestrian crossing facility	808 sites	1,728	4.72
Lane widening	93km	1,516	1.91

Gujarat (all roads)

Investment Plan Summary (US$)	Option 1
Investment (m)	56
Economic benefit (20 years) (m)	300
Benefit cost ratio	5
Deaths (per year)	
Before countermeasures	*221*
After countermeasures	*154*
Prevented	*67*
Deaths and serious injuries (20 years)	
Before countermeasures	*48,580*
After countermeasures	*33,798*
Prevented	*14,782*
Reduction	30%
Cost per death and serious injury prevented	$3,800

Top 5 Road Safety Countermeasures	Length / Sites	KSIs prevented (20yrs)	BCR
Roadside hazard removal	596km	5,751	5.93
Shoulder sealing/widening	122km	2,525	5.41
Pedestrian footpath	78km	1,545	2.90
Pedestrian crossing facility	155 sites	1,083	10.39
Improve delineation	163km	739	14.59

Karnataka: KSHIP Annuity Roads

Investment Plan Summary (US$)	Option 1
Investment (m)	107
Economic benefit (20 years) (m)	454
Benefit cost ratio	4
Deaths (per year)	
Before countermeasures	*186*
After countermeasures	*84*
Prevented	*102*
Deaths and serious injuries (20 years)	
Before countermeasures	*40,920*
After countermeasures	*18,429*
Prevented	*22,491*
Reduction	55%
Cost per death and serious injury prevented	$4,800

Top 5 Road Safety Countermeasures	Length / Sites	KSIs prevented (20yrs)	BCR
Road surface upgrade	260km	4,963	4.15
Shoulder sealing/widening	396km	4,945	3.46
Lane widening	147km	3,839	2.72
Roadside hazard removal	145km	3,091	10.58
Improve delineation	291km	2,568	30.73

Karnataka: KSHIP SCDP SH17

Investment Plan Summary (US$)	Option 1	Option 2	Option 3	Option 4
Investment (m)	19.8	9.7	5.8	3.2
Economic benefit (20 years) (m)	105	86	67	47
Benefit cost ratio	5	9	12	15
Deaths (per year)				
Before countermeasures	*71*	*71*	*71*	*71*
After countermeasures	*47*	*52*	*56*	*60*
Prevented	*24*	*19*	*15*	*11*
Deaths and serious injuries (20 years)				
Before countermeasures	*15,653*	*15,653*	*15,653*	*15,653*
After countermeasures	*10,456*	*11,376*	*12,340*	*13,314*
Prevented	*5,197*	*4,277*	*3,313*	*2,339*
Reduction	33%	27%	21%	15%
Cost per death and serious injury prevented	$3,800	$2,300	$1,750	$1,400

Top 5 Road Safety Countermeasures	Length / Sites	KSIs prevented (20yrs)	BCR
Roadside hazard removal	73km	1,306	11.65
Intersection - signalise	78 sites	1,195	5.93
Intersection - delineation	160 sites	866	3.11
Intersection – right turn lanes	91 sites	505	3.72
Motorcycle lanes	76km	403	7.24

Karnataka: KSHIP SCDP SH20

Investment Plan Summary (US$)	Option 1	Option 2	Option 3	Option 4
Investment (m)	45.1	9.8	6.8	3.4
Economic benefit (20 years) (m)	139	73	60	41
Benefit cost ratio	3	7	9	12
Deaths (per year)				
Before countermeasures	*82*	*82*	*82*	*82*
After countermeasures	*51*	*66*	*68*	*73*
Prevented	*31*	*16*	*14*	*9*
Deaths and serious injuries (20 years)				
Before countermeasures	*17,956*	*17,956*	*17,956*	*17,956*
After countermeasures	*11,078*	*14,340*	*14,974*	*15,941*
Prevented	*6,878*	*3,616*	*2,982*	*2,015*
Reduction	38%	20%	17%	11%
Cost per death and serious injury prevented	$6,500	$2,700	$2,300	$1,700

Top 5 Road Safety Countermeasures	Length / Sites	KSIs prevented (20yrs)	BCR
Duplication	38km	2,302	2.15
Roadside hazard removal	216km	1,870	6.57
Shoulder sealing/widening	104km	916	2.68
Pedestrian crossing facility	93 sites	507	10.10
Intersection – right turn lanes	47 sites	241	2.77

Karnataka: National Highways (NH234 & NH206)

Investment Plan Summary (US$)	Option 1
Investment (m)	94
Economic benefit (20 years) (m)	306
Benefit cost ratio	3
Deaths (per year)	
Before countermeasures	*147*
After countermeasures	*78*
Prevented	*69*
Deaths and serious injuries (20 years)	
Before countermeasures	*32,300*
After countermeasures	*17,145*
Prevented	*15,155*
Reduction	47%
Cost per death and serious injury prevented	$6,200

Top 5 Road Safety Countermeasures	Length / Sites	KSIs prevented (20yrs)	BCR
Roadside hazard removal	752km	4,638	3.68
Shoulder sealing/widening	367km	3,088	2.49
Improve delineation	481km	1,977	13.13
Road surface upgrade	83km	1,667	3.47
Lane widening	73km	1,661	1.89

9.2 Appendix B: List of abbreviations and acronyms

AADT	Annual Average Daily Traffic
AAUI	Automobile Association of Upper India
ABS	Anti-lock braking system
APRDC	Andhra Pradesh Road Development Corporation
ARRB	Australian Road Research Board
ASRP	Assam State Road Project
AusRAP	Australian Road Assessment Programme
BCR	Benefit cost ratio
BRAC	Bangladesh Rehabilitation Assistance Committee
EuroRAP	European Road Assessment Programme
FIA	Fédération Internationale de l'Automobile
FIAA	Federation of Indian Automobile Associations
GDP	Gross domestic product
GPS	Global Positioning System
GERI	Gujarat Engineering Research Institute
GRSF	Global Road Safety Facility
INR	Indian rupee
iRAP	International Road Assessment Programme
IRC	Indian Roads Congress
IRSM	Indian Road Survey and Management Pvt Ltd
KSHIP	Karnataka State Highway Improvement Project
KSI	Killed and serious injury
MoSRTH	Ministry of Shipping, Road Transport and Highways
PCU	Passenger Car Unit
PWD	Public Works Department
RAP	Road Assessment Programme
R&BD	Roads and Buildings Department
RPS	Road Protection Score
SRIP	Safer Roads Investment Plan
USD	United States dollar
usRAP	United States Road Assessment Programme
VKT	Vehicle kilometres travelled
WB	World Bank (International Bank for Reconstruction and Development)
WHO	World Health Organization

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