

## **RATING AND PRIORITIZATION OF ACCIDENT BLACK SPOTS AND ROAD SAFETY MEASURES. CASE STUDY: NATIONAL HIGHWAY 44 (AZADPUR TO SINGHU BORDER DELHI NCT)**

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### **ABSTRACT**

The study is focussed on star rating and prioritization of accident black spots based on severity and likelihood of accidents. The study also includes prioritization of road safety measures, economic analysis and investment plan for the same. The case study is an 18km road stretch on National Highway 44 in Delhi urban area, India. According to Delhi Police records, since 2008 more than 58000 people have faced injuries and about 15800 people have died in Delhi in road accidents. Study has been done on sixteen black spots identified along the national highway stretch. The data has been analyzed using International Road Assessment Program (iRAP) software, 'VIDA' and star rating scores have been calculated for vehicle occupants, Pedestrians, Motor Cyclists, Bicyclists separately at all blackspots. The findings suggest that an investment of about \$5 Million (USD) for Road safety counter measures on NH-44 Stretch from Azadpur to Singhu Border can save 9235 fatal & serious accidents in 20 years with Net Present Value of economic benefits \$28.46 Million (USD) & Benefit/Cost Ratio of 5.58

### **KEYWORDS**

Accident, fatalities, road safety, Accident blackspot, star rating

### **1. INTRODUCTION**

Road accident is a major but neglected public health issue worldwide. People deal with it on a day to day basis. As per World Health Organization, road traffic crashes is 8th leading cause of death and it is the main cause of death among those aged 15–29 years. Global Road Injury Mortality rate is 18 deaths per one lakh population and for India it is 18.9. 74 % of road traffic deaths occur in middle-income countries, which account for 70% of the world's population, but only 53% of the world's registered vehicles<sup>[1]</sup> As per National Crime Records Bureau, in India 1,77,423 people died in road accidents and 4,13,547 people got seriously injured in 1,48,707 road accidents in year 2015<sup>[2]</sup>. Out of the 53 metropolitan. The fatalities per 100 accidents (Accident Severity) in year 2014 was recorded highest in Ludhiana (66.9) followed by other metropolitan cities as shown in Table 1. The problem is dynamic and complex in nature and requires a collaborative effort of engineering, management, enforcement, education and

information technology measures. This paper deals with the engineering measure of blackspot prioritization to address the issue of road safety.

**TABLE 1 Top 10 Metro Cities Road Accident Statistics<sup>[3]</sup>**

| S. No | Fatal Accidents |      | Person Killed |      | Person Injured |      | Total Accidents |       | Accident Severity |      |
|-------|-----------------|------|---------------|------|----------------|------|-----------------|-------|-------------------|------|
| 1     | Delhi           | 1629 | Delhi         | 1671 | Chennai        | 9355 | Mumbai          | 22570 | Ludhiana          | 66.9 |
| 2     | Chennai         | 1083 | Chennai       | 1118 | Delhi          | 8283 | Chennai         | 9610  | Amritsar          | 57   |
| 3     | Bangaluru       | 703  | Bangaluru     | 729  | Indore         | 4848 | Delhi           | 8623  | Kanpur            | 48   |
| 4     | Kanpur          | 530  | Kanpur        | 600  | Bangaluru      | 4098 | Indore          | 5784  | Patna             | 41.3 |
| 5     | Lucknow         | 515  | Lucknow       | 537  | Mumbai         | 3938 | Bangaluru       | 5004  | Lucknow           | 39.6 |
| 6     | Mumbai          | 512  | Mumbai        | 534  | Kolkata        | 3604 | Kolkata         | 4561  | Surat             | 27.4 |
| 7     | Patna           | 493  | Agra          | 503  | Malapuram      | 3305 | Bhopal          | 3459  | Pune              | 25.4 |
| 8     | Allahabad       | 454  | Patna         | 493  | Jabalpur       | 3074 | Jabalpur        | 3124  | Jaipur            | 22.5 |
| 9     | Kolkata         | 431  | Allahabad     | 481  | Bhopal         | 2601 | Hyderabad       | 2908  | Delhi             | 19.4 |
| 10    | Raipur          | 425  | Kolkata       | 450  | Hyderabad      | 2561 | Mallapuram      | 2719  | Ahmedabad         | 16   |

## 2. ROAD ACCIDENT SCENARIO IN DELHI

As per Delhi police records, since 2008, 1280 accidents have occurred in Delhi in which 58640 people have got injured while 15660 people have died<sup>[4]</sup>. Accidents reported in year 2015 were 8,085, in which 1,582 fatalities occurred and 8,258 people were injured thus there were 9,880 road accident victims as shown in Table 2. This implies that 16.41% of victims lost their lives. This fatality rate was 16.79% in the year 2014.

**TABLE 2 Accident Trend in Delhi Up to 2015**

| Year         | Non-Injurious Accident | Non-Fatal Accidents | Fatal Accident | Total Accidents | Persons Injured | Persons Killed |
|--------------|------------------------|---------------------|----------------|-----------------|-----------------|----------------|
| 2008         | 362                    | 6058                | 2015           | 8435            | 7343            | 2093           |
| 2009         | 131                    | 5113                | 2272           | 7516            | 6936            | 2325           |
| 2010         | 63                     | 5093                | 2104           | 7260            | 7108            | 2153           |
| 2011         | 71                     | 5162                | 2047           | 7280            | 6975            | 2110           |
| 2012         | 115                    | 5000                | 1822           | 6937            | 6639            | 1866           |
| 2013         | 169                    | 5619                | 1778           | 7566            | 7098            | 1820           |
| 2014         | 209                    | 6785                | 1629           | 8623            | 8283            | 1671           |
| 2015         | 160                    | 6343                | 1582           | 8085            | 8258            | 1622           |
| <b>Total</b> | <b>1280</b>            | <b>45173</b>        | <b>15249</b>   | <b>61702</b>    | <b>58640</b>    | <b>15660</b>   |

Source: Road Accidents in Delhi 2015 Report

## 3. INTRODUCTION TO INTERNATIONAL ROAD ASSESSMENT PROGRAM (iRAP)

The International Road Assessment Program (iRAP) is a non-profit organization that works in partnership with government and non-government organizations for safer roads. They have developed online software named "VIDA" which gives star rating to roads in accordance to safety parameters. A road's Star Rating is based on an inspection of infrastructure elements that influence the likelihood and severity of crashes occurring on a road. Different road Protection Scores are produced for Car Occupants, Bicyclists, Pedestrians, motorized two wheeler Riders. Following the inspections of the road infrastructure elements, Star Rating Score (SRS) is calculated for each 100m section of road using the VIDA software. The SRS forms the basis for generating the Star Ratings (and, in turn, Safer Roads Investment Plans). A high score equates with a high level of risk, and a low score equates with a low level of risk.

**TABLE 3 Star Rating Corresponding to Mode wise Star Rating Score<sup>[5]</sup>**

| Star Ratings   | Star Rating Scores                |            |             |             |              |
|----------------|-----------------------------------|------------|-------------|-------------|--------------|
|                | Vehicle Occupants & Motorcyclists | Bicyclists | Pedestrians |             |              |
|                |                                   |            | Total       | Along       | Crossing     |
| <b>5 Stars</b> | 0 to < 2.5                        | 0 to < 5   | 0 to < 5    | 0 to < 0.2  | 0 to < 4.8   |
| <b>4 Stars</b> | 2.5 to < 5                        | 5 to < 10  | 5 to < 15   | 0.2 to < 1  | 4.8 to < 14  |
| <b>3 Stars</b> | 5 to < 12.5                       | 30 to < 30 | 15 to < 40  | 1 to < 7.5  | 14 to < 32.5 |
| <b>2 Stars</b> | 12.5 to 22.5                      | 30 to < 60 | 40 to < 90  | 7.5 to < 15 | 32.5 to < 75 |
| <b>1 Star</b>  | 22.5+                             | 60 +       | 90+         | 15+         | 75+          |

After star rating the model is calibrated, an estimate of the existing number of deaths and serious injuries at any point on the network can be made. This information can then be used to examine the potential death and serious injury reduction that is possible through the application of proven engineering countermeasures at any location. The countermeasures are also subject to a hierarchy, with the most comprehensive countermeasures taking precedence. This ensures that there is no duplication of treatments that impact the same road feature. The step is followed by a comprehensive road safety investment plan in which unit rates of every countermeasure treatment are taken by applying wholesale price index of current year schedule of rates provided by Public Works Department (PWD) India

#### 4. MEASURES TO IMPROVE ROAD ACCIDENTS

The basic principle of road safety is to improve “Driver expectancy” by removing ambiguity in road environment. The geometric design of roads must be consistent without any abrupt change. Further special care must be taken for protection of vulnerable road Users like Pedestrians and Bicyclists. The major road safety measures that have been applied on the accident black spots have been briefly described in Table 4.

**TABLE 4 Major Engineering Treatments<sup>[6]</sup>**

| S. No | Safety measure                       | Cost   | Life Years | Effectiveness | Remark   |
|-------|--------------------------------------|--------|------------|---------------|--|
| 1     | Additional Lane, Lane widening       | High   | 10-20      | 25-40%        | Provides a safe opportunity for one direction of traffic to overtake and can improve traffic flow. |
| 2     | Road safety Barriers                 | Medium | 10-20      | 40-60%        | Flexible, rigid or semi rigid barriers made of steel, rails etc.                                   |
| 3     | Delineation                          | Low    | 1-5        | 10-25%        | Line markings, retro reflective markers, guideposts, warning signs, chevron signs                  |
| 4     | Signalized intersections             | Medium | 10-20      | 25-40%        | vehicle actuated signals with dynamic signal time cycle & pedestrian phase                         |
| 5     | Pedestrian Facilities                | Medium | 10-20      | 40-60%        | Pedestrian Fencing, refuge islands, Footpaths  |
| 6     | Shoulder sealing                     | Medium | 5-10       | 25-40%        | reduces head on crashes, better grip, and serve as safe cycling space                              |
| 7     | Traffic Calming measures             | Medium | 10-20      | 25-40%        | speed humps, table topping, kerb built-outs, roundabouts   |
| 8     | Speed management                     | Medium | 5-10       | 25-40%        | Roundabouts, Gateway treatments, pavement narrowing , curve treatments                             |
| 9     | Grade separated Pedestrian Crossings | High   | 10-20      | Above 60%     | Eliminate Pedestrian-Vehicular conflicts   |
| 10    | Service lanes & Bicycles lanes       | High   | 10-20      | 40-60%        | Safe Movement Of Vulnerable Road Users   |

## 5. CASE STUDY: DELHI NCT (TOP 10 BLACK SPOTS)

As per Delhi police, an accident Blackspot has been defined as a location on road where 3 or more fatal accidents or 10 or more non-fatal accidents take place within a year. Out of 137 black spots identified by Delhi Police, 16 black spots lying within the Delhi Urban area along an 18km stretch on National Highway 44 have been studied and more than 90 road attributes have been recorded such as delineation, median type, pavement condition, curve sharpness, street lightening etc. As shown in Table 5, 197 accidents have taken place on these blackspots in year 2015 in which 84 people have died while 113 faced serious injuries

**TABLE 5 Blackspots Spots NH-44 from Azadpur to Singhu Border <sup>[5]</sup>**

| S.No. | Accident Prone Zones | Non-Fatal Accident | Fatal Accident | Total Accidents |
|-------|----------------------|--------------------|----------------|-----------------|
| 1     | Azadpur Bus Terminal | 10                 | 1              | 11              |
| 2     | Azadpur Chowk        | 10                 | 8              | 18              |
| 3     | Azadpur Sabzi Mandi  | 10                 | 9              | 19              |
| 4     | Mukharba Chowk       | 4                  | 8              | 12              |
| 5     | SGT Nagar            | 7                  | 8              | 15              |
| 6     | CNG Pump SGT Nagar   | 3                  | 8              | 11              |
| 7     | Libaspur Bus Stand   | 7                  | 3              | 10              |
| 8     | Swaroop Nagar        | 6                  | 4              | 10              |
| 9     | Nangli Budhpur       | 3                  | 7              | 10              |
| 10    | Budhpur Ganda Nala   | 9                  | 4              | 13              |
| 11    | Sai Baba Mandir      | 6                  | 5              | 11              |
| 12    | Shani Mandir         | 6                  | 3              | 9               |
| 13    | Bakoli Bus Stand     | 11                 | 3              | 14              |
| 14    | Khampur Village      | 6                  | 3              | 9               |
| 15    | Tikri Khurd Village  | 8                  | 5              | 13              |
| 16    | Singhu Border        | 7                  | 5              | 12              |
|       | <b>Total</b>         | <b>113</b>         | <b>84</b>      | <b>197</b>      |

## 6. BLACK SPOT ANALYSIS

### 6.1 Near Azadpur Bus Terminal

**TABLE 6 Mode wise Star Rating on NH-44 near Azadpur Bus Terminal**

| Star Rating  | Vehicle Occupant |             | Motorcycle |             | Pedestrian |             | Bicycle  |             |
|--------------|------------------|-------------|------------|-------------|------------|-------------|----------|-------------|
|              | Length (Km)      | %           | Length     | (%)         | Length     | %           | Length   | %           |
| 5 Star       | 0                | 0           | 0          | 0           | 0          | 0           | 0        | 0           |
| 4 Star       | 0                | 0           | 0          | 0           | 0          | 0           | 0        | 0           |
| 3 Star       | 0.5              | 25          | 0.5        | 25          | 0.8        | 40          | 0        | 0           |
| 2 Star       | 0.40             | 20          | 0.4        | 20          | 1.2        | 60          | 1.9      | 95          |
| 1 Star       | 1                | 55          | 1.1        | 55          | 0          | 0           | 0.1      | 5           |
| <b>Total</b> | <b>2</b>         | <b>100%</b> | <b>2</b>   | <b>100%</b> | <b>2</b>   | <b>100%</b> | <b>2</b> | <b>100%</b> |

### Inference

Analysis results show that 55% of road stretch near Bus Terminal has 1 star rating for four Wheeler riders and Motorcyclists. While 95% of the stretch has 2 star rating for Bicyclists and 60% of the stretch has 2 Star rating for Pedestrians.

## 6.2 Near Azadpur Junction

**TABLE 7 Mode wise Road Star Rating On NH-44 near Azadpur Junction**

| Star Rating  | Vehicle Occupant |            | Motorcycle |            | Pedestrian |            | Bicycle  |            |
|--------------|------------------|------------|------------|------------|------------|------------|----------|------------|
|              | Length(Km)       | %          | Length     | %          | Length     | %          | Length   | %          |
| 5 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0        | 0          |
| 4 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0        | 0          |
| 3 Star       | 0.5              | 50         | 0.5        | 50         | 0          | 0          | 0        | 0          |
| 2 Star       | 0.00             | 0          | 0          | 0          | 0          | 0          | 0.9      | 90         |
| 1 Star       | 1                | 50         | 0.5        | 50         | 1          | 100        | 0.1      | 10         |
| <b>Total</b> | <b>1</b>         | <b>100</b> | <b>1</b>   | <b>100</b> | <b>1</b>   | <b>100</b> | <b>1</b> | <b>100</b> |

### Inference

Analysis results show that 50% of road Stretch near Azadpur Chowk has 1 star rating for 4 Wheeler riders and Motorcyclists. While the entire stretch has 1 star rating for Pedestrians and 90% of stretch has 2 Star rating for Bicyclists.

## 6.3 Near Azadpur Sabzi Mandi

**TABLE 8 Mode wise Star Rating on NH-44 near Azadpur Sabzi Mandi**

| Star Rating  | Vehicle Occupant |            | Motor Cycle |            | Pedestrian |            | Bicycle    |            |
|--------------|------------------|------------|-------------|------------|------------|------------|------------|------------|
|              | Length (Km)      | %          | Length      | %          | Length     | %          | Length     | %          |
| 5 Star       | 0                | 0          | 0           | 0          | 0          | 0          | 0          | 0          |
| 4 Star       | 0                | 0          | 0           | 0          | 0          | 0          | 0          | 0          |
| 3 Star       | 0.4              | 29         | 0.2         | 14         | 0          | 0          | 0          | 0          |
| 2 Star       | 0.10             | 7          | 0.3         | 21         | 0          | 0          | 1.4        | 100        |
| 1 Star       | 1                | 64         | 0.9         | 64         | 1.4        | 100        | 0          | 0          |
| <b>Total</b> | <b>1.4</b>       | <b>100</b> | <b>1.4</b>  | <b>100</b> | <b>1.4</b> | <b>100</b> | <b>1.4</b> | <b>100</b> |

### Inference

Analysis results from Table 8 shows that 64% of Road stretch near Azadpur Vegetable Market has 1 star rating for 4 Wheeler riders and Motorcyclists. While the entire stretch has 1 star rating for Pedestrians and 2 Star rating for Bicyclists.

## 6.4 Near Mukarba Junction

**TABLE 9 Mode wise Star Rating on NH-44 near Mukarba Junction**

| Star Rating  | Vehicle Occupant |            | Motorcycle  |            | Pedestrian  |            | Bicycle     |            |
|--------------|------------------|------------|-------------|------------|-------------|------------|-------------|------------|
|              | Length (Km)      | %          | Length      | %          | Length      | %          | Length      | %          |
| 5 Star       | 0                | 0          | 0           | 0          | 0           | 0          | 0           | 0          |
| 4 Star       | 1.88             | 90         | 0           | 0          | 0           | 0          | 0           | 0          |
| 3 Star       | 0                | 0          | 1.88        | 73         | 0           | 0          | 0           | 0          |
| 2 Star       | 0.20             | 10         | 0.2         | 8          | 0           | 0          | 2.08        | 100        |
| 1 Star       | 0                | 0          | 0.5         | 19         | 2.08        | 100        | 0           | 0          |
| <b>Total</b> | <b>2.08</b>      | <b>100</b> | <b>2.58</b> | <b>100</b> | <b>2.08</b> | <b>100</b> | <b>2.08</b> | <b>100</b> |

### Inference

Analysis results from Table 9 show that 90% of Stretch at Mukarba Chowk has 4 star rating for 4 Wheeler riders and 3 Star rating for Motorcyclists. While the entire stretch has 1 star rating for Pedestrians and 2 Star rating for Bicyclists.

### 6.5 Near Sanjay Gandhi Transport Nagar (SGT Nagar)

TABLE 10 Mode wise Star Rating on NH-44 near SGT Nagar

| Star Rating  | Vehicle Occupant |            | Motorcycle |            | Pedestrian |            | Bicycle    |            |
|--------------|------------------|------------|------------|------------|------------|------------|------------|------------|
|              | Length (Km)      | %          | Length     | %          | Length     | %          | Length     | %          |
| 5 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 4 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 3 Star       | 2.2              | 67         | 2.2        | 67         | 0          | 0          | 0          | 0          |
| 2 Star       | 1.10             | 33         | 1.1        | 33         | 0          | 0          | 3.3        | 100        |
| 1 Star       | 0                | 0          | 0          | 0          | 3.3        | 100        | 0          | 0          |
| <b>Total</b> | <b>3.3</b>       | <b>100</b> | <b>3.3</b> | <b>100</b> | <b>3.3</b> | <b>100</b> | <b>3.3</b> | <b>100</b> |

#### Inference

Analysis results from Table 10 show that 67% of the stretch at Swaroop Nagar has 3 star rating for 4 Wheeler riders and Motorcyclists. While the entire stretch has 1 star rating for Pedestrians and 2 Star rating for Bicyclists. The stretch is most unsafe for vulnerable road users i.e. Pedestrians and Bicyclists due to lack of Infrastructure.

### 6.6 Near SGT Nagar CNG Pump

TABLE 11 Mode wise Star Rating on NH-44 near SGT Nagar CNG Pump

| Star Rating  | Vehicle Occupant |            | Motorcycle |            | Pedestrian |            | Bicycle    |            |
|--------------|------------------|------------|------------|------------|------------|------------|------------|------------|
|              | Length (Km)      | %          | Length     | %          | Length     | %          | Length     | %          |
| 5 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 4 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 3 Star       | 1.3              | 100        | 0.7        | 54         | 0          | 0          | 0          | 0          |
| 2 Star       | 0.00             | 0          | 0.6        | 46         | 0          | 0          | 1.3        | 100        |
| 1 Star       | 0                | 0          | 0          | 0          | 1.3        | 100        | 0          | 0          |
| <b>Total</b> | <b>1.3</b>       | <b>100</b> | <b>1.3</b> | <b>100</b> | <b>1.3</b> | <b>100</b> | <b>1.3</b> | <b>100</b> |

#### Inference

Analysis results from Table 11 shows that entire stretch SGT Nagar has 3 star rating for 4 Wheeler riders. 54% of the road stretch has 3 star rating for Motorcyclists. While the entire stretch has 1 star rating for Pedestrians and 2 Star rating for Bicyclists.

### 6.7 Near Shani Mandir

TABLE 12 Mode wise Star Rating on NH-44 near Shani Mandir

| Star Rating  | Vehicle Occupant |            | Motor Cycle |            | Pedestrian  |            | Bicycle     |            |
|--------------|------------------|------------|-------------|------------|-------------|------------|-------------|------------|
|              | Length (Km)      | %          | Length      | %          | Length      | %          | Length      | %          |
| 5 Star       | 0                | 0          | 0           | 0          | 0           | 0          | 0           | 0          |
| 4 Star       | 0                | 0          | 0           | 0          | 0           | 0          | 0           | 0          |
| 3 Star       | 0                | 0          | 0           | 0          | 0           | 0          | 0           | 0          |
| 2 Star       | 1.88             | 90         | 1.88        | 90         | 0           | 0          | 2.08        | 100        |
| 1 Star       | 0.20             | 10         | 0.20        | 10         | 2.08        | 100        | 0           | 0          |
| <b>Total</b> | <b>2.08</b>      | <b>100</b> | <b>2.08</b> | <b>100</b> | <b>2.08</b> | <b>100</b> | <b>2.08</b> | <b>100</b> |

#### Inference

Analysis results from Table 12 shows that entire stretch near Shani Mandir has 2 star rating for Vehicle Occupants and Motorcyclists, while the entire stretch has 1 star rating for Pedestrians and 2 star rating for Bicyclists. A sharp curve in this area makes it vulnerable to vehicular accidents as observed from site visit.

## 6.8 Libaspur Bus Stand

**TABLE 13 Mode wise Star Rating on NH-44 near Libaspur Bus Stand**

| Star Rating  | Vehicle Occupant |            | MotorCycle |            | Pedestrian |            | Bicycle    |            |
|--------------|------------------|------------|------------|------------|------------|------------|------------|------------|
|              | Length (Km)      | %          | Length     | %          | Length     | %          | Length     | %          |
| 5 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 4 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 3 Star       | 2                | 74         | 2          | 74         | 0          | 0          | 0          | 0          |
| 2 Star       | 0.10             | 4          | 0.1        | 4          | 0          | 0          | 2.7        | 100        |
| 1 Star       | 0.6              | 22         | 0.6        | 22         | 2.7        | 100        | 0          | 0          |
| <b>Total</b> | <b>2.7</b>       | <b>100</b> | <b>2.7</b> | <b>100</b> | <b>2.7</b> | <b>100</b> | <b>2.7</b> | <b>100</b> |

### Inference

Analysis results from Table 13 shows that entire stretch near Libaspur has 2 star rating for Bicyclists and 1 star rating for Pedestrians. 74% of the road stretch has 3 star rating for Motorcyclists and four wheeler Riders

## 6.9 Swaroop Nagar

**TABLE 14 Mode wise Star Rating on NH-44 near Swaroop Nagar**

| Star Rating  | Vehicle Occupant |            | Motor Cycle |            | Pedestrian |            | Bicycle    |            |
|--------------|------------------|------------|-------------|------------|------------|------------|------------|------------|
|              | Length (Km)      | %          | Length      | %          | Length     | %          | Length     | %          |
| 5 Star       | 0                | 0          | 0           | 0          | 0          | 0          | 0          | 0          |
| 4 Star       | 0                | 0          | 0           | 0          | 0          | 0          | 0          | 0          |
| 3 Star       | 2.2              | 67         | 2.2         | 67         | 0          | 0          | 0          | 0          |
| 2 Star       | 1.10             | 33         | 1.1         | 33         | 0          | 0          | 3.3        | 100        |
| 1 Star       | 0.0              | 0          | 0           | 0          | 3.3        | 100        | 0          | 0          |
| <b>Total</b> | <b>3.3</b>       | <b>100</b> | <b>3.3</b>  | <b>100</b> | <b>3.3</b> | <b>100</b> | <b>3.3</b> | <b>100</b> |

### Inference

Analysis results from Table 14 shows that entire stretch near Swaroop Nagar has 2 star rating for Bicyclists and 1 star rating for Pedestrians. 67% of the road stretch has 3 star rating for Motorcyclists and four wheeler riders while 33% of the stretch has 2 star rating for motorcyclists and four wheeler riders.

## 6.10 Nangli Budhpur Village

**TABLE 15 Mode wise Start Rating On NH-44 near Nangli Budhpur Village**

| Star Rating  | Vehicle Occupant |            | MotorCycle |            | Pedestrian |            | Bicycle    |            |
|--------------|------------------|------------|------------|------------|------------|------------|------------|------------|
|              | Length (Km)      | %          | Length     | %          | Length     | %          | Length     | %          |
| 5 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 4 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 3 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 2 Star       | 2.40             | 100        | 2.4        | 100        | 0          | 0          | 0          | 0          |
| 1 Star       | 0.0              | 0          | 0          | 0          | 2.4        | 100        | 2.4        | 100        |
| <b>Total</b> | <b>2.4</b>       | <b>100</b> | <b>2.4</b> | <b>100</b> | <b>2.4</b> | <b>100</b> | <b>2.4</b> | <b>100</b> |

### Inference

Analysis results from Table 15 shows that entire stretch near Nangli Budhpur Village has 2 star rating for four wheelers and Motorcycles. While for Pedestrians and Bicyclists the entire stretch and 1 star rating.

### 6.11 Sai Baba Mandir

**TABLE 16 Mode wise Star Rating on NH-44 near Sai Baba Mandir**

| Star Rating  | Vehicle Occupant |            | Motorcycle |            | Pedestrian |            | Bicycle    |            |
|--------------|------------------|------------|------------|------------|------------|------------|------------|------------|
|              | Length (Km)      | %          | Length     | %          | Length     | %          | Length     | %          |
| 5 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 4 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 3 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 2 Star       | 2.70             | 113        | 2.7        | 100        | 0          | 0          | 2.7        | 100        |
| 1 Star       | 0.0              | 0          | 0          | 0          | 2.7        | 100        | 0          | 0          |
| <b>Total</b> | <b>2.4</b>       | <b>113</b> | <b>2.7</b> | <b>100</b> | <b>2.7</b> | <b>100</b> | <b>2.7</b> | <b>100</b> |

#### Inference

Analysis results from Table 16 shows that entire stretch near Sai Baba Mandir has 2 star rating for Bicyclists, four wheelers and Motorcycles for entire stretch and 1 star rating for Pedestrians.

### 6.12 Budhpur Ganda Naala

**TABLE 17 Mode wise Star Rating on NH-44 near Budhpur Ganda Naala**

| Star Rating  | Vehicle Occupant |            | MotorCycle |            | Pedestrian |            | Bicycle    |            |
|--------------|------------------|------------|------------|------------|------------|------------|------------|------------|
|              | Length (Km)      | Percent    | Length     | %          | Length     | %          | Length     | %          |
| 5 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 4 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 3 Star       | 1                | 91         | 1          | 91         | 0          | 0          | 0          | 0          |
| 2 Star       | 0.10             | 9          | 0.1        | 9          | 0          | 0          | 1.1        | 100        |
| 1 Star       | 0.0              | 0          | 0          | 0          | 1.1        | 100        | 0          | 0          |
| <b>Total</b> | <b>1.1</b>       | <b>100</b> | <b>1.1</b> | <b>100</b> | <b>1.1</b> | <b>100</b> | <b>1.1</b> | <b>100</b> |

#### Inference

Analysis results from Table 17 shows that 91% of the stretch near Budhpur Ganda Naala has 3 star rating for Vehicle users and Motorcyclists while entire stretch has 2 star rating for Bicyclists and 1 star rating for Pedestrians.

### 6.13 Bakoli Bus Stand

**TABLE 18 Mode wise Star Rating on NH-44 near Bakoli Bus Stand**

| Star Rating  | Vehicle Occupant |            | Motorcycle |            | Pedestrian |            | Bicycle    |            |
|--------------|------------------|------------|------------|------------|------------|------------|------------|------------|
|              | Length (Km)      | %          | Length     | %          | Length     | %          | Length     | %          |
| 5 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 4 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 3 Star       | 4.1              | 100        | 3.3        | 80         | 0          | 0          | 0          | 0          |
| 2 Star       | 0.00             | 0          | 0.8        | 20         | 0          | 0          | 4.1        | 100        |
| 1 Star       | 0.0              | 0          | 0          | 0          | 4.1        | 100        | 0          | 0          |
| <b>Total</b> | <b>4.1</b>       | <b>100</b> | <b>4.1</b> | <b>100</b> | <b>4.1</b> | <b>100</b> | <b>4.1</b> | <b>100</b> |

#### Inference

Analysis results from Table 18 shows that entire stretch has 3 star rating for Vehicle Occupants , while 80% of the stretch has 3 star rating for motorcycles . Entire stretch has 2 star rating for Bicyclists and 1 star rating for Pedestrians



### 6.14 Khampur Village

**TABLE 19 Mode wise Star Rating on NH-44 near Khampur Village**

| Star Rating  | Vehicle Occupant |            | Motorcycle  |            | Pedestrian  |            | Bicycle     |            |
|--------------|------------------|------------|-------------|------------|-------------|------------|-------------|------------|
|              | Length (Km)      | %          | Length      | %          | Length      | %          | Length      | %          |
| 5 Star       | 0                | 0          | 0           | 0          | 0           | 0          | 0           | 0          |
| 4 Star       | 0                | 0          | 0           | 0          | 0           | 0          | 0           | 0          |
| 3 Star       | 2.97             | 88         | 2.97        | 88         | 0           | 0          | 0           | 0          |
| 2 Star       | 0.10             | 3          | 0.1         | 3          | 0           | 0          | 3.07        | 91         |
| 1 Star       | 0.3              | 9          | 0.3         | 9          | 3.37        | 100        | 0.3         | 9          |
| <b>Total</b> | <b>3.37</b>      | <b>100</b> | <b>3.37</b> | <b>100</b> | <b>3.37</b> | <b>100</b> | <b>3.37</b> | <b>100</b> |

#### Inference

Analysis results from Table 19 show that 88% of the road stretch has 3 star rating for Vehicle occupants and Motorcyclists while entire stretch has 1 star rating for Pedestrians and 91% of the stretch has 2 star rating for Bicyclists.

### 6.15 Tikri Khurd Village

**TABLE 20 Mode wise Star Rating on NH-44 near Tikri Khurd Village**

| Star Rating  | Vehicle Occupant |            | MotorCycle |            | Pedestrian |            | Bicycle    |            |
|--------------|------------------|------------|------------|------------|------------|------------|------------|------------|
|              | Length (Km)      | %          | Length     | %          | Length     | %          | Length     | %          |
| 5 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 4 Star       | 0                | 0          | 0          | 0          | 0          | 0          | 0          | 0          |
| 3 Star       | 2.1              | 91         | 2.1        | 91         | 0          | 0          | 0          | 0          |
| 2 Star       | 0.20             | 9          | 0.2        | 9          | 0          | 0          | 2.3        | 100        |
| 1 Star       | 0.0              | 0          | 0          | 0          | 2.3        | 100        | 0          | 0          |
| <b>Total</b> | <b>2.3</b>       | <b>100</b> | <b>2.3</b> | <b>100</b> | <b>2.3</b> | <b>100</b> | <b>2.3</b> | <b>100</b> |

#### Inference

Analysis results from Table 20 shows that 91% of the road stretch near Tikri Khurd Village has 3 star rating for Vehicle occupants and Motorcyclists while entire stretch has 1 star rating for Pedestrians and 2 star rating for Bicyclists.

### 6.16 Singhu Border

**TABLE 21 Mode wise Star Rating on NH-44 near Singhu Border**

| Star Rating  | Vehicle Occupant |            | Motor Cycle |            | Pedestrian |            | Bicycle    |            |
|--------------|------------------|------------|-------------|------------|------------|------------|------------|------------|
|              | Length (Km)      | %          | Length      | %          | Length     | %          | Length     | %          |
| 5 Star       | 0                | 0          | 0           | 0          | 0          | 0          | 0          | 0          |
| 4 Star       | 0                | 0          | 0           | 0          | 0          | 0          | 0          | 0          |
| 3 Star       | 0                | 0          | 2.1         | 64         | 0          | 0          | 0          | 0          |
| 2 Star       | 0.60             | 50         | 0.6         | 18         | 0          | 0          | 1.2        | 100        |
| 1 Star       | 0.6              | 50         | 0.6         | 18         | 1.2        | 100        | 0          | 0          |
| <b>Total</b> | <b>1.2</b>       | <b>100</b> | <b>3.3</b>  | <b>100</b> | <b>1.2</b> | <b>100</b> | <b>1.2</b> | <b>100</b> |

#### Inference

Analysis results from Table 21 shows that half of the stretch has 1 star rating and other half has 2 star rating for Vehicle Occupants and Motorcyclists. While entire stretch has 1 star rating for Pedestrians and 2 star rating for Bicyclists.

## 7. PRIORITIZATION OF ROAD SAFETY MEASURES AND ROAD INVESTMENT PLAN

The Roads Investment Plan shows a list of affordable and economically sound road safety treatments. Each countermeasure proposed is supported by strong evidence that, if implemented, it will prevent deaths and serious injuries in a cost-effective way. Countermeasure cost per fatal and serious injury (FSI) along with benefit cost ratio (BCR) has been shown in Table 22. The most cost effective measure has highest BCR and is given the highest priority followed by others countermeasures. All costs shown in Table 22 are in Indian Rupee (INR)

**TABLE 22 Safer Road Investment Plan for 20 Years All 16 Black Spots**

| S. No        | Road Safety Countermeasures<br>(In decreasing order of Priority with regards to Benefit/Cost ratio of investment in the counter-measure ) | Length / Sites | Fatal and serious injuries (FSI) saved | Present Value (PV) of safety benefit (Millions INR) | Estimated Cost (Millions INR) | Cost per FSI saved | Benefit Cost Ratio (BCR) |
|--------------|---|----------------|--|---|-------------------------------|--------------------|--------------------------|
| 1            | Pedestrian fencing (Highest Priority)   | 3.10 km        | 876                                    | 171.95  | 0.06                          | 755                | 260                      |
| 2            | Improve curve delineation   | 1.40 km        | 116                                    | 22.7  | 0.04                          | 2,427              | 81                       |
| 3            | Shoulder rumble strips  | 8.27 km        | 294                                    | 57.7  | 1.06                          | 3,615              | 54                       |
| 4            | Footpath provision passenger side   | 29.3 km        | 1,683                                  | 330.16  | 31.62                         | 18,794             | 10                       |
| 5            | Signalized Crossing   | 26 Sites       | 1,620                                  | 317.82  | 34.21                         | 21,124             | 9                        |
| 6            | Traffic calming   | 18.39 km       | 3,300                                  | 647.6   | 4.75                          | 14,402             | 14                       |
| 7            | Improve Delineation   | 32.76 km       | 641                                    | 125.76  | 16.90                         | 26,379             | 7                        |
| 8            | Signalized intersection   | 27 sites       | 715                                    | 140.27  | 27.2                          | 40,755             | 5                        |
| 9            | Upgrade Pedestrian Facility   | 3 Sites        | 19                                     | 3.7   | 0.8                           | 41,101             | 5                        |
| 10           | Delineation at Intersection   | 27 Sites       | 680                                    | 133.5   | 36.97                         | 54,358             | 4                        |
| 11           | Protected Turn Lane   | 9 Sites        | 409                                    | 80.24   | 20.47                         | 50,075             | 4                        |
| 12           | Motorcycle Lane (Painted Logos)   | 3.4 km         | 12                                     | 2.4   | 0.58                          | 46,553             | 4                        |
| 13           | Road side Barriers  | 6.07 km        | 251                                    | 49.28   | 14.84                         | 59,107             | 3                        |
| 14           | Protected Turn Lane Improvement   | 5 sites        | 127                                    | 24.95   | 8.07                          | 63,511             | 3                        |
| 15           | Clear Roadside Hazards  | 4.70 km        | 123                                    | 24.20   | 8.80                          | 71,377             | 3                        |
| 16           | Restrict/combine direct access points   | 2.5 km         | 98                                     | 19.28   | 6.46                          | 66,039             | 3                        |
| 17           | Off Road Bicycle Lane   | 3.4 km         | 45                                     | 8.83  | 3.33                          | 74,058             | 3                        |
| 18           | Road Barrier (Driver side)  | 0.5 km         | 19                                     | 3.79  | 1.32                          | 68,591             | 3                        |
| 19           | Grade separated Pedestrian Facility   | 1              | 210                                    | 41.26   | 21.99                         | 104,601            | 2                        |
| 21           | Signalize Side road   | 8 sites        | 122                                    | 23.88   | 39.10                         | 321,183            | 1                        |
| 22           | Segregated Motorcycle Lane  | 3.07 km        | 108                                    | 6.89  | 5.72                          | 162,916            | 1                        |
| 23           | Shoulder sealing  | 0.47           | 5                                      | 1.25  | 1.07                          | 35,439             | 1                        |
| <b>Total</b> |   |                | <b>9,235</b>                           | <b>181.2 Crores</b>                                 | <b>32.73 Crores</b>           | <b>35,439</b>      | <b>5.53</b>              |

### Inference

An investment of about 32.73 Crores Indian rupees on this 18 km stretch on National Highway 44 can save 9235 fatal and serious injuries in coming 20 years of time with net present value of economic benefits of 181.2 Crores and benefit cost ratio of 5.53. The average cost of counter measures per fatal and serious injury comes out to be 35,439 Indian rupees (INR)

## 8. PRIORITIZATION OF BLACK SPOTS

Prioritization of Black Spots can be done on economic analysis parameters i.e. Cost saved per Fatal and serious injury saved (FSI) and Benefit/Cost Ratio (BCR) as shown in Table 23. The

blackspots have been arranged in hierarchy of decreasing benefit cost ratio in the Table 23. The blackspot with highest priority has been shown to top followed by others and blackspot with lowest priority at bottom.

**TABLE 23 Prioritization of Black Spots Based on Benefit Cost Ratio**

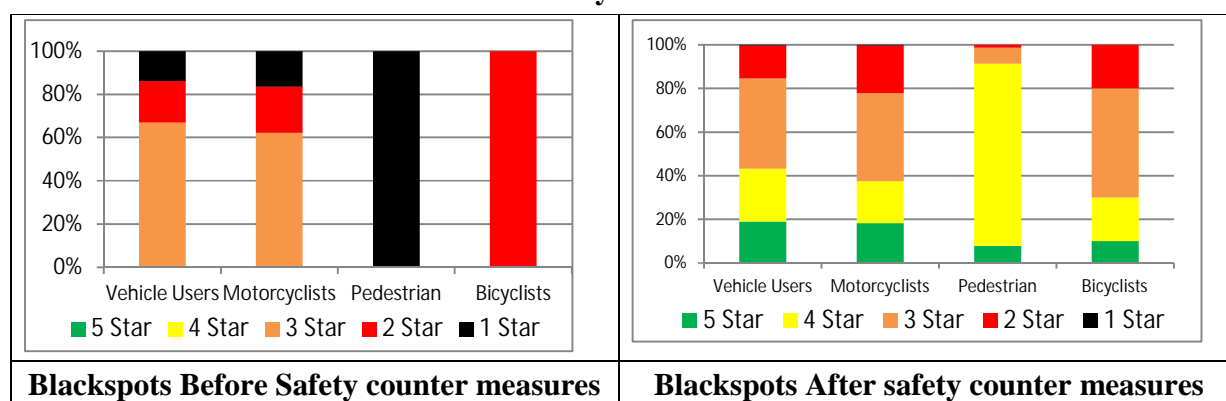
| Prioritization Hierarchy | Black Spot          | FSI Saved | PV of FSI Saved (Million INR) | Estimated Cost (Million INR) | Cost per FSI Saved | BCR |
|--------------------------|---------------------|-----------|-------------------------------|------------------------------|--------------------|-----|
| 1                        | Shani Mandir        | 974       | 191.13                        | 20.05                        | 20,539             | 10  |
| 2                        | Bakoli Bus Stand    | 94        | 18.49                         | 2.13                         | 22,583             | 9   |
| 3                        | Azadpur Bus Stand   | 170       | 33.41                         | 4.00                         | 23,530             | 8   |
| 4                        | SGT Petrol Pump     | 487       | 95.58                         | 12.78                        | 26,247             | 7   |
| 5                        | Tikri Khurd Village | 462       | 90.67                         | 13.09                        | 28,334             | 7   |
| 6                        | Swaroop Nagar       | 858       | 168.45                        | 26.72                        | 31,130             | 6   |
| 7                        | Khampur Village     | 735       | 144.25                        | 23.43                        | 31,880             | 6   |
| 8                        | Nangli Budhpur      | 1,430     | 280.5                         | 48.93                        | 34,233             | 6   |
| 9                        | Singhu Border       | 655       | 128.61                        | 23.13                        | 35,295             | 6   |
| 10                       | Azadpur Sabzi Mandi | 615       | 120.61                        | 22.02                        | 35,834             | 5   |
| 11                       | Budhpur Ganda Nala  | 538       | 105.65                        | 22.56                        | 41,914             | 5   |
| 12                       | Sai Baba Mandir     | 673       | 132.05                        | 29.05                        | 43,172             | 5   |
| 13                       | Azadpur Chowk       | 247       | 48.38                         | 13.17                        | 53,449             | 4   |
| 14                       | Mukarba Chowk       | 565       | 110.93                        | 33.50                        | 59,262             | 3   |
| 15                       | SGT Nagar           | 104       | 20.36                         | 7.62                         | 73,474             | 3   |
| 16                       | Libaspur Bus Stand  | 227       | 18.25                         | 6.02                         | 80,254             | 3   |

### Inference

Prioritization of Blackspots suggests Shani Mandir on NH-44 has highest priority with cost per FSI saved 20,539 rupees & BCR 10. Fatal and serious injuries can be prevented in 20 years of time on NH-44 stretch near Shani Mandir. Table 23 shows the prioritization hierarchy of all 16 blackspots.

## 9. CONCLUSION

**Figure 1 Combined Star Rating Chart for NH-44 Road Stretch before and After Road Safety Counter Measures**



As shown in Figure 1, the star ratings get improved for all kinds of road users on NH-44 after application of road safety improvement plan. Initially On NH-44 Corridor 67% of road stretch has 3 star Rating for Vehicle Occupants, 62% of the stretch had 3 star rating for Motorcyclists

while the entire stretch had 2 star rating for Bicycle Riders & 1 star rating for pedestrians. After application of countermeasures we find that nearly 20% of the road stretch gets 5 star rating for four wheeler riders and Motorcyclists while 80% of the stretches on blackspots achieve 4 star rating for Pedestrian safety and 10% of the stretch achieves 5 star rating. For Bicyclists 50% of the stretch achieves 3 star rating and 15% of the blackspot stretches achieve 3 star rating while 8% of the stretch achieves 5 star rating.

An investment of about 32.73 Crores (\$5Million US Dollar) Indian rupees on blackspots of this 18 km stretch on National Highway 44 can save 9235 fatal and serious injuries in coming 20 years of time with net present value of economic benefits of 181.2 Crores (\$ 28.46 Million US Dollars) and benefit cost ratio of 5.53. The average cost of counter measures per fatal and serious injury comes out to be 35,439 Indian rupees. Prioritization of Road Safety Countermeasures suggests that Pedestrian Fencing has highest priority with BCR 260 and Lowest FSI followed by improved Curve delineation and others. Prioritization of Road Safety Countermeasures suggests that Pedestrian Fencing has highest priority with BCR 260 and Lowest FSI, followed by improved Curve delineation and others. Prioritization of Black spots Suggests Shani Mandir on NH-44 Corridor has highest priority with cost per FSI saved 20539 & BCR 10. 974 fatal and serious injuries can be prevented in 20 years of time on NH-44 stretch near Shani Mandir. Table 23 shows the prioritization hierarchy of all 16 blackspots.

The methodology used in this work with help of iRAP for prioritization of Road safety counter measures as well as prioritization of accident blackspots can serve as tool for comparison of safety measures and blackspots at a global level on a common platform. Further the road investment plan and estimation of fatalities saved can help various government organizations to carry out road safety investment plans in an efficient manner with scientific approach.

## 10. WAY FORWARD

Star Rating is not sensitive towards assessing potential impact of Intelligent Transport Systems (ITS) measures. Research on impact of ITS in Infrastructure can be done and integrated with Road infrastructure rating to further enhance Road safety. Diurnal Variation in Star rating of Road Infrastructure components and corresponding Countermeasures can further make roads safer.

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