Accident Data Analysis with Economic Evaluation of Suggested Countermeasures using iMAAP and Accident Modification Factors

Presented by:

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INTRODUCTION

- As per the **World Health Organization** accident-related deaths, are known to be the **eighth leading cause of death** and the first largest cause of death among children aged 5-14 and adults in the age 15-29.
- iMAAP is internet based Micro Accident Analysis Package for analysis of road crashes.
- Economic Evaluation helps us to determine whether a scheme is worth investing or not. It helps us to compare the advantages yielded with respect to the investment involved for a reliable forecast period
- Safety Performance Functions are Accident Prediction models which relate accidents of different types with site characteristics. It includes site traffic volume and may include other parameters such as lane width, shoulders, degree of curves etc.
- Accident Modification Factor (AMF) is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site.
- AMFs can be used to estimate safety effects of countermeasures, compare benefits among various locations, check cost effective strategies and location in term of crash effects.

OBJECTIVES

- To locate the hotspots along the corridor and risk analysis and conduct risk analysis using iMAAP software.
- To suggest countermeasures for reduction of road accidents on the study corridor as per IRC SP: 88 (2019) Road Safety Audit Manual
- To perform economic evaluation of suggested countermeasures and identify cost effective countermeasures.
- To develop safety performance Function (SPF) for the study corridor.

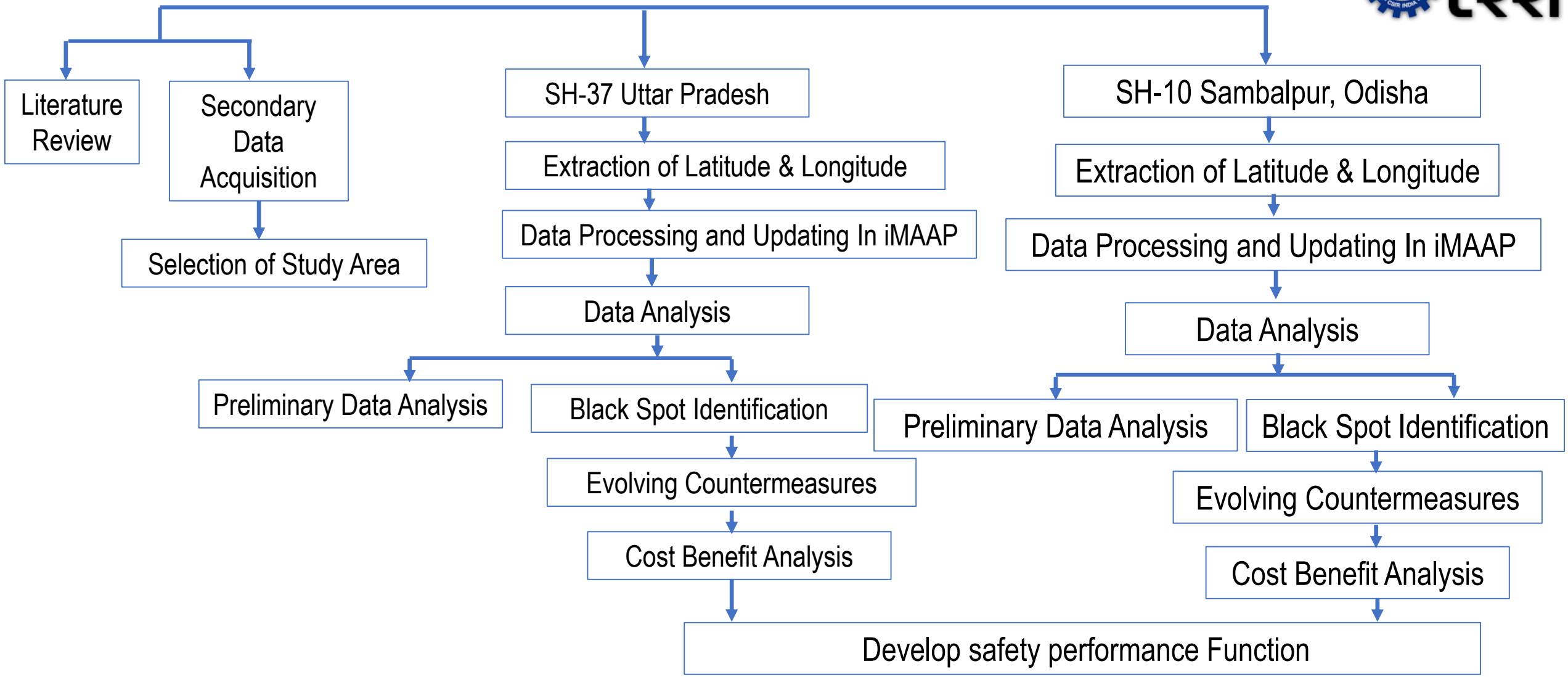
SCOPE

- The scope of the study contains two locations
  - (i) SH 37 in Uttar Pradesh connecting Bareilly to Kichha and
  - (ii) SH 10 in Sambalpur, Odisha connecting Sambalpur to Koratpur.
- The developed SPF can be used for accident analysis for Highways with similar Traffic and Geometric features

Summary Of Literature Review

- Literature study was conducted on the aspects of black spot identification and prioritization, suggestion of remedial measures for deficiencies of road, countermeasure effectiveness and benefit-cost analysis related to road safety measures.
- Various methods of employed for the identification of the black spot have been discussed which included Accident rate method, Empirical bayes method, accident reduction potential with empirical bayes method, kernel density estimation method, weighted severity index, accident density and sliding window method.
- Thereafter, the appropriate remedial measures are studied aimed reducing the number or at least severity of road accidents based on IRC SP:88, 2019 Road Safety Audit Manual.
- Then review has been done regarding the effectiveness of countermeasures and benefit-cost analysis of road safety measures considering the Benefit cost, Net Present Value and Internal Rates of Return method. The effectiveness value for countermeasures were considered based on available literature.
- Literature and Statistical methods related to SPF were studied to find methods for developing SPF and use of AMF for road safety and accident prevention.

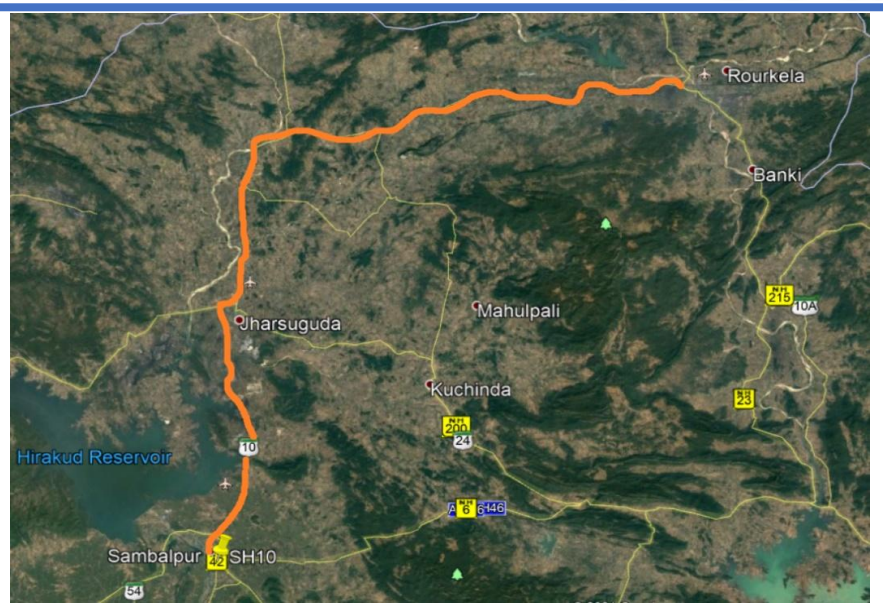
METHODOLOGY



Study Area

SH-37, Uttar Pradesh *Source: Google Earth*

- As per MoRT&H, Uttar Pradesh stands third and Odisha on Twelfth in terms of highest road accidents.
- Both the road stretches have dual carriageway road with clear width of 7m and divided by median of 3m width.



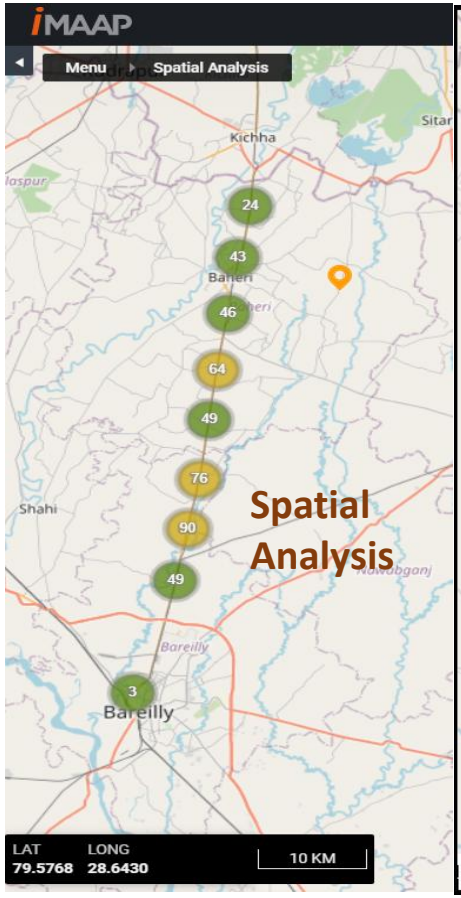
SH-10, Odisha *Source: Google Earth*

- The study area is a road stretch of 56 km also called as Nainital Road, connecting Bareilly to Kichha.
- The study stretch starts from Donha Toll Plaza Bareilly Nainital Highway Uttar Pradesh State Highways Authority and merges into National Highway 74 (Uttrakhand SH 49).
- The accident data is between the year 2016 and 2019.

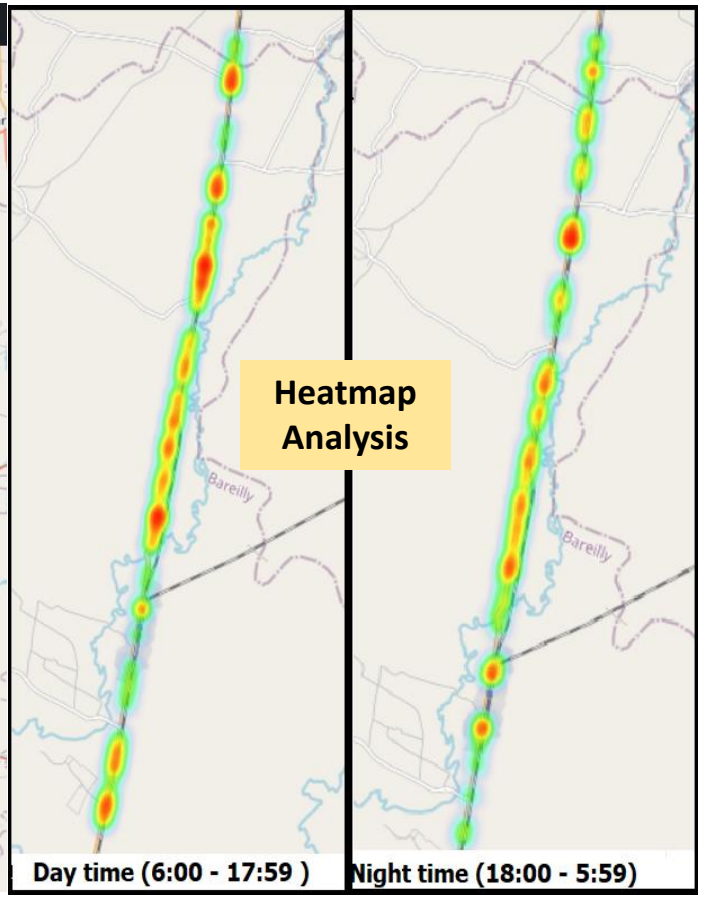
- The study area is a road stretch of 167 km, part of SH-10 Odisha, connecting Sambalpur to Rourkela.
- The start is from Sambalpur passing through major cities and towns till Rourkela where it joins National Highway 143.
- The accident data is between the year 2018 and 2020.

Preliminary Analysis

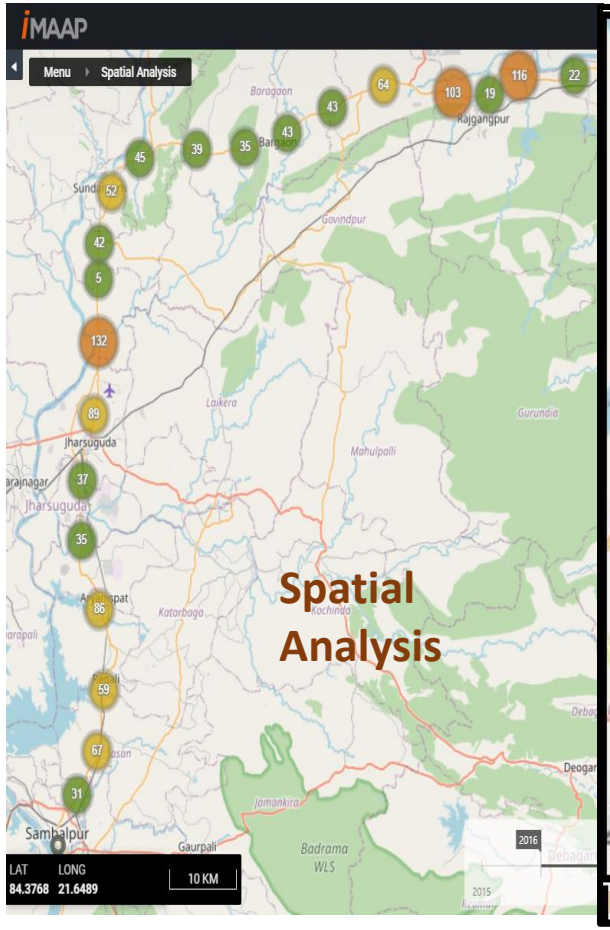
SH- 37 Uttar Pradesh



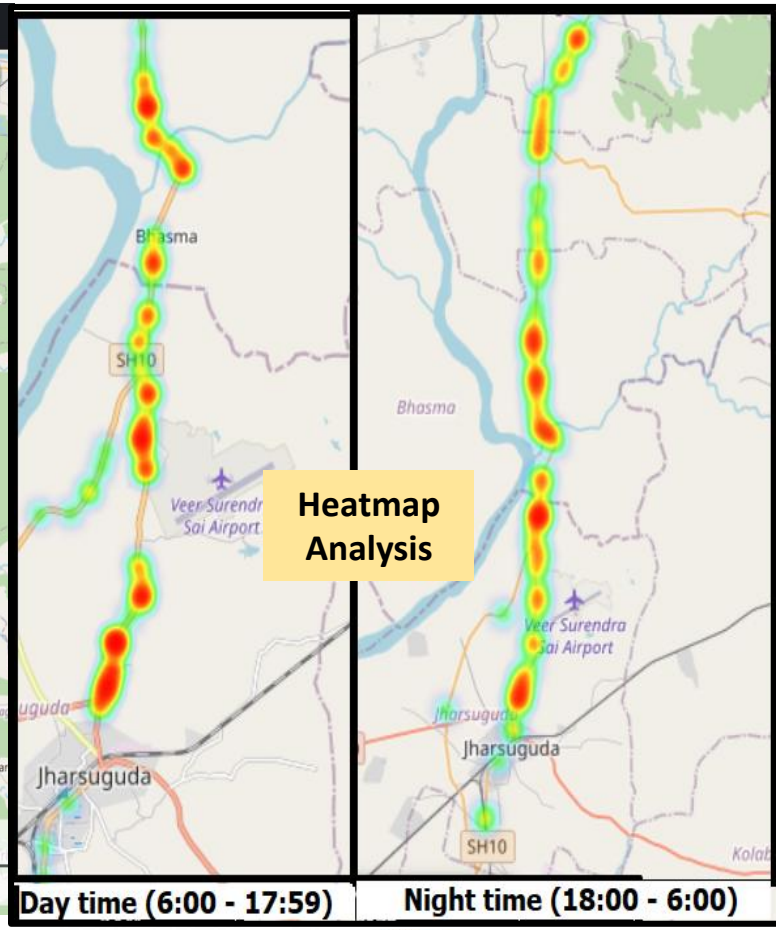
Spatial Analysis



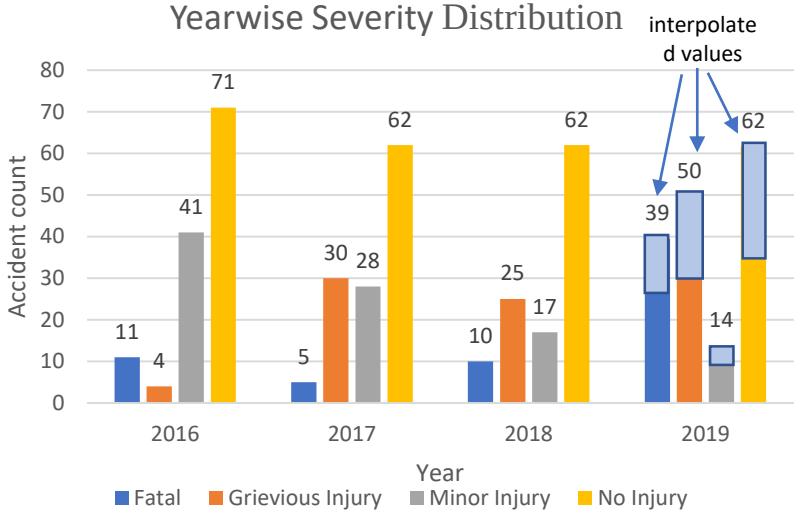
SH- 10 Odisha



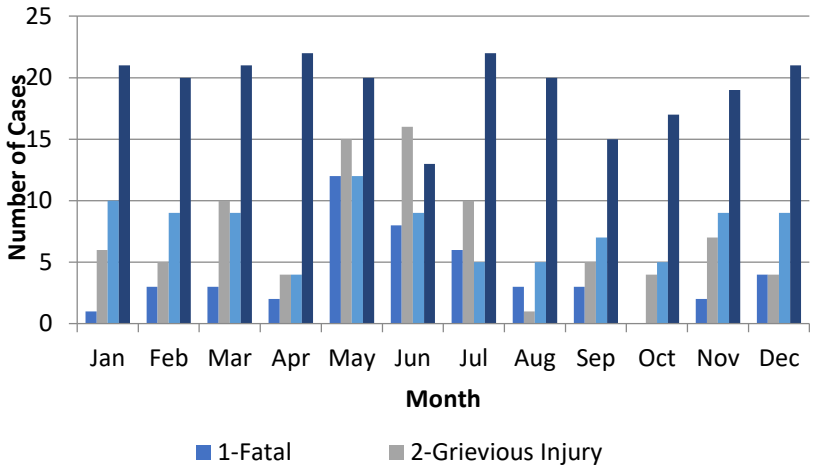
Spatial Analysis



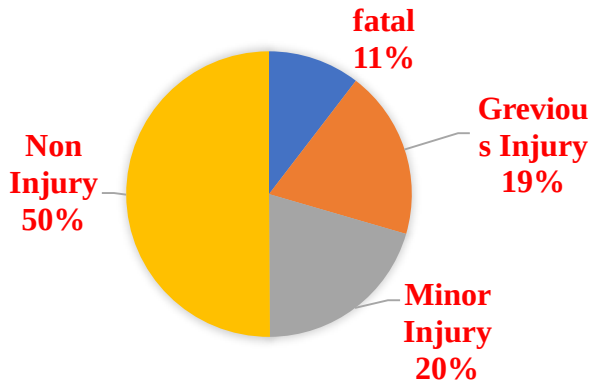
Preliminary Analysis



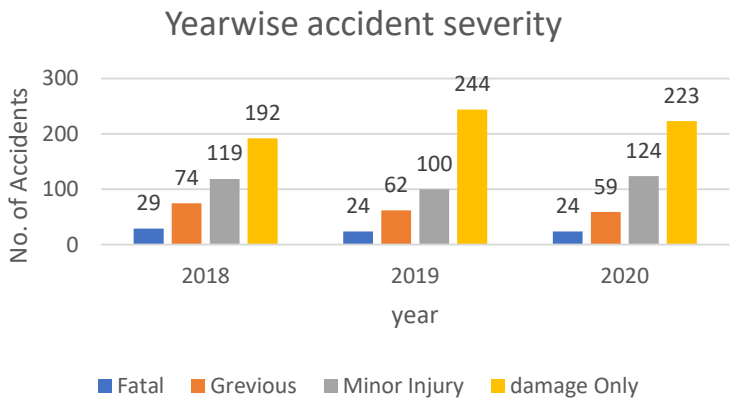
Year wise Accident Severity Variation (SH 37, U.P.)



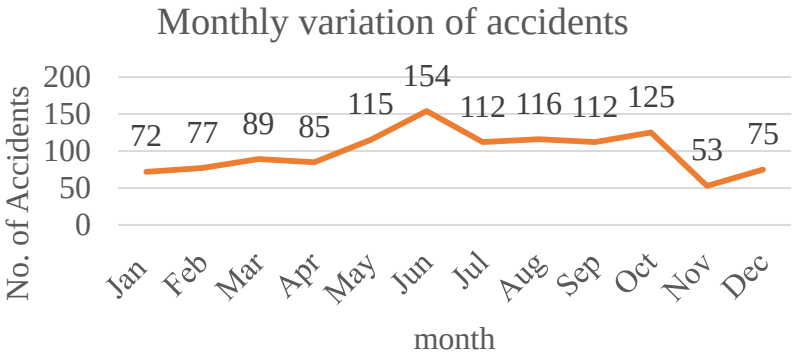
Monthly Variation of Accident Severity.(SH 37, U.P.)



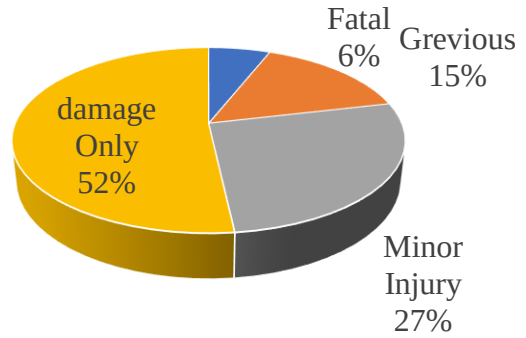
Accident Severity Distribution (SH 37, U.P.)



Year wise Distribution of Accident Severity



Monthly distribution of Accident



Distribution based on type of Accidents (SH 10, Odisha)

Cluster Analysis

Cluster Analysis is performed for minimum 5 accidents over a stretch of 500 m and site was ranked based on severity score.

Cluster Report of SH-37, Uttar Pradesh

Site Name	Fatal	Grievous Injury	Minor Injury	Damage Only	Location (from start)	Score	Accident Factor
cluster 1	1	4	3	146	4.5 KM	185	Overspeed
cluster 2	3	6	5	56	24.6 KM	131	Overspeed
cluster 3	2	5	2	34	19.15 KM	85	Overspeed
cluster 4	1	3	2	16	39.1 KM	47	Other
cluster 5	0	3	3	19	15.7 KM	43	Overspeed
cluster 6	0	0	2	35	30.3 KM	41	Overspeed
cluster 7	0	0	0	36	0.100 KM	36	Overspeed
cluster 8	1	2	1	4	42.3 KM0	27	Overspeed

Cluster Report of SH-10, Odisha

Site Name	Fatal	Grievous Injury	Minor Injury	Damage Only	Distance	Score	Accident Factor
cluster 1	1	8	8	11	8.06 KM	101	Overspeed
cluster 2	1	5	7	13	5.53 KM	79	Overspeed
cluster 3	0	2	3	24	14.86 KM	47	Overspeed
cluster 4	0	0	0	46	134.95 KM	47	Overspeed
cluster 5	0	0	0	38	113.02 KM	46	Overspeed
cluster 6	0	0	0	35	118.11 KM	40	Overspeed
cluster 7	0	0	0	33	54.52 KM	39	Overspeed
cluster 8	1	1	2	8	4.25 KM	38	Suspected Alcohol
cluster 9	0	0	1	26	68.45 KM	37	Overspeed
cluster 10	0	3	0	7	12.88 KM	37	Overspeed
cluster 11	0	1	4	6	11.35 KM	35	Overspeed
cluster 12	1	1	1	5	1.68 KM	34	Overspeed
cluster 13	0	0	0	25	51.68 KM	33	Overspeed
cluster 14	0	0	0	22	123.94 KM	31	Dangerous Driving
Cluster 15	0	0	1	15	26.05 KM	30	Dangerous driving

Identification of Blackspots

Criteria for Blackspot Identification: Stretch of 500 m with more than 5 road accidents during last 3 calendar years

Method Used: Weighted severity index - In this method, the weighted severity index is calculated based on the classification of road crashes as fatal, grievous injuries minor injuries. Location having highest severity index value is ranked first followed by the rest.

Severity Weightings to calculate Accident Severity Index (ASI)

Accident Severity	Fatal	Grievous Injury	Minor Injury	Damage Only
Weighting	10	5	3	1

After the Severity Analysis 7 blackspots were identified for SH-37, Uttar Pradesh

Average ASI score = 32

Blackspots for SH- 37, Uttar Pradesh

Hotspot Name	Location (chainage)	Fatal accidents	Grievous accidents	Minor injury	Damage only	ASI	rank
Blackspot 1	35.6-36.1 KM	2	1	1	2	55	1
Blackspot 2	19.45 -19.95 KM	1	2	1	4	50	2
Blackspot 3	46.4-46.9 KM	1	1	0	6	40	3
Blackspot 4	48.7- 49.2 KM	1	1	1	2	34	4
Blackspot 5	15.1 - 15.6 KM	1	1	0	3	32	5
Blackspot 6	20.5-21 KM	1	0	0	7	32	6
Blackspot 7	23.5-24 KM	1	0	0	7	31	7

Blackspots for SH- 10, Odisha

10 Blackspots for SH-10, Odisha. These were ranked based on the ASI value

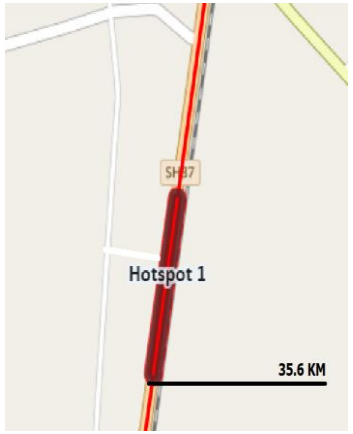
Average ASI score = 22.7

Hotspot	chainage (KM from start)	fatal	grievous	minor	damage	ASI	Rank
Blackspot 1	16.7-17.2	1	1	7	4	40	1
Blackspot 2	118.01-118.5	1	0	7	1	32	2
Blackspot 3	74.58-75.08	1	2	1	2	25	3
Blackspot 4	65.16-65.66	0	3	2	3	24	4
Blackspot 5	144.14-144.64	1	0	3	3	22	5
Blackspot 6	10.86-11.36	1	1	1	2	20	6
Blackspot 7	15.26-15.76	0	1	5	0	20	7
Blackspot 8	17.66-18.16	0	1	4	1	18	8
Blackspot 9	71.58-72.08	0	1	3	1	15	9
Blackspot 10	19.14-19.64	0	1	1	3	11	10

- After the blackspot identification, blackspots with ASI value above the average were considered and countermeasures were suggested as per IRC SP 88 (2019), Road Safety Audit Manual.
- The countermeasures were divided into short term, medium term and long term to take a phased implementation considering the capital cost constraints and time taken to implement the countermeasures

Suggested Countermeasures before economic evaluation

SH-37, Uttar Pradesh

Black spot		Short-term Countermeasures	Medium-term Countermeasures	Long-term Countermeasures	Nature of Accidents
KM 35.6-36.1		1. Transverse Bar Marking or rumble strips of 10 mm thick on both directions of travel. 2. Improvement of Intersection geometrics, provision of delineators, median markers, chevron markings and associated sign boards including the missing informatory sign boards at the junction	1. Installation of Traffic signal at the intersection with all necessary accessories. 2. Installing of W-Beam Crash barrier on right of way of both sides (2x500m).	1. Grade separated 4 lane intersection (1x20m VUP) shall be with its appurtenances 2. Paved Shoulder 2.5 m wide on both sides of the highway, at least for the blackspot location 3. Service lanes with 1.5 m earthen shoulders for the connecting roads of towns and villages	1. A total of 6 accidents took place in the stretch for the span of 2016-2019 2. The major contributing factor for the blackspot is head on collision and overturning. The section is straight with speed limit of 80 kmph
KM 19.45-19.95		1. Transverse Bar Marking or rumble strips of 10 mm thick on both directions of travel. 2. Channelization of intersection by providing islands and refuge islands for pedestrians. 3. Delineation of intersection by providing and fixing of RPM, kerb marker.	1. Installation of Traffic signal at the intersection with all necessary accessories.	1. Paved Shoulder 2.5 m wide on both sides of the highway, at least for the blackspot location 2. Service lanes with 1.5 m earthen shoulders for the connecting roads of towns and villages	1. A total of 8 accidents took place in the stretch for the span of 2016-2019 2. The major cause of the accidents is overturned and head on collisions

Similarly, countermeasures for SH-10, Odisha study corridor were suggested.

Economic Evaluation of Countermeasures

- Economic evaluation for the suggested countermeasures for the study corridor is performed as per IRC SP: 30 (2019) Manual on Economic Evaluation of Highway Projects.
- The methods considered are the (i) cost-benefit ratio, (ii) First year rate of return.
- Analysis period considered is 10 years with a discount rate of 12%. Considering reference year as 2021and maintenance cost is taken as 5% of the construction cost.
- Accident Cost Calculation: The accident cost according to severity of accidents provided in IRC SP 30:2019 have been used in this study after updating them to present day levels.

$$\text{Benefit} - \text{Cost Ratio} = \frac{\textit{Total benefits over the analysis years discounted to the reference year}}{\textit{Total cost over the analysis years discounted to the reference year}}$$

If Benefit-Cost Ratio is greater than 1 then the measure is effective economically.

Annual Average Accident Cost= (Average annual fatal accidents x cost of fatal accidents) + (Average annual grievous accidents x cost of grievous accidents) + (Average annual minor injury accidents x cost of minor injury accidents) + (Average annual non-injury accidents x cost of non- injury accidents)

Effectiveness of Countermeasures: the effectiveness percentage was considered based on safety manuals of other countries, journals and experience.

Cumulative Effectiveness: = [1- {(1-E1) *(1-E2) *…(1-En)}] where, E1,E2…….En are Effectiveness of individual countermeasure

Accident Reduction= (cumulative effectiveness * number of accident)

Summary of Economic Evaluation of Countermeasures (SH-37, Uttar Pradesh)

Blackspot	Countermeasures	B-C ratio	FYRR	Cost Effective
Blackspot 1 (35.6–36.1 KM)	Short term	6.27	1.13	Yes
	Medium Term	1.043	0.19	Yes
	Long Term	0.069	0.0097	No
Blackspot 2 (19.45-19.95 KM)	Short term	6.45	1.17	Yes
	Medium Term	1.28	0.23	No
	Long Term	0.61	0.187	No
Blackspot 3 (46.4-46.9 KM)	Short term	6.76	1.22	Yes
	Medium Term	1.72	0.31	Yes
Blackspot 4 (48.7-49.2 KM)	Short term	7.22	1.30	Yes
	Medium Term	1.60	0.29	Yes

Based on the above results economically feasible countermeasures were suggested for the study corridor.

Safety Performance Function

The data was divided into homogeneous sections, length shorter than 200m and greater then 3 km were avoided to mitigate heteroskedascity.

This resulted in 54 segments out of which 70% data was considered for Regression modelling and 30% for validating the model.

The dependent variable is accident frequency and independent variables were access density, median density and exposure.

Initially Poisson's loglinear model was tested and it was found to be overdispersed. Finally, the Negative Binomial model was found out to be the best fit.

$$\text{Access Density} = \frac{\text{No. of intersections}}{\text{Length of the segment}} \qquad \text{Median Density} = \frac{\text{No. of Median gaps}}{\text{Length of the segment}} \qquad \text{Exposure} = \frac{\text{AADT}}{\text{Length of the segment}}$$

Parameter	B	Std. Error	95% Profile Likelihood Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-6.708	.4735	-7.658	-5.801	200.697	1	.000
segment_length	-.550	.2120	-.962	-.131	6.737	1	.009
Mediangap_den	.351	.0957	.164	.540	13.474	1	.000
Access_den	-.226	.0735	-.378	-.089	9.437	1	.002
(Negative binomial)	1.047E-7	6.1423E-5	.000	.[b]			

Dependent Variable: acc_freq
Model: (Intercept), segment_length, Mediangap_den, Access_den, offset = ln_exposure

e^{ε_i} is a gamma distributed function with mean 1 and variance α. The variance α is also called the over dispersion parameter.

$$acc_{freq} = AADT * segment_{length} * e^{i} * e^{-6.708-(0.550*segment_{length})+(0.351*mediangap_{den})-(0.226*access_{den})}$$

Results

- The yearly weighted severity analysis for SH 37, U.P. shows that accident severity has increased over the years for the study corridor, the rising trend is important to focus as the fatalities have increased for a smaller number of accidents.
- For SH- 10, Odisha, keeping in consideration the lockdown situation throughout the country due to Covid-19 pandemic, the traffic flow was reduced, yet there is no significant decrease in fatalities.
- Both the study areas the month of May and July are highest prone to severe accidents the suspected cause may be the pre monsoon condition leading to wet surface.
- The major cause of accidents for SH-37, U.P. are over speeding followed by dangerous driving and dominant type of collisions are overturned and head on collision. Since the number of Head on collisions are significantly high it can be inferred that wrong side driving is prominently the major reason for reduced safety. While for SH-10, Odisha the major causes are overspeeding and drunken driving, the collisions are dominated by ran off road and head on collisions
- The major contributing vehicles in the accidents for the study areas were heavy articulated vehicles, trucks and cars, the cost involved with these are high and have been considered in economic evaluation.
- Spatial and heat maps indicate that the accidents are more during the night time reason may be the increased movement of transporting and transit vehicles.

- In top four blackspots (considering number & severity of accidents), blackspots with more severity is contributed by blackspots with intersections and gap in medians.

- A total of seven black spots were identified for SH-37, U.P. and ten for SH- 10, Odisha. These were ranked along the study stretch and the top four black spots whose accident severity index value was greater than average accident severity index value were considered for suggestion of countermeasures.

- The long term countermeasures such as paved shoulder and service lanes for the study corridor was not found economically beneficial. But considering the long term safety and the rapid growing traffic it is advised to construct paved shoulders of minimum 2.5 m at least for the major blackspots and locations near residential development. Also it is suggested to construct service lanes for the locations connecting the nearby towns to the highway coupled with 1.5 m earthen shoulders

- Based on the available data the independent variables used for modelling were segment length, access density and median density followed by development of Generalized Linear Model for the accident data and it was found that Negative Binomial is a better fit for the accident data due to the overdispersion characteristic.

- The deviance values and parameter estimates were found equal for Poisson's loglinear and Negative Binomial distribution. But the AIC and BIC values signifies that the latter is an improved model and hence should be preferred.

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