BITS Pilani
Hyderabad Campus

TRIAL Transportation Research Innovation Analysis Lab

Global Road Infratech Summit & Expo

"Vision Zero India: Integrating Safety, Sustainability and Technology in Infra"

Development of a Systematic Methodology for Improving Road Safety on Urban Roads in India

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IRF INDIA CHAPTER

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IRF INTERNATIONAL ROAD FEDERATION

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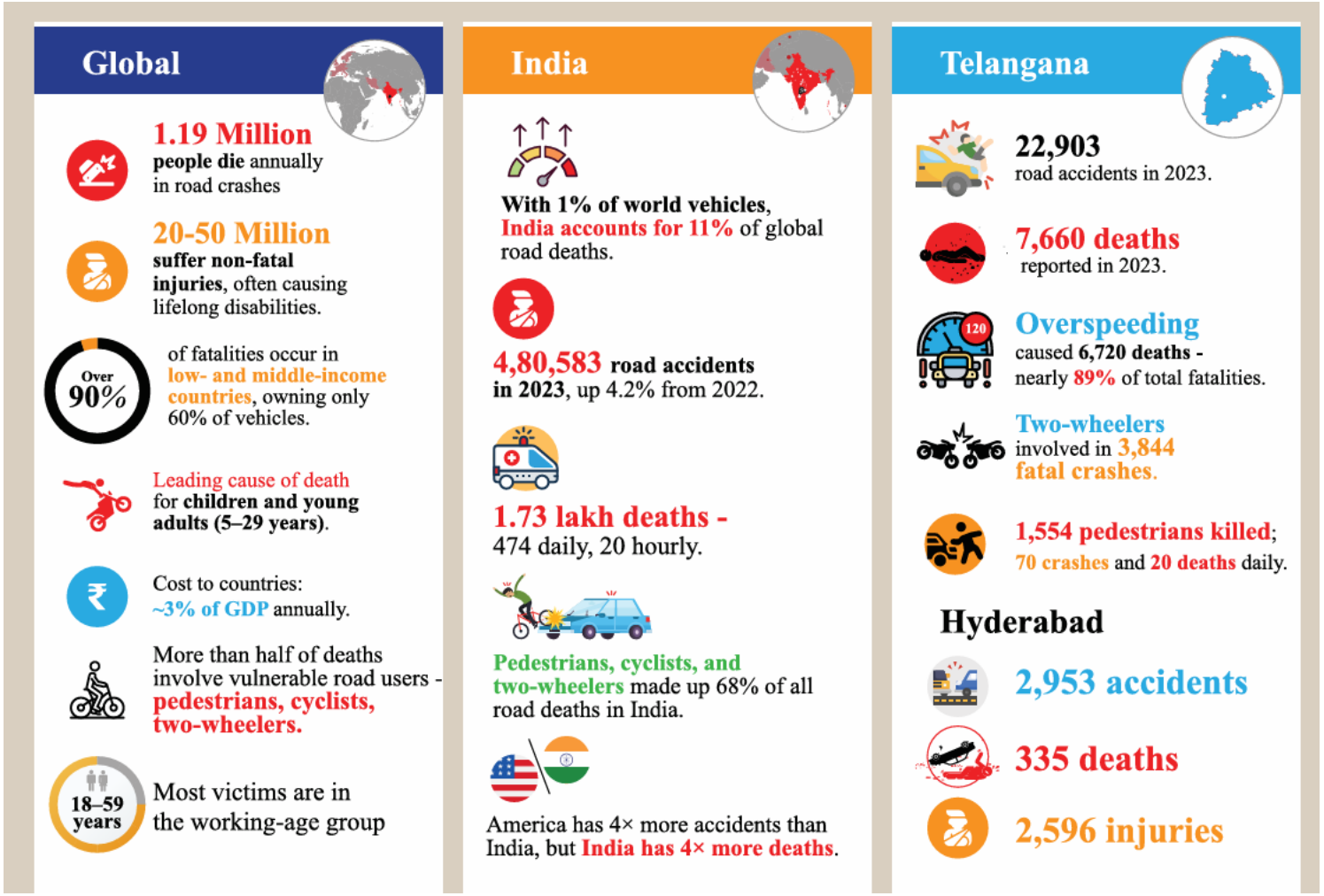
Background - Crash Statistics



Global status report on road safety 2023. Geneva: World Health Organization; 2023. Licence: CC BY-NC-SA 3.0 IGO
MoRTH. (2025). *Road Accidents in India 2023*

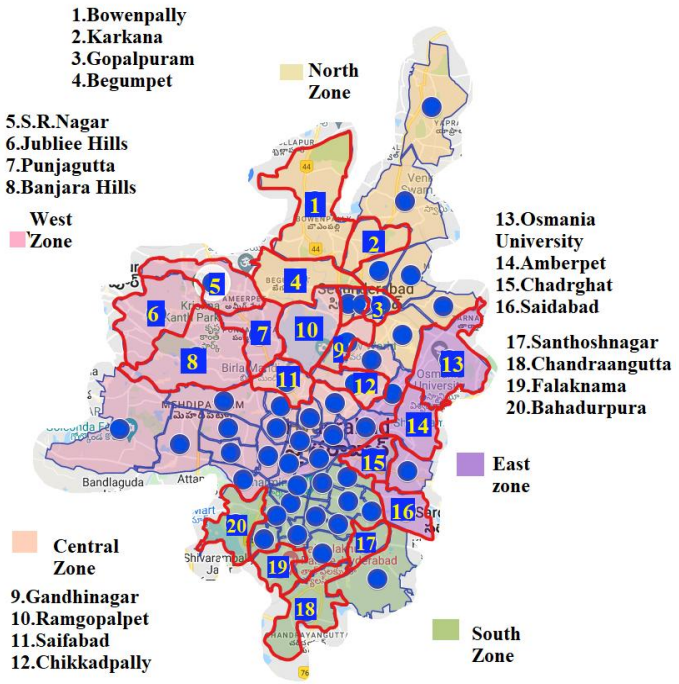
Study Area

Ranked among top 10 cities for the last 5 years for total crashes

Highest personal vehicle dependence among India's six megacities

Slated to become one of 43 megacities word wide

Hyderabad



Total of 60 Police stations (Jurisdictions)

5 Zones: East, West, North, South and Central Zones

Top 20 stations from 5 zones have been identified as shown in figure

Objectives

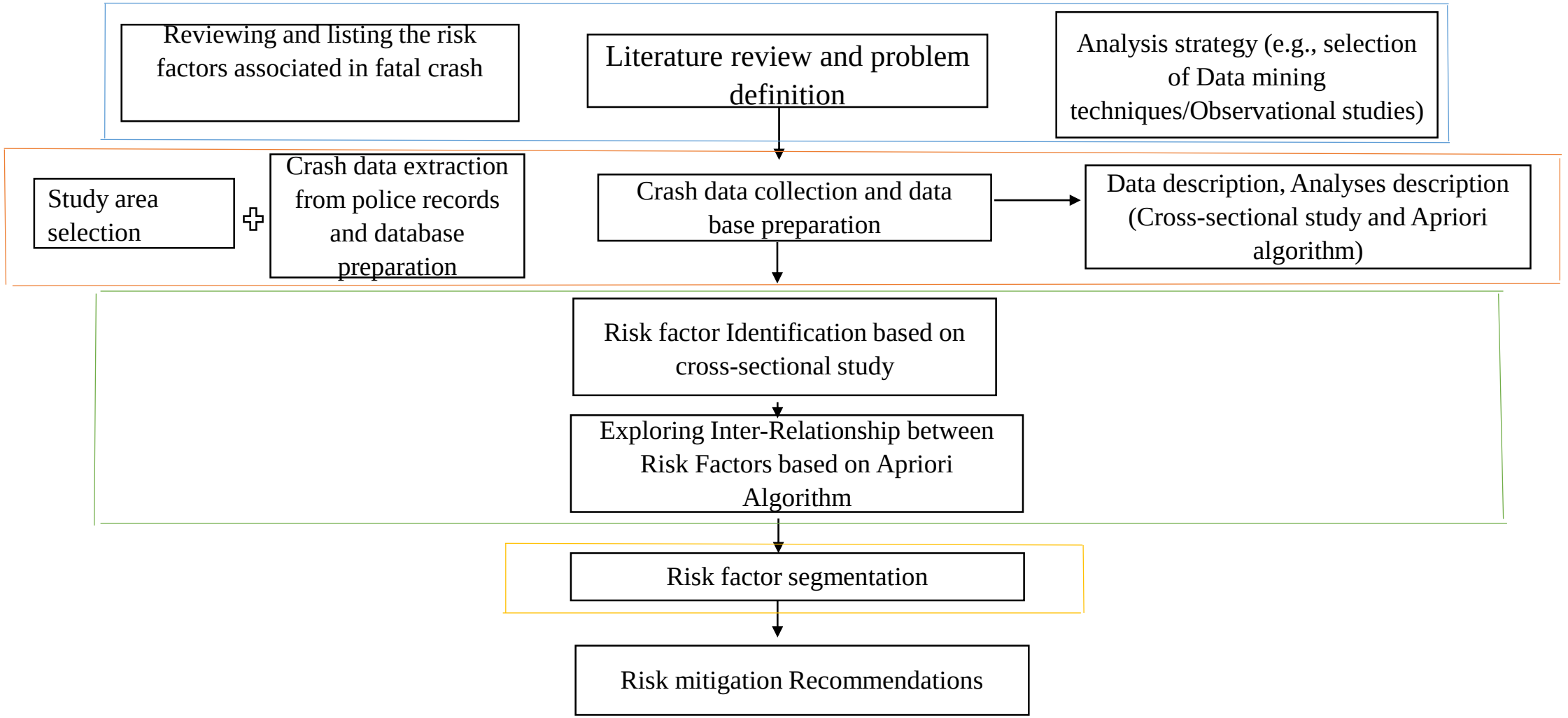
1. To identify the road traffic fatality risk factors using police data in an urban Indian context.

2. 2. To investigate the influence of roadway traffic and geometric and physical characteristics on urban crash fatality and frequency.

3. 3. To evaluate the existing road safety condition at a set of critical roadway locations using a proactive approach and prioritization of a set of RTC countermeasures in an urban roadway network

Identification of Risk Factors Based on Police Crash Data

Methodological Framework

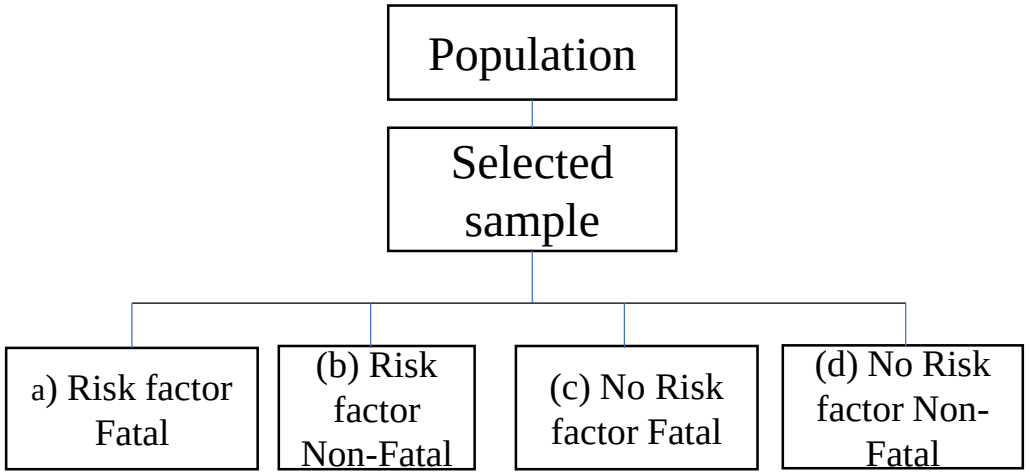


Determination of Risk Factors

- Three types of observational studies, such as Case-control, cohort, and cross-sectional, are generally employed in epidemiological research

- Odds ratios (OR) or Risk Ratio (RR) are commonly used as the measure of association between exposure and outcome.

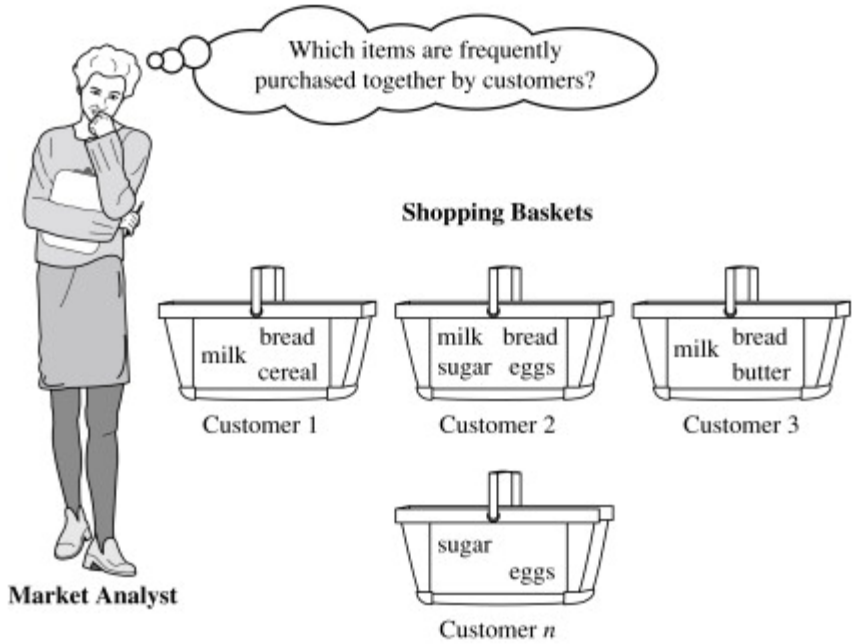
- RR is noted to be a more accurate measure of association than OR for cross-sectional analyses



	Develop outcome	**Do not Develop outcome**
Exposed	a	b
Not Exposed	c	d

Risk Factors Determination

- Association rules mining or market basket analysis helps in identifying sets of items that occur together.
- 'Apriori algorithm' is commonly used in ARM
- In the Apriori algorithm, support, confidence, and lift are the three important indicators used to discover association rules



Source: Data Mining: Concepts and Techniques Jiawei Han, Micheline Kamber and Jian Pei

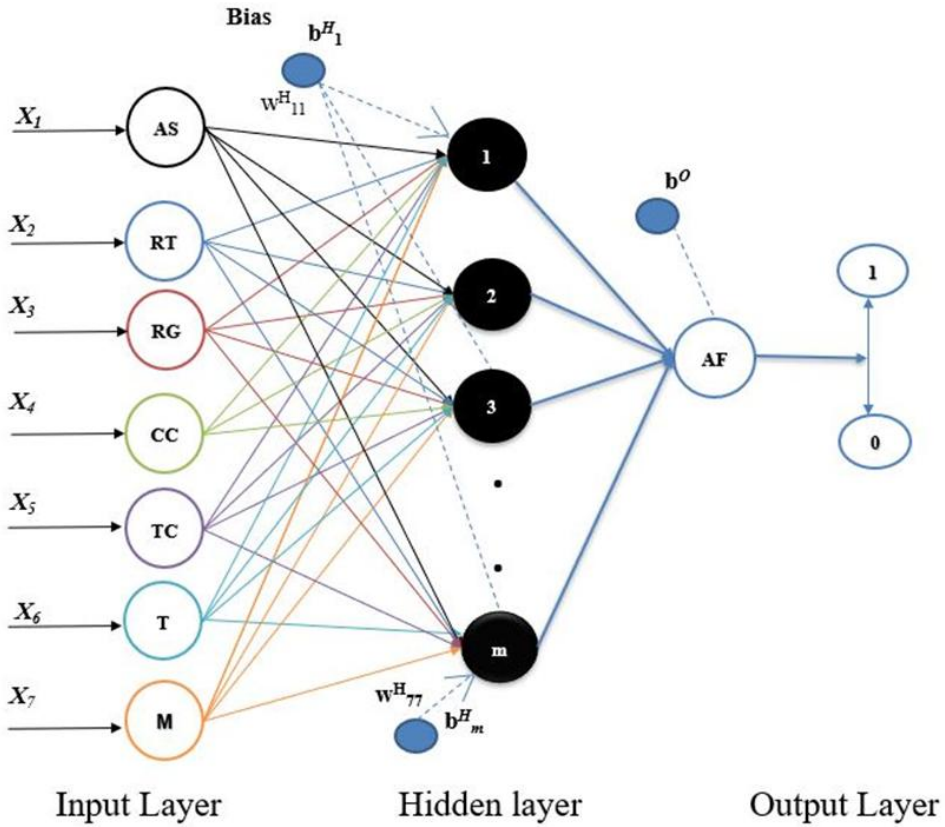
Final Risk Factor Segmentation Results

Risk factor segment		Cross-sectional study output			Apriori Algorithm Association towards fatal crash outcomes	
Segment No.	Description	Significant risk factor	Insignificant risk factor	Non-risk factor	present	absent
Segment 1	Very High-Risk Factors	✓	×	×	✓	×
Segment 2	High-Risk Factors	✓	×	×	×	✓
Segment 3	Moderate Risk Factors	×	✓	×	✓	×
Segment 4	Low-Risk Factors	×	✓	×	×	✓
Segment 5	Very Low-Risk Factors	×	×	✓	✓	×
Segment 6	Extremely Low Factors	×	×	✓	×	✓

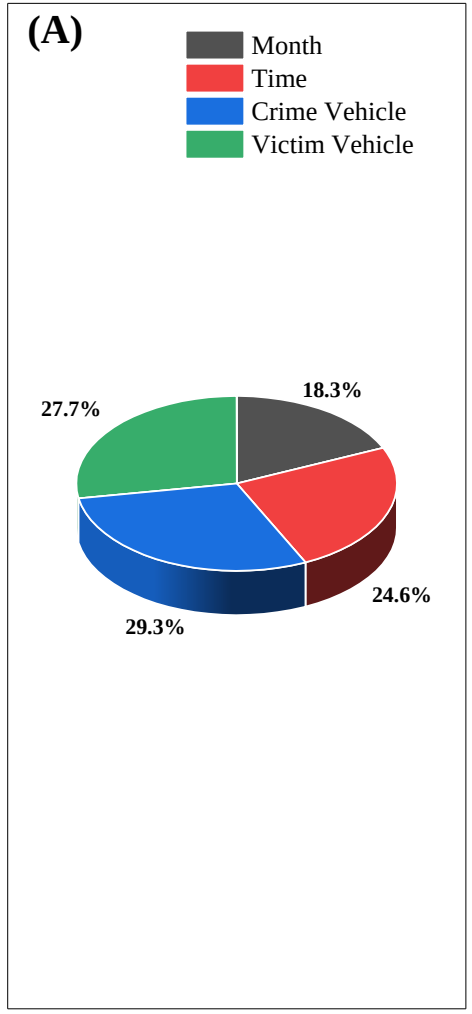
Segments	Identified Risk Factors
Very High-Risk Factors	○ HMV (Accused vehicle) ○ Unknown (Accused vehicles) ○ Pedestrians (Victim vehicles) ○ Others (Victim vehicles & Accused vehicle)
High-Risk Factors	○ Mid-night (12:00 a.m. – 3:00 a.m.) ○ Night (9:00 pm – 12:00 am) ○ Other vehicles (Accused vehicles)
Moderate Risk Factors	○ Summer (Season)
Low-Risk Factors	○ Three-Wheeler (victim) ○ Post Mid-night hours (3:00 am- 6:00 am) ○ Early afternoon (12:00 pm -3:00 pm) ○ Late afternoon (3:00 pm – 6:00 pm)
Very low-Risk Factors	○ Late morning (9:00 a.m. -12:00 p.m.) ○ Evening (6:00 pm – 9:00 pm) ○ Two-wheelers (accused) ○ Two-wheelers (victim) ○ Four-Wheeler (accused) ○ Monsoon (Season)
Extremely low-Risk Factors	○ Autumn, Spring and Winter (season) ○ Early morning (6:00 am – 9:00 am)3W (accused &victim) ○ 4W (victim) ○ Pedestrian (Accused) ○ HMV (Victim) ○ Unknown (Victim)

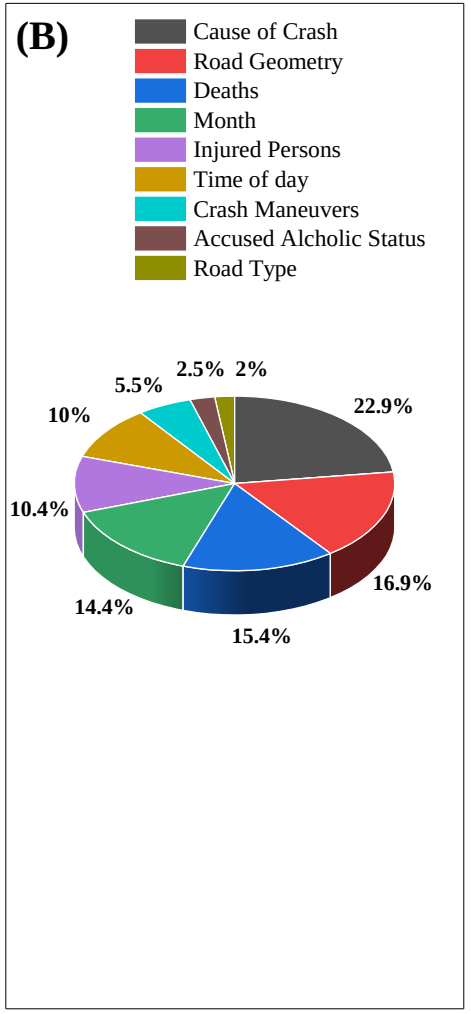
Risk Factors -Artificial Neural Network

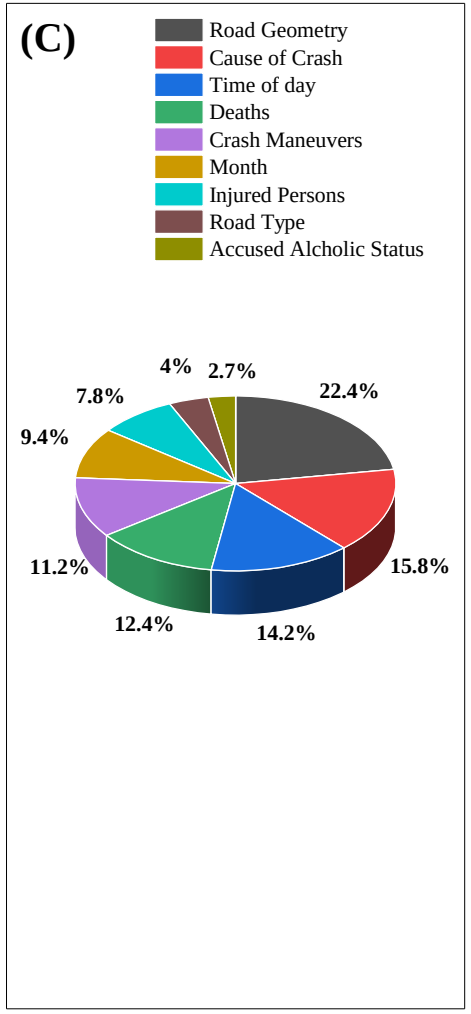
- Artificial Neural Networks (ANNs) are biologically inspired and capable of modeling complex non-linear functions
- Model parameters in an ANN model represent the weights and biases correlated with various neurons
- Root mean squared error (RMSE), mean absolute error (MAE), coefficient of correlation (R), and other values are used to evaluate an ANN model's output



Sensitivity Analysis using ANN & LIME







Sensitivity Analysis output:

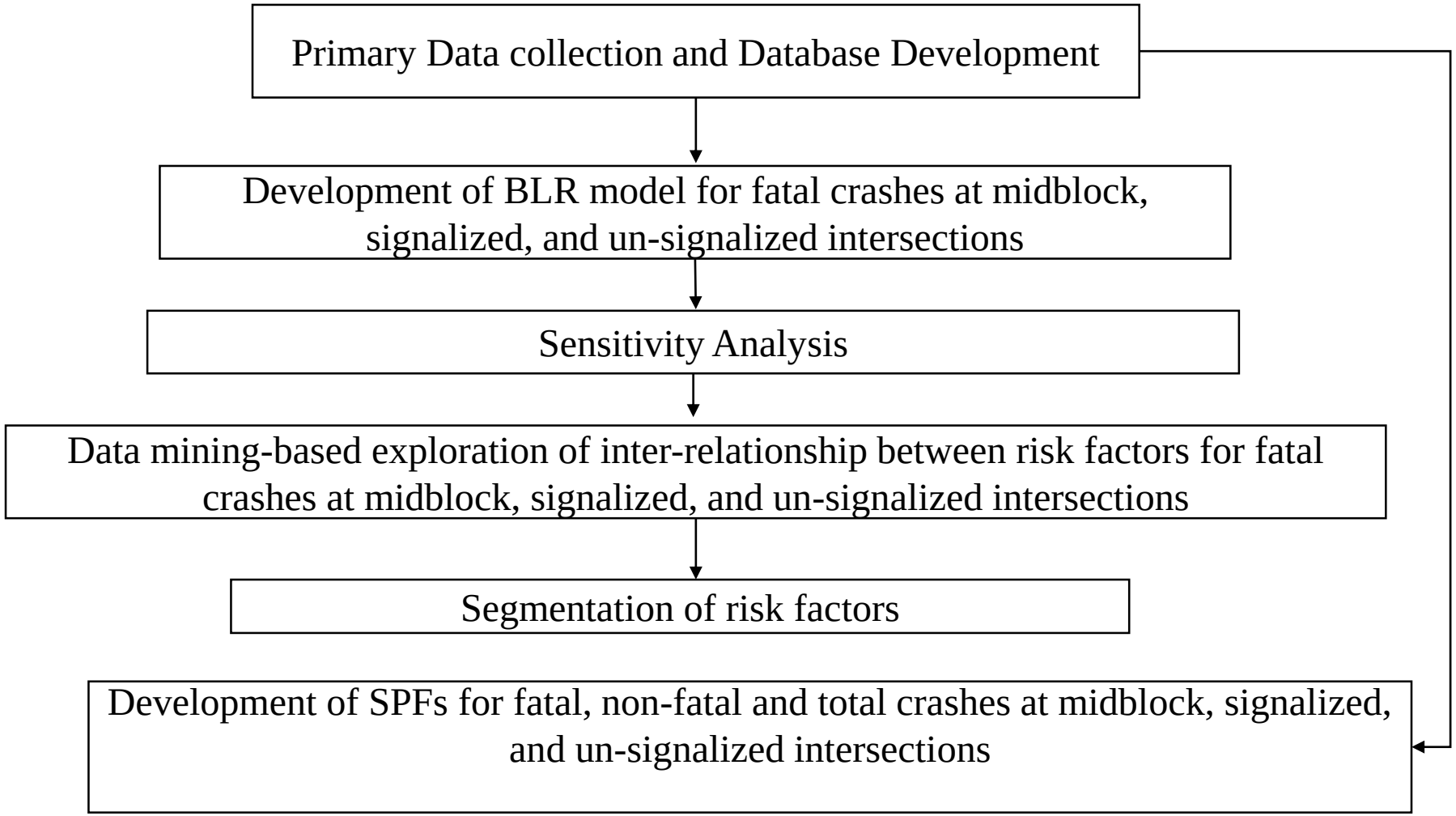
(A) based on 2015–2019 (20 police stations data);

(B) based on 2019 (20 police stations data);

(C) based on 2019 (30 police stations data)

Methodological Framework for the Investigation of Key Factors Influencing Urban Crash Fatality and Frequency

Methodological Framework



Segmentation of Key Factors

Factor categorization	Predicted probability	No. of times appeared in best rules	Midblock	Signalized	Un-Signalized
Highly influencing risk factors	≥ 20%	≥ 3	Footpath, Speed, Lane width, Good physical condition, Concrete median	Major Road - width, Pedestrian signals	No Stop mark
Moderately influencing risk factors	10-20%	2	Paved shoulders, Straight roads	Visibility of road markings, Cycle time, No. of lanes, no stop marks, presence of vertical curve	ADT, Footpath (1/0), Traffic sign, Absence of zebra crossing, Presence of horizontal and vertical curves
Low influencing risk factors	< 10%	1	Number of lanes, ADT, Median Width, Presence of vertical curves and No traffic signs	Right Turn - Protected, ADT, Presence of Horizontal curve, physical condition, four-legged intersection, exclusive free left	Median width on a major road (m), Number of Lanes (1,2,3), Major Road width (m), Three-legged intersection, mixed land use.

Midblock-SPF's

Variable Characteristics	Explanatory variables (Total)	Coefficient	Explanatory variables (Fatal)	Coefficient	Explanatory variables (non-Fatal)	coefficient
Geometric and infrastructure factors	Median width (m)	-0.0594***	Median width (m)	-0.1079***	Median width (m)	-0.0377**
	Lane Width (m)	0.0078**	Lane Width (m)	0.0443***	Midblock length(m)	0.0002***
	Midblock length(m)	0.0002***	Midblock length(m)	0.0003***	-	-
	Footpath (1/0)	-0.0811**	Footpath (1/0)	-0.2969***	-	-
	-	-	Number of Lanes	-0.0899*	-	-
Traffic related factors	Speed (kmph)	0.0446***	Speed (kmph)	0.0479**	Speed (kmph)	0.0466***
	LOG (ADT)	0.2251***	-	-	LOG (ADT)	0.6548**
Model summary	Constant	-0.5809*	Constant	-1.8138***	Constant	-0.6548**
	Log likelihood	-3069.818	Log likelihood	-1121.539	Log likelihood	-2970.115
	AIC	6155.6	AIC	2259.1	AIC	5952.2
	Alpha	0.884	Alpha	0.242	Alpha	0.866
	N	1396				

****99% significance level, **95% significance level, * 90% significance level*

Signalized Intersection-SPF's

Variable Characteristics	Explanatory variables (Total)	Coefficient	Explanatory variables (Fatal)	Coefficient	Explanatory variables (non-Fatal)	coefficient
Geometric and infrastructure factors	Major road width (m)	0.0110*	Major road width (m)	0.0329**	Good Condition	-0.2011***
	Minor road width (m)	0.0274**	Minor road width (m)	0.0506**	Four Legged	-0.2431***
Traffic-related factors	No. of signal phases	-0.1148**	Protected right turn	-1.3872***		
	Log (ADT)	0.6961***	Log (ADT)	-1.5255**	Log (ADT)	1.3313***
Model summary	Constant	2.1487*	Constant	5.7130*	Constant	-4.9839***
	Log likelihood	-741.875	Log likelihood	-269.233	Log likelihood	-752.282
	AIC	1495.8	AIC	548.5	AIC	1514.6
	Alpha	1.224	Alpha	0.09	Alpha	0.941
	N	291				

****99% significance level, **95% significance level, * 90% significance level*

Un-Signalized Intersection-SPF's

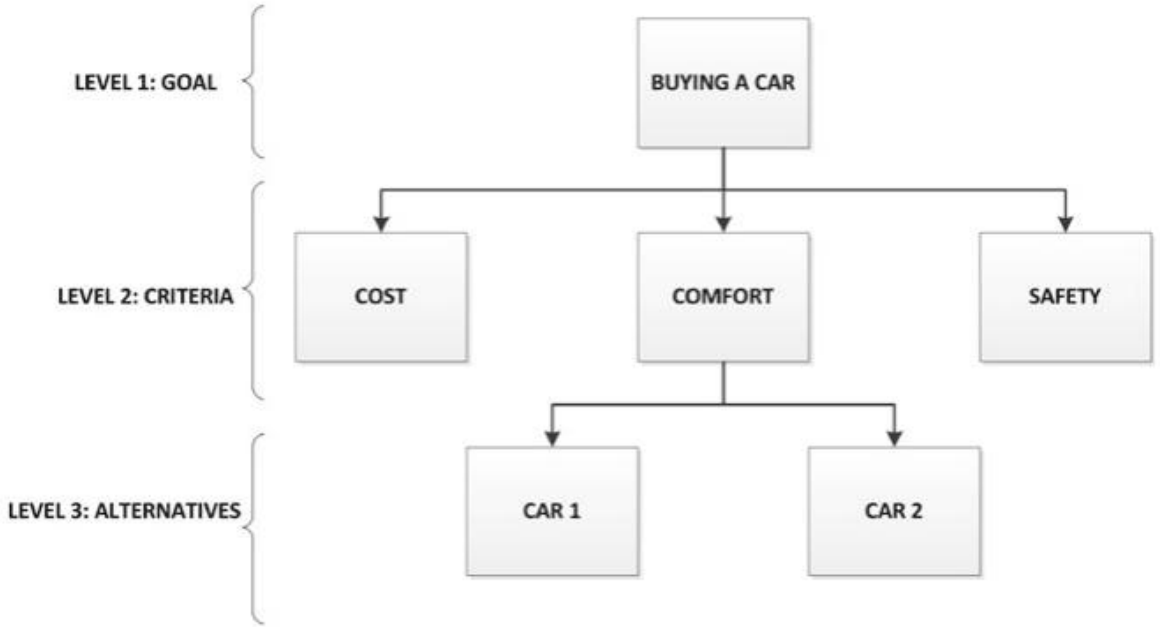
Variable Characteristics	Explanatory variables (Total)	Coefficient	Explanatory variables (Fatal)	Coefficient	Explanatory variables (non-Fatal)	coefficient
Geometric and infrastructure factors	Major road width	0.0164**	Footpath	-0.4192**	Major road width	0.0148**
	Presence of Vertical curve	0.1567*	Presence of Traffic signs	-0.4818**	Presence of Vertical curve	0.1669*
Traffic-related factors	Presence of Traffic signs	-0.2544***	Log (ADT)	1.646***	Presence of Traffic signs	-0.3152***
	Log (ADT)	0.5327***			Log (ADT)	0.4975**
Model summary	Constant	-1.6784*	Constant	-8.8137***	Constant	1.5869*
	Log likelihood	-746.937	Log likelihood	-265.010	Log likelihood	-725.642
	AIC	1505.9	AIC	528.0	AIC	1463.3
	Alpha	0.839	Alpha	0.10146D-04	Alpha	0.831
	N	340				

****99% significance level, **95% significance level, * 90% significance level*

Evaluation of the Existing Roadway Safety Condition and Prioritization of RTC Countermeasures

Analytical Hierarchy Process (AHP)

- Analytic Hierarchy Process (AHP), structuring complex problems into a hierarchy.
- Elements are compared in pairs to assess their relative importance using a scale (e.g., 1,3,5,7, and 9)
- Consistency of judgments is checked, and priorities are calculated to identify the best alternative.
- Useful in prioritization, resource allocation, and complex decision-making where factors are independent.



Decision hierarchy for buying a car

Source: Practical Decision Making.An Introduction to AHP
Mu, E. : Peryara Rojas, M.

Identification of Safety Factors

Midblock Elements

- Built Environment Characteristics
- Geometric and Physical Characteristics
- Traffic characteristics

Signalized Intersection Elements

- Traffic signal Operation Related Characteristics
- Traffic Signs/Markings Related Characteristics
- Traffic Movement Related Characteristics
- Intersection Geometric and physical characteristics

Un-Signalized Intersection Elements

- Traffic Signs/Markings Related Characteristics
- Traffic volume and Geometric Characteristics
- Physical characteristics

S.No.	Attribute A	Ranking Attribute A over B					Ranking Attribute B over A				Attribute B
1	Shoulder width	9	7	5	3	1	3	5	7	9	Shoulder type
2	Shoulder width										Median width
3	Shoulder width										Median type
4	Shoulder width										Presence of foot path
5	Shoulder width										Type of land use
6	Shoulder type										Median width
7	Shoulder type										Median type
8	Shoulder type										Presence of foot path
9	Shoulder type										Type of land use
10	Median width										Median type
11	Median width										Presence of foot path
12	Median width										Type of land use

Application of Condition Index

Midblock Condition Index (MCI)

Midblock Sections	MCI	Ranking	Fatal	Non- Fatal	Total crashes
Rasoolpura Jn- Prakash nagar metro	0.11	1	2	69	71
Prakash nagar metro- Taj vivanta	0.14	2	2	50	52
Taj Vivanata Jn - Katta Maisamma	0.24	3	2	43	45
CTO Jn – NCC Jn	0.31	4	2	17	19
Tivoli Jn- Sweekar Jn	0.32	5	1	15	16
Tivoli Jn – Praklane	0.33	6	0	11	11
Sweekar Jn –JBS Jn	0.36	7	1	1	2

Relative Weights - Rear-End Countermeasures

Category	Countermeasures	AHP relative weight	Rank
Overspeeding	Installation of speed limit signs along the road and speed cameras	0.39	1
	Provision of Rumble strips	0.22	2
	"REDUCE SPEED" (Variable Message Signs)	0.21	3
	Provision of zig-zag barriers	0.16	4
Involving Pedestrian	Provision of the manual guard at critical sections	0.27	1
	Installation of pedestrian barriers	0.19	2
	Pelican crossing activated by roadside call buttons	0.18	3
	Refuge islands to separate two main directions of traffic	0.13	4
	Raised Pedestrian Crossings (Table Top)	0.10	5
	Installation/improvement of signing or marking pedestrian crosswalks	0.09	6

Category	Countermeasures	AHP relative weight	Rank
Lost Control	Reduce the speed limit on approaches	0.20	1
	High Friction Surface Treatments (HFST)	0.18	2
	Roadside delineators	0.17	3
	Grooving of Pavement	0.16	4
	Improvement of pavement markings	0.15	5
	"slippery when wet" signs	0.14	6
Junctions	Provision of All-red interval	0.28	1
	Advanced stop or yield lines (20-50ft)	0.22	2
	Installation of barriers	0.20	3
	Provision of left-turning lanes	0.16	4
	Prohibition of Right-Turns	0.11	5

Conclusion

- The likelihood of a fatal crash at midblock is observed to increase by 34% as speed increases from 20km to 60 Km.
- The likelihood of fatal crashes at signalized junctions is observed to increase by 36% as the major road width increases from 15 m – 40 m.
- The presence of a footpath and traffic signs at unsignalized intersections has been shown to lower fatal crashes by 14% and 15%, respectively.
- This study is one of the few attempts to study police study , develop safety index for existing roads and develop a guide for countermeasures specific to dominant crash types .

Thank you