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Safety Evaluation of Urban Roundabouts in India: A Safety Performance Function based Approach

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OVERVIEW

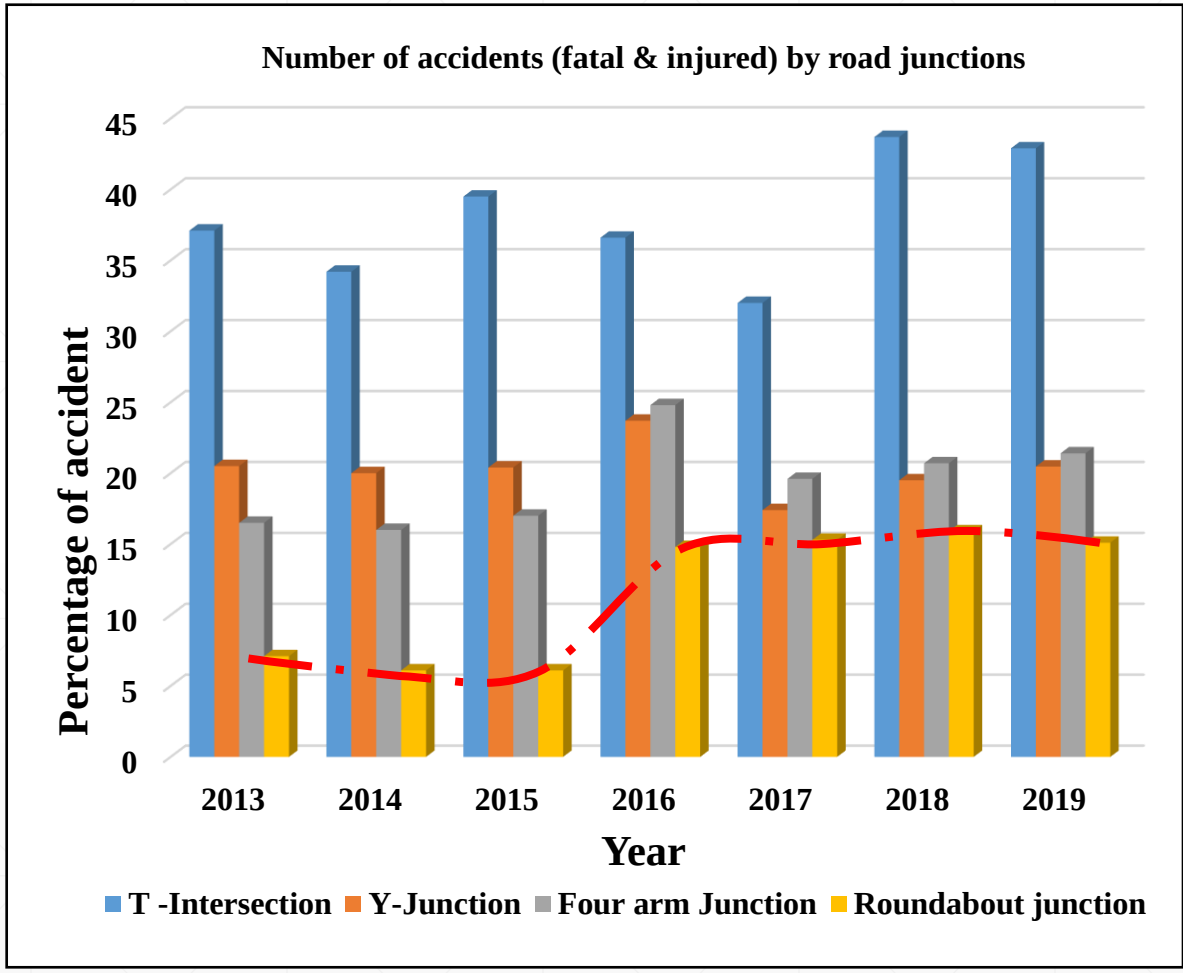
- Introduction
- Research Motivation
- Objective
- Data collection
- Descriptive Statistics
- Data Analysis and Results
- Conclusions

Introduction

- Intersections have a significant role in ensuring a safe and efficient operation of traffic in a transportation network
- Roundabouts considered as safe among the various intersection types
- It provides better intersection safety based on orderly continuous traffic flow, less delay, reducing the conflict and eliminating the crash severity
- Studies are globally grounded on the estimation of capacity, delay aspects and pointed either towards gap acceptance behavior
- As per global accident (2018) status -1.35 million persons killed, but 90 % was reported in developing countries
- As per Ministry of Road Transport, and Highways (MoRTH) -2019, approximately 151,113 deaths and 451,361 injuries, India
- Safety measures can provide a useful platform from which to identify high risk factor in the traffic stream and guide cost-effective intervention strategies

Research Motivation

- Few studies have analyzed crash-based safety performance function outcomes at uncontrolled intersections and roundabouts.
- Lack of comprehensive research in roundabout safety- due to the limited access to field crash data
- Detailed information about the factors causing crashes at the roundabouts is essential for planners and designers to identify existing deficiencies and refine the design criteria
- Design guidelines IRC-65 (2017) and Indo-HCM (2017) focused on developing capacity and level of service determination of roundabouts. it could not address the crash data-based safety evaluation tool



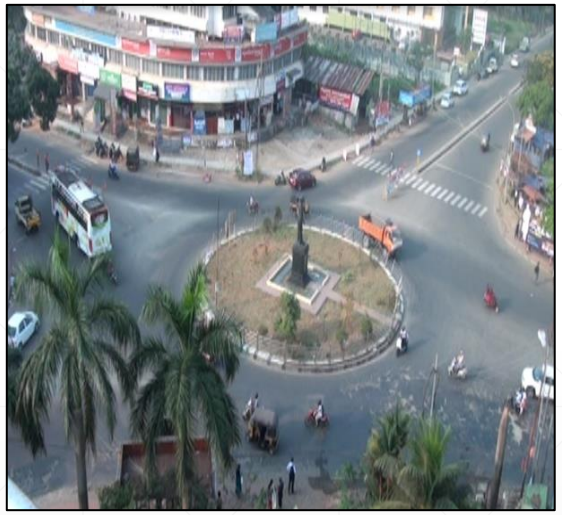
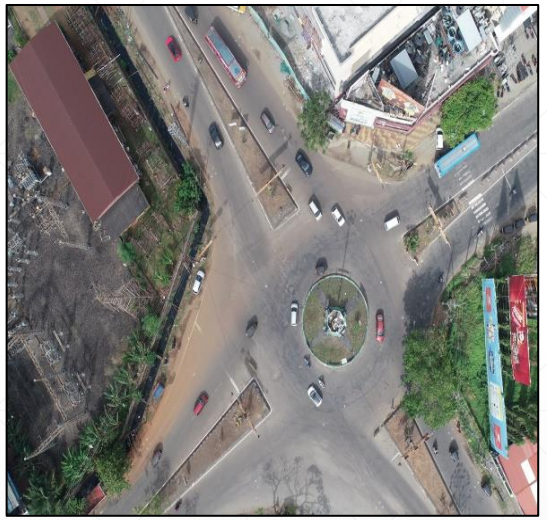
Source: MoRTH: 2019

Objective

- To develop a safety performance function model for assessing the safety evaluation of roundabouts, especially at approach and intersection level, while considering the geometric design features, traffic characteristics, and historical crash occurrence data

Data Collection



Snapshot of few roundabout study locations

No. of locations	Data collection method	Crash data collection	No. of Years
20-India (Kerala, Maharashtra)	Video graphic ,Total Station Export -AutoCAD	Referring FIR based report from police station	2015-2019 (5 year)

Descriptive Statistics

Variables (Unit)	Minimum	Maximum	Mean	Standard Deviation
Average daily traffic at junction (PCU/Day)	30469	104967	60016.63	22728.40
Central island diameter (meter)	8.10	50.61	20.23	10.90
Central island Height (meter)	0.22	1.00	0.55	0.21
Circulating road width (meter)	6.62	29.20	12.34	4.21
Inscribed circle diameter (meter)	29	70.40	43.05	13.15
Approach width (meter)	3.00	13.60	6.62	2.48
Departure width (meter)	3.00	14.37	6.69	2.66
Entry Angle (degree)	7.00	131.00	40.45	25.77
Exit angle (degree)	5.00	123.23	39.33	22.27
Entry radius (meter)	4.12	221.00	35.37	35.07
Exit Radius (meter)	5.39	301.00	49.71	59.64
Entry width (meter)	4.23	27.80	10.51	4.16
Exit width (meter)	4.13	29.00	11.67	4.74
Weaving width (meter)	7.0	43.15	14.49	5.48
Weaving length (meter)	9.10	70.91	28.75	12.50
Angle to next leg (degree)	32.85	178.00	104.81	32.55
Splitter Island length (meter)	0.0	70.0	12.69	17.05
Splitter Island width (meter)	0.0	15.80	3.41	4.22
Number of circulating lanes	2 lanes (83.7%), 3 lanes (16.3%)			
Number of legs	3 leg (28.3%), 4 leg (64.8%), 5 leg (6.7%)			
Number of lanes in Approach	Single lane (25.7%), 2 lanes (65.7%), 3 lanes (8.1%)			
Number of lanes in a departure	Single lane (25.7%), 2 lanes (64.28%), 3 lanes (10%)			
Presence of pedestrian cross marking	No (64.5%), Faded (35.5), Yes (0%)			
Presence of road lane marking	No (72.5%), Faded (27.4%), Yes (0%)			
Presence of traffic signboard	No (85.4%), Faded (12.9%), Yes (3.2%)			
Presence of road surface condition	Bad (5.06%), Medium (91.3%), Yes (3.8%)			
Presence of street light conditions	Yes (42%), No (58%)			
Day-Night	Day (69.8%), Night (30.2%)			
Type of Land use	Mixed land use (26.5%), Commercial (48.2%), Residential (21.6%), Institutional (3.6%)			

Note: - *PCU- passenger car unit for roundabouts (as per IRC-65-2017), Presence of road surface condition is good (no cracking, no potholes, smooth surface), Average daily traffic (ADT) at a junction: - Total volume at the roundabout junction for one day (PCU/Day)*

Safety performance function (SPF)

- SPF are very useful tools in explaining the safety at road segments
- Traffic accident - contributing factors - driver behaviour, road geometry, traffic and environmental characteristics
- To handle count data with excess zeros, NB can accommodate over-dispersion (V>M) that may exist in the crash data counts
- Dependent variable Y is count (0, 1.2.. Positive)
- The proposed Safety performance function.

$$Y = \exp(\beta_0 + (\sum_{i=1}^{n} \beta_i x_i + \varepsilon_i)$$

Y: Expected number of crashes at the roundabout vicinity

x_i : explanatory variables for roundabout vicinity

β_0: Intercept

β_i : Model coefficients associates with x_i

n = total number of variables, ε_i Error term

Analysis and Results

Development of Safety Performance Function (SPF)

- 29 variables were considered for this study, 18 variables as continuous, and the rest as categorical
- A Pearson correlation matrix: (correlation coefficient is > 0.5 and P<0.05)
- Multicollinearity (Variance Inflation Factor>10)
- In-depth understanding of traffic, geometric characteristics, and environmental factors SPF is divided into two
- Model Evaluation & Goodness of fit: ρ^2 statistic, Akaike's Information Criterion (AIC), Mean Squared Prediction Error (MSPE), Mean Absolute Deviation (MAD)

SPFs at Roundabout Entering Approach Level

Roundabout Category wise SPFs	Parameters	Coefficients	St. Error	t-Stat.	Sig:
Entering Approach level	Constant	2.73	-	-	-
	Average daily traffic at junction (ADT_JN) **	0.400	0.142	2.816	0.005
	Inscribed circle diameter (ICD)**	-0.340	0.164	-2.073	0.045
	Entry Angle (EA)*	0.202	0.90	0.224	0.026
	Exit radius (EXR)**	0.286	0.092	3.11	0.002
	Weaving length (WL)**	0.241	0.105	2.29	0.022
	Presence of road lane marking (PRLM)**	-0.448	0.22	-2.03	0.050
Approach level Goodness' of fit & Validation	Dispersion parameter	0.40			
	log-likelihood ratio (ρ^2)	0.117			
	Deviance &Pearson Chi-Square	1.15 & 1.03			
	AIC	473.31			
	MSPE and MAD	0.14 & 0.31			

Note: *Significant at 95% confidence level**; Akaike's Information Criterion (AIC), Mean squared prediction error (MSPE), Mean absolute deviation (MAD)*

Analysis and Results (Contd.)

SPFs at Intersection Level

Roundabout Category wise SPFs	Parameters	Coefficients	St. Error	t-Stat.	Sig:
Intersection level	Constant	2.53	-	-	-
	Average daily traffic at junction (ADT-JN) **	0.441	0.133	3.31	0.001
	Two-Wheeler (%) (TW) **	3.09	1.57	1.96	0.050
	Number of circulatory lane (NCL)**	-1.02	0.36	-2.83	0.005
	Heavy vehicle (%) (HV)*	7.74	4.57	1.69	0.09
Intersection level Goodness' of fit & Validation	Dispersion parameter	0.207			
	log-likelihood ratio (ρ^2)	0.10			
	Deviance & Pearson Chi-Square	1.4 & 1.39			
	AIC	213.35			
	MSPE and MAD	0.94 & 1.1			

Note: *Significant at 95% confidence level**;Significant at 90% confidence level*, Akaike's Information Criterion (AIC), Mean squared prediction error (MSPE), Mean absolute deviation (MAD)*

- The number of crashes deliberated as the dependent variable; geometric and traffic characteristics as the independent variables
- Modeling was done with the statistical IBM-SPSS software
- Percentage of two-wheelers was dominant in all the roundabouts
- TW considered a vulnerable vehicle class component; it has high manoeuvrability power and filtering behaviour
- The variance of crash data was larger than the mean - dispersion parameter was significantly different from zero, NB distribution assumption is acceptable for this model

Conclusions

- Safety performance function model (SPF) was developed using negative binominal model, based on geometric elements, traffic characteristics, and historical crash occurrence data
- Percentage of TW, percentage of HV, average daily traffic at the junction, entry angle, and weaving length were significantly associated with increased crash occurrence
- Number of circulatory lanes, inscribed circle diameter, and presence of road lane marking were negatively associated with the increased crash occurrence
- Average daily traffic was the most influencing factors across the entire roundabout vicinity
- The asymmetric effects of geometric variables on the crash rate at different sections of the roundabout
- The proposed SPFs tool will help engineers to examine the safety treatments of roundabouts in terms of design adequacy, quantifying the crash contributing factors, and future crash predictions
- The variables, such as speed and acceleration at the time of the accident are not considered in this study
- Transferability of the models to different regions with similar traffic and geometric characteristics need to be carried out in future research

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THANK YOU