Development of Strategies to Enhance the Safety at Roundabouts

Abhishek Singh[1] Pradeep Kumar Agrawal[2] Himanshu Jaiswal[3] Sandeep Choudhary[4]
[1]UG Student [2]Professor [2]M. Tech. Student [4]Ph.D. Scholar
[1,2,3,4]Department of Civil Engineering
[1]National Institute of Technology, Raipur, 492010 India [2,3,4]Maulana Azad National Institute of Technology, Bhopal, 462003

Abstract— The amount of road accidents and fatalities at intersection in worldwide is alarming. A large number of traffic accidents take place at intersections on urban roads in India. These statistical data indicate that intersections are the place of serious safety concern. Roundabout is a type of intersection which is designated for safe and smooth channelization and movements of vehicles in desired direction through a central island. Weaving, Crossing, merging, diverging are some process, which leads to complex movement conditions at roundabouts especially on mix traffic condition in Indian roads. It may be said that roundabout intersections are among the most hazardous locations on Indian roadway system. Hence, objective of this study is to develop some strategies that can be useful to enhance the safety at roundabout. There are a total number of fifteen factors which effects the roundabout safety and among them we present the major three of them in our study. The proposed strategies are illustrated with the help of three roundabouts of the capital city of Bhopal. It may be concluded from the study that the strategies proposed are useful to enhance safety at roundabout. Thus, it is expected that this analysis may be useful for enhancing safety on urban roads in India.

Key words: Roundabout, Road Safety, Road Safety Strategies, Road Accidents

I. INTRODUCTION

The increase in the motorization on the roads hike the possibilities of accidents. The austerities of these road calamities are so dreadful that it can even lead to death. By taking these considerations of our day today life we have tried to develop some strategies to enhance the safety at roundabouts. From the recent studies it has found that the total number of individuals killed in road calamities raised by 4.6 per cent from 1,39,671 in 2014 to 1,46,133 in 2015(RSR 15). Road accident injuries have also increased by 1.4 per cent from 4, 93,474 in 2014 to 5,00,279 in 2015(RSR 15). The severity of road accidents, measured in terms of number of persons killed per 100 accidents has boosted from 28.5 in 2014 to 29.1 in 2015(RSR 150). These data are heart throbbing for the society. Figure 1 presents the information about percentage distributions of intersection crashes to overall crashes.

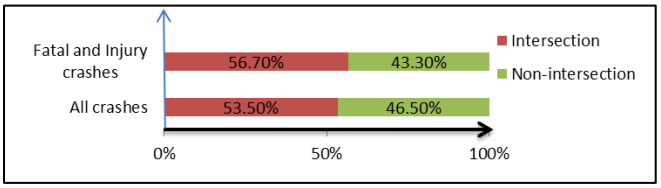

Fig. 1: Percentage distributions of intersection crashes to overall crashes (FHWA, 2006)

The foremost criteria which is taken into account while designing or construction any project of civil engineering is the safety of the individuals who will be going to use that as a resource. Safety regarding the roads is the most important one to be considered, because there is a regular movement of users at different rates on the road. The strategies which we are present here can be actively used to enhance the roundabout safety more precisely and accurately. Figure 2 presents the crucial information about the Number of Fatalities per 100000 populations at Intersection and Non-intersection in USA in year 2006 (FHWA, 2006).

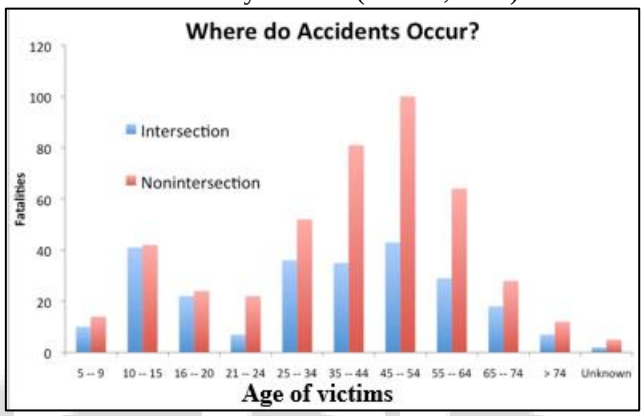

Fig. 2: Number of Fatalities per 100000 populations at Intersection and Non-intersection in USA in year 2006 (FHWA, 2006)

This paper is organized into 5 sections. Section 1 presents the introduction of the paper. Section 2 gives the literature review of the previous works which were done in the same field. Section 3 illustrate the strategies which we have considered. In section 4 we present the case study by taking all the actual data in account. The whole paper is concluded in section 5.

II. LITERATURE REVIEW

Some of the critical literature reviews are carried out and important findings are summarized below;

Ashar Ahmed et al., (2014) collected the accidents data from MIROS (Malaysian Institute of Road Safety Research). The collected data was analyzed separately for each attribute. The effect of each subtype on the overall behavior of accident was observed. Since, road width is one of the governing parameter in the geometric design of unsignalized intersections; hence, all other attributes were analyzed further with respect to this attribute.

A. Ahemad et al. (2015) analyzed the four parameter namely Road width, traffic control, lane marking, land use with respect the road accident. They analyzed 442 unsignalized intersections in the northern part of West Malaysia. The geometric parameters that affect accident severity are observed and their results are discussed. They form a simple technique in which the "Severity Index" of each sub-type falling into each parameter is calculated and the results are compared. Severity Index can be defined as the number of deaths per 100 accidents occurring at an

intersection. It is a measure of the seriousness of accidents occurring at any intersection. It can be calculated by the following formula:

$$\text{Severity Index} = \frac{\text{Fatal Accidents}}{\text{All Accidents}} \times 100$$

By evaluating the severity index using above formula in different cases and conditions the results are described in Figure 3 which shows the Severity Index of each sub-class for all parameters.

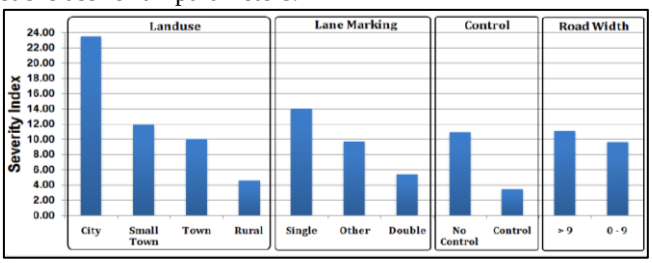

Fig. 3: Severity Index of each sub-class for all parameters.

Sonia Rahman (2012) collected data to analysis the severity of accident in Bangladesh at Intersection. She collected the data of accident from 2005 to 2009. Her main concerns were the intersections of Dhaka city. She developed a model of accident prediction with the collected data. From these data we found that accidents increase in good weather, it may be because in good weather drivers may be more relaxed and less conscious as they think that everything is seen clearly.

Murthy et al. (2015) analyzed the factors influencing road accidents using regression analysis in SPSS model. Area of study is part of Hyderabad. The objective of the paper was to review relation between accident per year and intersection Parameters, to develop prediction models, to test their validity, to suggest improvement measures to prevent road accidents and to derive a model for accident parameters.

III. Strategies to Enhance Safety at Roundabouts

There are three major strategies which affects the roundabout safety i.e. Strategy 1 (Enhancing Safety by varying roundabout approach width), Strategy 2 (Enhancing Safety by varying relative speed of traffic at roundabout), Strategy 3 (Enhancing Safety by varying roundabout diameter). In the following section we discussed these strategies one by one and their effects on the safety of roundabout. The desired values of various parameters used in all the strategies for multi-lane urban roundabout is concluded with the help of "IRC Guidelines for Roundabout".

A. Strategy 1 (Enhancing Safety by varying roundabout approach width)

Approach width of carriageway is the distance from the edge of deflecting island to edge of inscribed circle diameter. Approach width of roundabout is an important component that affects safety. Narrow approach lane causes more accidents at roundabouts than the wider approach. And wider approach can make the user to drive at more speed hence may cause accidents.

1) RHI_1 Approach Width Index

A condition index is developed to evaluate safety hazardous condition at roundabout due to inadequate approach width. That can be determined using Equation 1. Index is developed in such a way that "Zero" values of proposed index shows the safest condition and "One" value of index presents the least safety condition at existing roundabout.

$$AWI_R = \left|\frac{DAW - AAW}{DAW}\right| \qquad (1)$$

Where,

AWI_R = Approach width index at roundabout R.

DAW = Desired approach width in meter.

AAW = Available minimum approach width in meter.

From the above equation we can find the index of the approach width and in Figure 4 we will present the variation of index with respect to the change in approach width from desired value.

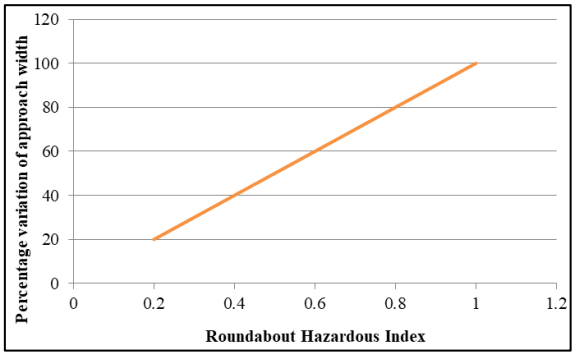

Fig. 4: Percentage variation of Approach width with Hazardous Index

From the Figure 4, it is concluded that as the variation of the approach width increases from the desired value, the hazards also increases at the roundabout i.e. safety decreases.

B. Strategy 2 (Enhancing Safety by varying relative speed of traffic at roundabout)

More relative speed of entering and circulating vehicles at the point of crossing can cause road accidents. It is one of the major circulatory stream characteristics that affect safety very much. The entering / circulating vehicle accident rate on any particular approach is largely related to the potential relative speed of entering and circulating vehicles. Minimizing the potential relative speed of entering and circulating vehicles will minimize the entering / circulating vehicle accident rate. The potential relative speed of entering and circulating vehicles should be limited to 50km/h.

1) RHI_2 Relative speed Index

A condition Index is developed to evaluate the safety hazardous condition due to the relative speed of entering and circulating vehicles. That can be determined using Equation 2. Index is developed in such a way that "Zero" values of proposed index shows the safest condition and "One" value of index presents the least safety condition at existing roundabout.

$$RSI_R = \left|\frac{ARS}{PRS}\right| \qquad (2)$$

Where,

RSI_R = Relative speed of entering and circulating vehicles index at roundabout.

ARS = Average relative speed of entering and circulating vehicles in kmph.

PRS = Potential relative speed of entering and circulating vehicles in kmph.

The index of the relative speed can be find with the help of Equation 2, and it is concluded from Figure 5 that as the variation of the relative speed increases from the desired

maximum value, the hazards also increase at the roundabout i.e. safety decreases.

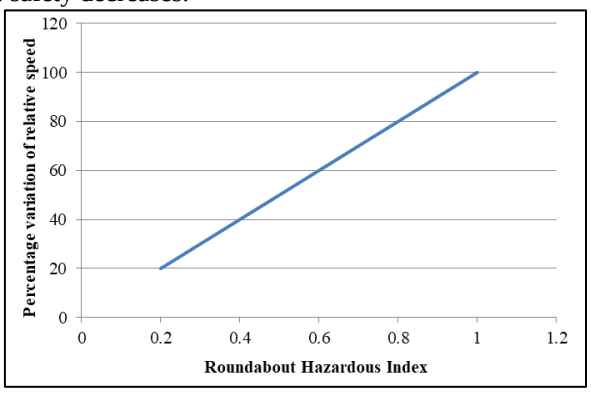

Fig. 5: Percentage variation of relative speed with Hazardous Index

The above Figure 5 shows that as the relative speed of traffic varies from the maximum limited value, the safety at roundabout decreases.

C. Strategy 3 (Enhancing Safety by varying roundabout diameter)

Central Island diameter index evaluates the safety hazardous condition at roundabout due to the improper diameter of Central Island. Diameter of Central Island affects the safety at roundabout directly. Inadequate diameter of central island reduce the turning radius of circulatory road way and make the movement of vehicles more hazardous. Also more than required diameter of Central Island affects the safety by developing the psychology of road user to drive at more speed hence increase the probability of collision.

1) RHI_3 Central Island Diameter Index

A condition index is developed to evaluate the hazardous condition of improper diameter of Central Island. That can be determined using Equation 3. Index is developed in such a way that "Zero" values of proposed index shows the safest condition and "One" value of index presents the least safety condition at existing roundabout.

$$CIDI_R = \left|\frac{15}{ACD}\right| \quad (3)$$

Where,

$CIDI_R$ = Central Island diameter index at roundabout.

ACD = Available Central Island diameter in meters.

The index of the diameter of central island can be find with the help of Equation 3, and it is concluded from Figure 6 that as the variation of the diameter increases from the minimum value(i.e. 15m), the hazards decreases at the roundabout i.e. safety increases.

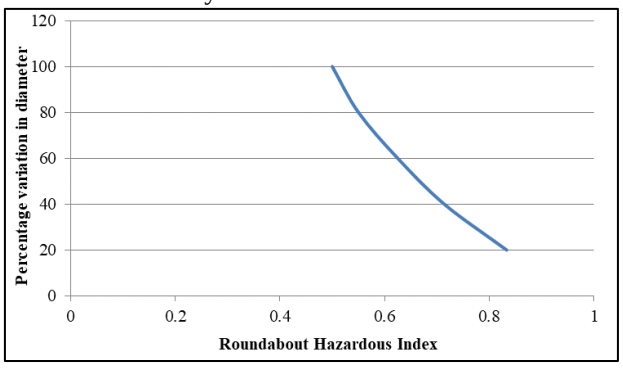

Fig. 6: Percentage variation of diameter with Hazardous Index

The above Figure 6 shows that as the diameter of central island varies from the minimum limit to maximum limit, the safety at roundabout increases.

IV. Case Study of Roundabouts in State Capital Bhopal

A. Study Area

Three Roundabouts have been considered in the Bhopal city for the description of the strategies and details of these three Existing Roundabouts.

1) Matamandir Roundabout (R1)

Matamandir square is one of the important intersections which connects the Habibganj Road that is Link no 2 road with New Market and with Maulana Azad National Institute of Technology. Matamandir intersection is very important junction regarding road safety due to the high volume of traffic. Photo 1 shows the top view of Matamandir square.

Fig. 7: Top view of Matamandir Roundabout -R1 (Source: https://www.google.co.in/maps)

B. Polytechnic Roundabout (R2)

Polytechnic intersection is also an important roundabout in view of road safety. It is one of the most heavy traffic intersections of Bhopal city. It connects Roshanpura square, Jawahar chowk, CM house and Kamla Park square. Photo 2 shows the top view of polytechnic roundabout.

Fig. 8: Top view of Polytechnic Roundabout R2 (Source: https://www.google.co.in/maps)

C. P&T Roundabout (R3)

Fig. 9: Top view of P&T Roundabout R3 (Source: https://www.google.co.in/maps)

P&T roundabout is also an important roundabout located in link road no 2. It connects the link no2 road with Kotra Sultanabad Road. Photo 3 shows the Goggle Image of P&T Roundabouts.

In this section we analyze the strategies by applying it on all the three roundabouts and comparing the results. Table 1 presents the details of the roundabouts.

S. No.	Input data parameter	Notation	Input data		
			R1	R2	R3
1	Available Minimum Approach Width (meter)	AAW_R	9.2	10.7	12
2	Average Relative Speed of Entering and Circulating Vehicles (kmph)	RSI_R	22	24	28
3	Available Central Island diameter (meter)	ACD_R	30	29	19

Table 1 Details of the roundabouts

The calculation of the hazardous indices for the strategies can be done by using the Equation 1-3. Table 2 presents the hazardous indices of the strategies for the roundabouts.

S. No	Index of Strategy	Notation	R-1	R-2	R-3
1	Approach width index	AWI_R	0.31	0.528	0.71
2	Relative speed of Entering and Circulating vehicles Index	RSI_R	0.44	0.48	0.56
3	Central Island Diameter Index	$CIDI_R$	0.50	0.517	0.748

Table 2 Calculation of indices

From the calculated indices of Table 2 we have drawn the relation of all the indices with respect to their roundabouts. Figure 10 to Figure12 shows the relation.

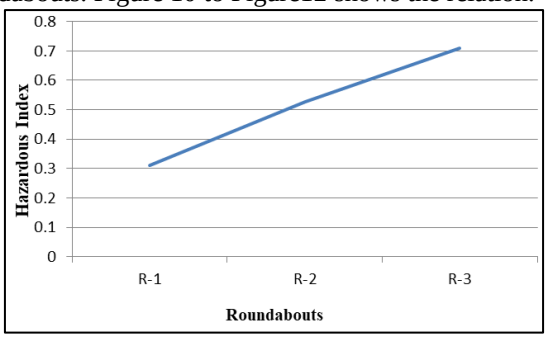

Fig. 10: Graph between AWI and roundabouts

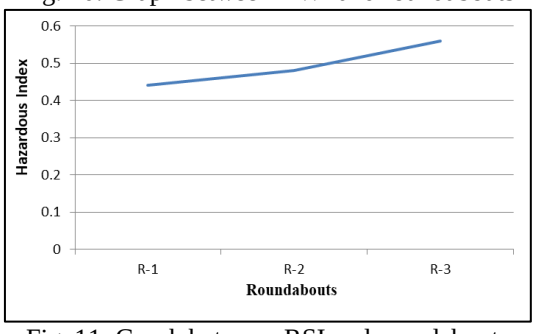

Fig. 11: Graph between RSI and roundabouts

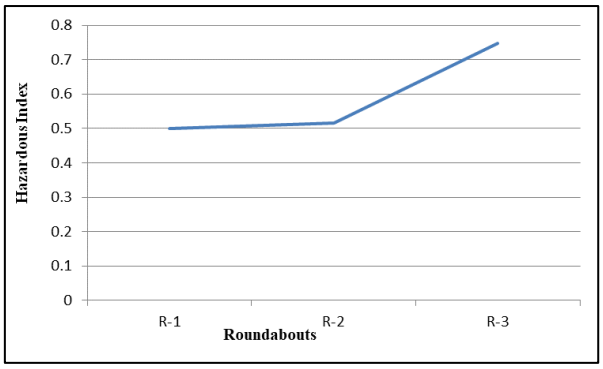

Fig. 12: Graph between CIDI and roundabouts

The above Figure 10 to 12 show that Roundabout R3 i.e. P&T Roundabout has the maximum hazardous index in all the three strategies means it should be the least safe. The analysis of our strategies also show that if there is a maximum deviation from the desired value then there would be least safety that can be shown by our ground analysis.

By applying all the factors which affects the safety of roundabout we calculated the actual or field Roundabout Hazardous Index in which we tale all the real values of present scenario. The overall index can be calculated with the help of Equation 4 and the calculated values are compared in Table 3.

$$RHI_{ER} = \sum_{i=1}^{i=n} HCI_{ER} \times W_{HCER} \qquad (4)$$

Where,

RHI_R = Roundabout Hazardous Index at roundabout.

HCI_R = Hazardous Condition Index at roundabout for safety hazardous components.

W_{HCR} = Global weight of hazardous component roundabout.

n = Total number of hazardous components.

S. No.	Roundabout	ID	RSI_{ER}	Rank	Remark
1.	Mata Mandir Roundabout	R1	0.329	1	RHI_R value is lowest hence this is the safest Roundabout.
2.	Polytechnic Roundabout	R2	0.356	2	RHI_R value is between R-1 and R-3, hence it is safety level is between R-1 and R-3.
2.	P&T Roundabout	R3	0.409	3	RHI_R value is highest hence it is the least safe Roundabout.

Table 3 Comparison of all the three roundabouts

Figure 13 shows the Ranking of the Roundabout Hazardous Index (RHIR) of the Roundabouts according to the data in the Table 3.

From the Figure 10 it is concluded that the P&T roundabout is least safe because it has the maximum hazardous index. This also indicates the result of our field case study.

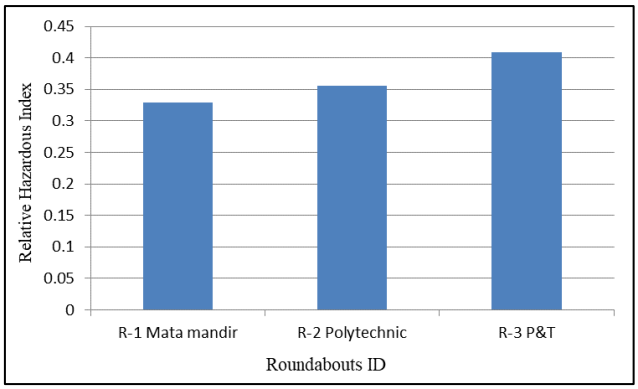

Fig. 13: Overall hazardous index considering all the factors

V. CONCLUSION

Some important conclusions drawn from this study are as follows:

- Road accident is 'a global tragedy' with ever-rising trend. Road accidents are the major misfortune for human being in any country. Roundabouts in any road network are most identified accident prone location. To improve the road safety, it is necessary to improve the roundabout safety performance. So in this study there are some strategies that can enhance the road safety.
- This study demonstrate the major three strategies which can be used to enhance the roundabout safety.
- The 3 strategies are Strategy 1 (Enhancing Safety by varying roundabout approach width), Strategy 2 (Enhancing Safety by varying relative speed of traffic at roundabout), Strategy 3 (Enhancing Safety by varying roundabout diameter). The demonstration of these three strategies which plays a major role in determining whether the roundabout is hazardous or not is detailed. For the case study we have taken three roundabouts of Bhopal city and rank them considering the strategies.
- In section 3, all the strategies are presented. In, Strategy 1 (Enhancing Safety by varying roundabout approach width) the discussion is on the effect of approach width on the roundabout safety. It can be concluded that as the approach width of the roundabout increases, safety decreases.
- In, Strategy 2 (Enhancing Safety by varying relative speed of traffic at roundabout) the discussion is on the effect of Relative speed of Entering and Circulating Vehicles on the roundabout safety. It is concluded that as the speed of vehicle increases, crossing the maximum permissible limit then the safety at that roundabout decreases.
- In, Strategy 3 (Enhancing Safety by varying roundabout diameter) the discussion is on the effect of the diameter of the central island on the roundabout safety. It is concluded that as the diameter of central island increases, the safety at that roundabout also increases
- The conclusion from the case study is that the P&T Roundabout(R3) is least safe due to its higher hazardous index in which the major contribution is by the three strategies which we have discussed. Mata Mandir Roundabout(R1) is the most safe because it has the least hazardous index.
- It may be concluded from the this study that strategies proposed in this study are useful to enhance safety at roundabout.

Thus, it is expected that this study may be useful for enhancing safety on urban roads in India.

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