Design of Multi-Lane Roundabout for an Urban Intersection

Abhinav Bhagat [1], Mangesh Bhorkar [2]

[1] M.Tech, Transportation Engineering, Department of Civil Engineering, G H Raisoni College of Engineering, Nagpur 440016, India

[2] Assistant Professor, Department of Civil Engineering, G H Raisoni College of Engineering, Nagpur 440016, India

Abstract: Rapid urbanization is an extreme issue confronted by a maximum of the metropolitan cities in India. Many people migrate from rural to urban regions and this urbanization has resulted in the growth of number of vehicles plying on the road. Though the growth of vehicles follows an exponential trend, the infrastructure growth does no longer compensate on an equal level, as a result there is increase in traffic congestion on roads. Less utilization of public transport, in addition, aggravates the congestion condition. One way to manage the traffic at an intersection is to implement a roundabout or rotary intersection. Most of the current research on design of a roundabout or capacity evaluation of a current rotary is mainly targeting intersections having four approach roads that intersect at proper angles. Various guidelines have been provided by many researchers for roundabout design, but most of them are suitable for geometrically aligned four leg roundabout. An attempt has been made to design a roundabout for a multi-leg intersection with the help of autoCAD software.

Keywords: Roundabout, design vehicle, splitter island, entry angle

1. Introduction

The rapid growth of traffic because of globalization have necessitated implementation of modern infrastructure to cope with the city traffic demands. The most commonly used traffic infrastructure to regulate the traffic is the traffic signal. It can be allocated at any intersection, but it has certain drawbacks. It cannot be proved to be effective and beneficial with an intersection with higher traffic volume due to more delay and increased queue lengths (Ariniello and Przybyl, 2011). It depends on which traffic parameters should be given priority at a specific intersection. Depending on the traffic conditions and number of approach routes, a roundabout has been proven to be a better alternative to a traffic signal (Pratelli, 2006).

Modern roundabouts, additionally known as second-era roundabouts, are primarily based on extraordinary design standards from the ones of traffic circles, or first-era roundabouts, constructed within the first half of 20th century. The first era roundabouts gave precedence to traffic flows coming into branches and were designed thinking about the weaving actions as a simple goal (Al-Masaeid, 1999). This way, the circles emerge as very large, with lengthy distances among successive branches and with extraordinarily low speeds and circulating flows. On the other side, modern roundabouts gave precedence to circles and are designed for reducing speeds, with dimensions basically described through the variety of branches, predicted capacity and through the turning route of large vehicles (IRC:65, 2017).

A roundabout for an intersection can be designed after studying the traffic conditions and its requirement for a smooth flow. The geometry of the intersection should be studied to identify the dimensions of every area. AutoCAD software can be used to plot the geometry and obtain an accurate dimension. Guidelines provided by various researchers and journals can be followed, depending on various factors.

2. Methodology

2.1 Study area

Nagpur is a metropolitan city in India with a high vehicular population of 1.7 million in 2020 and is rapidly rising every year. The increase in number of vehicles have caused congestion on various routes, which ultimately showed an increase in accidents. To manage and regulate the traffic, most of the intersection are signalized. But, it cannot be effective on every intersection due to varied traffic conditions. Orange city square is a signalized intersection consisting of five routes connecting to the various part of the city. It connects residential, commercial and industrial zones and as a result the traffic volume at these intersection is high. A signal has been implemented to regulate the traffic, but it have certain limitations. The long traffic cycle has resulted increase in waiting time and thus, more delay of vehicles. There is a queue length formation at every route due to stopping at red signal. The delay and queue length formation leads to high emission from vehicles and more consumption of fuel. Traffic signal breaking is a common incident at the intersection which may lead to accident. There is a need to provide a better alternative which can overcome the limitation on that particular signalized intersection.

Fig.1: Orange city square (Source: Google maps)

2.2 Data collection

Data collection of vehicles is a process of measuring the traffic volume at the intersection which can be used to analyse the traffic conditions. There is a need to identify the peak hour at the particular intersection to obtain a maximum data. For Orange city square, the morning peak hour was 9:00 to 10:00 am and evening peak hour was 6:00 to 7:00 pm. Data collection was carried out for both peak hours during working day with the help of videographic method. A camera was placed on a terrace of a building, adjoining to the intersection in such a way that it might cover all the approach routes of the intersection.

The data was extracted from the recorded video to calculate the traffic volume at each route. The extracted data of vehicles was categorized into six classes i.e. bike, auto-rickshaw, passenger car, light commercial vehicle, truck/bus and cycle. Later, the number of vehicles were converted into Passenger Car Unit (PCU) values to represent the capacity of route.

Table 1: Passenger Car Units (Indo-HCM,2017)

Vehicles	Bike	Auto-rickshaw	Passenger Car	LCV	Truck/Bus	Cycle
PCU	0.32	0.83	1	1.46	3.05	0.28

The distribution of traffic of traffic should be extracted from video recording to identify the vehicle movements. The origin and destination routes of vehicles should be identified for the analysis purpose.

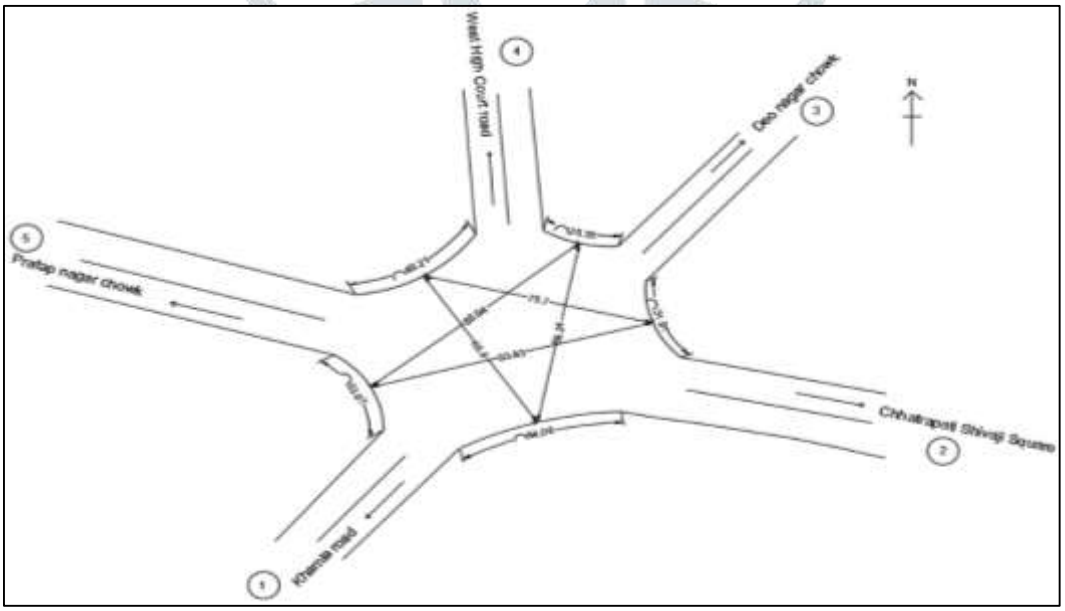

Fig. 2: Geometry of intersection on AutoCAD

For design of roundabout, there is a need for measurements of the intersection. Due to busy intersection it was difficult to measure the intersection dimensions manually. So, the google map image of intersection was plotted to scale in AutoCAD software and the dimensions were obtained. But, there is a need to measure at least one dimension manually to be used as a reference for accurate result on autoCAD.

2.3 Inscribed Circle Diameter (ICD) and Central Island

Inscribed circle is the diagonal distance from the edges of the intersection and is used as a parameter to define size of roundabout (Code of Practice: Part 2, IUT). ICD is the summation of central island diameter and double the width of circulatory carriageway. The size of ICD should be large enough to accommodate the weaving traffic and to handle maneuver of a design vehicle safely. The width of circulatory carriageway is dependent on the ICD and the approach width. The circulatory carriageway width should be same or upto 1.2 times that of approach width (Indo-HCM, 2017).

Central island is the raised portion located centrally in the roundabout. It accommodates vehicle movement in a clockwise direction from entry to exit (Brilon, 1988). The purpose of central island is to convert the direct conflict points into angular, such the collision impact between vehicles can be reduced (Retting et al.,2001). An apron can be provided around the central island which can be used by large trailers while movement through roundabout. The central island can also be used for landscaping.

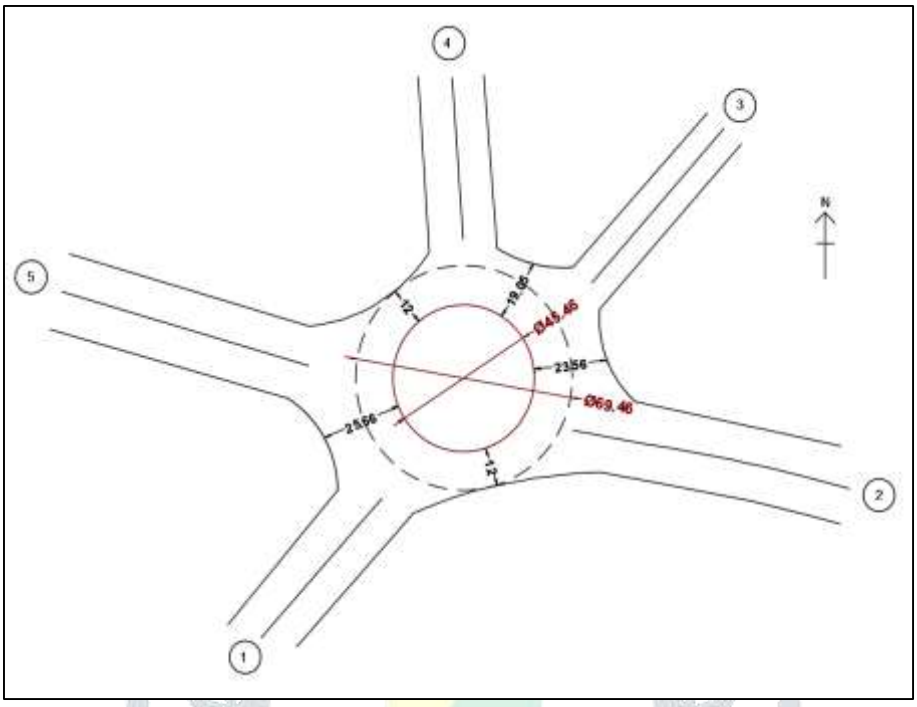

Fig. 3: ICD and Central island designed on AutoCAD

After following the guidelines provided by the IRC-65 and Institute of Urban Transport, a ICD and central island diameter was obtained. The minimum ICD possible on the intersection is 69.46m and the central island diameter obtained is 45.46m. With reference to the shape of central island, the splitter island for each approach routes can be designed to obtain a safe entry and exit angles for the vehicles.

2.4 Design vehicle

A roundabout should be capable to handle the movement of the largest vehicle which might use the intersection. Usually, these vehicles are the least maneuverable and is complicated to accommodate them in a roundabout. Such vehicles are called design vehicle and a roundabout should be designed accordingly. A roundabout should be able to accommodate large trailer or if there is a land constraint then a truck apron can be provided around central island. A roundabout of ICD 28 to 36m can manage the movement of design vehicle like massive trailer of 16.7m length, 2.58m width and a 13.8m turning radius (Code of Practice: Part 2, IUT). It is important to design a roundabout to accommodate a design vehicle, so as to assure the feasibility of roundabout for the intersection.

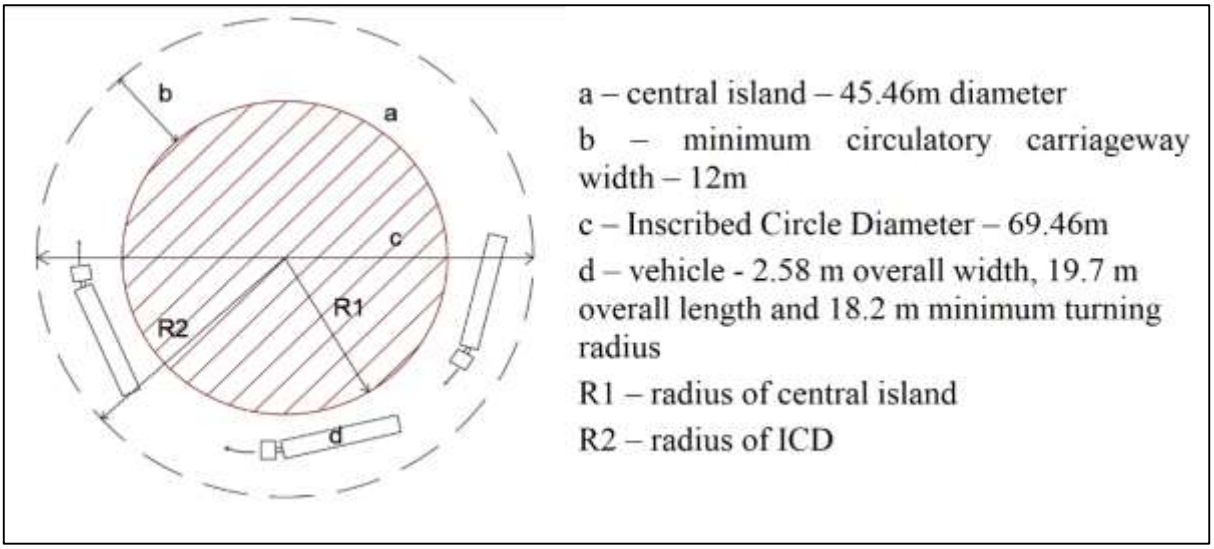

Fig. 4: Design vehicle on AutoCAD

The roundabout can cater the movement of a design vehicle through a ICD of 69.46m and 12m minimum circulatory carriageway width. The designed roundabout is of 69.46m which is larger than 36m, hence it is safe and efficient to cater any movement.

2.5 Design speed

The vehicles at a roundabout function at a decrease speed than the route previous and succeeding as they should comply with the give manner behaviour and gap acceptance within the circulating traffic. Usually, vehicles have to no longer run greater than 30km/h in urban roundabout. The rural roundabout would possibly have better speed however the car speed have to be decrease than mid-block section.

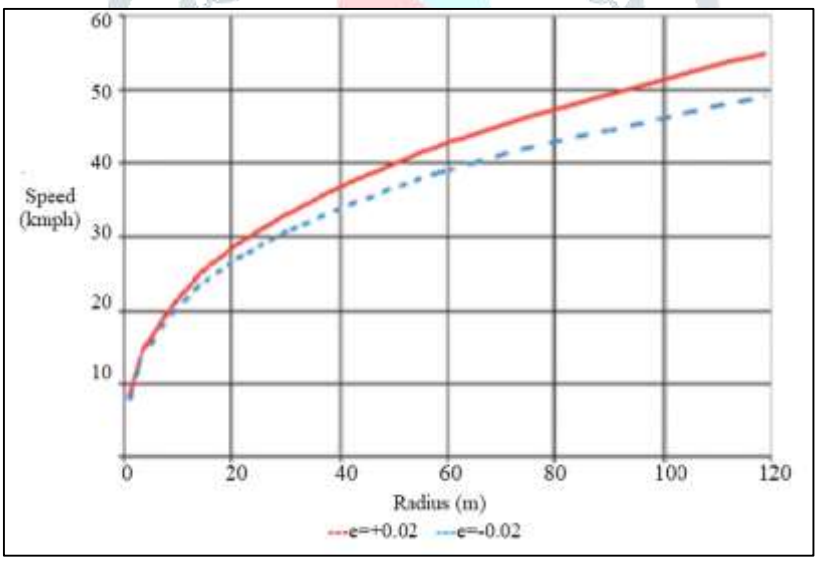

Fig.5: Relationship of radius of central island and speed (IRC: 65, 2017)

Depending upon the turning radius and sight distance, the design velocity may be decreased however it would lead in growth of delay at roundabout (IRC: 65, 2017). Ultimately, it would additionally have an effect on the extent of level of service of the roundabout. The graph represents the relationship among radius of central island and speed for the roundabout.

2.6 Splitter Island

Splitter island is provided on every approach route to separate the incoming and outgoing traffic of roundabout. They are the raised island of sufficient width to alert the drivers before entering the roundabout. The shape is such that it prohibits the driver from taking a wrong turn. A pedestrian crossing can be provided through a splitter island and it should be of sufficient width to shelter a pedestrian. A curve is provided at the entry and exit side of island such that vehicles can enter safely into the roundabout and merge with the circulating traffic (Elvik, 2003). It also helps in controlling vehicle speed. The splitter island is useful to define an entry angle of vehicles. The curves provided to the island are used as a reference to identify a safe entry angle of entering traffic.

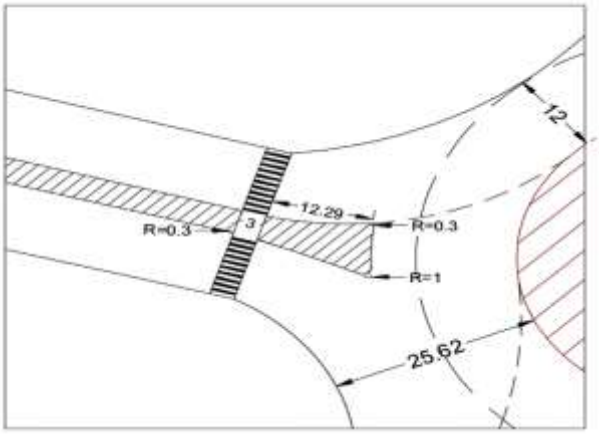

Fig. 6: Splitter island for approach road 5

A splitter island is provided at a safe distance from roundabout to prevent the entering vehicles from instantly merging with the circulating traffic. A curve of radius 0.3m and 1m is provided at the entry and exit side of splitter island respectively (Indo-HCM, 2017). A pedestrian crossing is provided at a safe distance from roundabout to avoid any mishap. It is provided at least 7.5m from the tip of the splitter island. The splitter island curve should be designed such that when extended should meet the central island tangentially. The purpose is to safe entry and exit of vehicles in the roundabout. The width of splitter island should be sufficient enough to be visible to the approaching traffic, so that they may lower their speed and enter the roundabout with reduced speed.

2.7 Entry angle

Entry angle is the angle at which the entering traffic will enter the roundabout. It defines the conflict angle between an entering vehicle and a circulating vehicle (IRC:65, 2017). An entry angle of any approach road is dependent on the splitter island curve at the entry point. It plays an important role in merging of entering and circulating traffic safely. A vehicle entering the roundabout should be able to enter the circulating flow safely and entry angle have a vital role. The chances of head-on or T collision reduces and significantly reducing the intensity. Entry angle of a multi-lane roundabout should lie between 20° to 60°.

Entry angle of any approach road can be calculated by:

- CD being locus of the mid- point of the nearest kerb
- EF plotted as a tangent to CD
- AB drawn as locus of the circulatory carriageway
- ∠ BAF- Entry angle

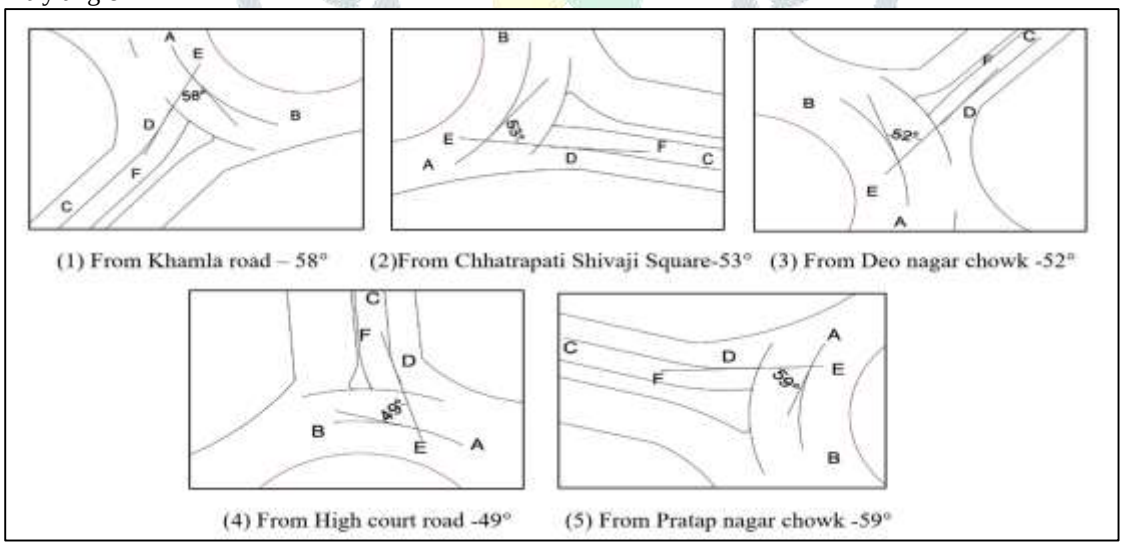

Fig.7: Entry angle of five approach roads on AutoCAD

3. Final design of roundabout

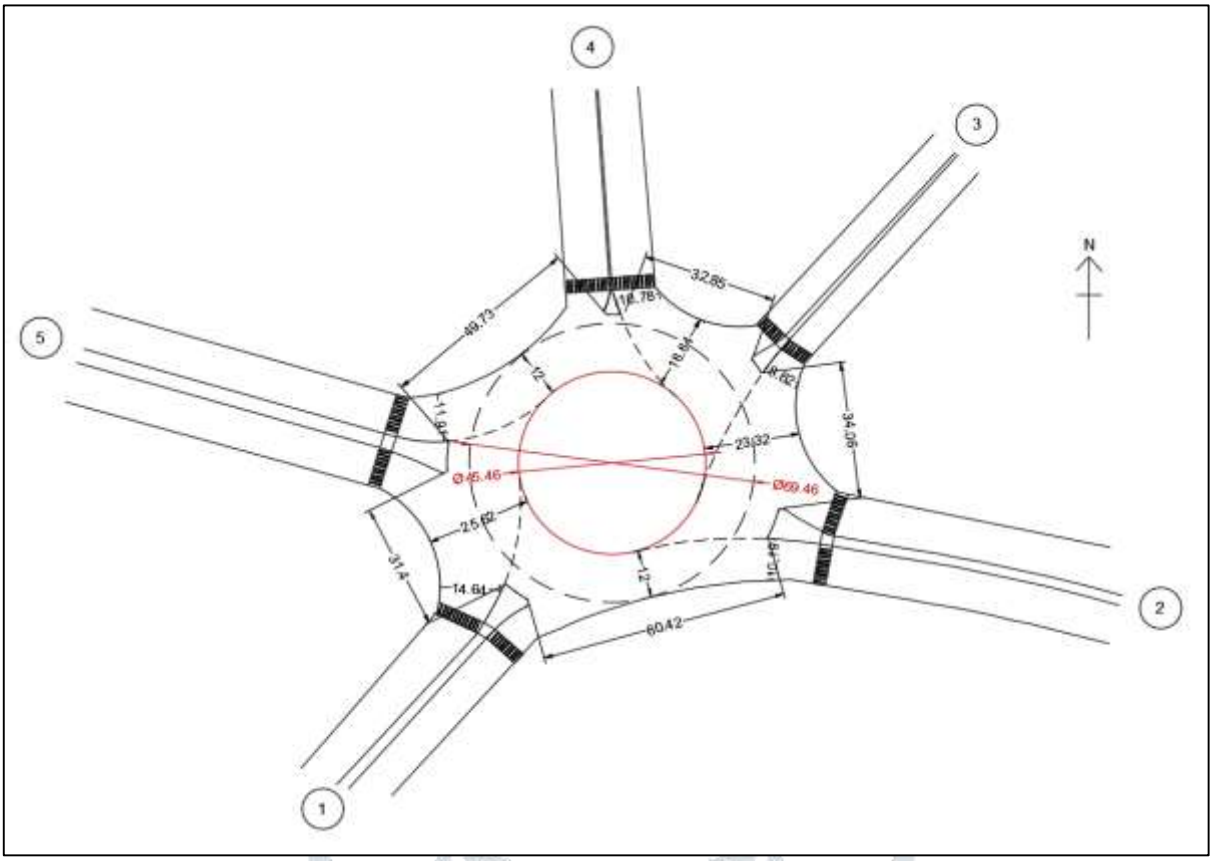

Fig.8: Design of Roundabout on AutoCAD

Minimum Inclined Circle Diameter: 69.46m

Central Island diameter: 45.46m

Minimum circulatory carriageway width: 12m

Approach width: Leg1-14.64m; Leg 2-10.19m; Leg 3- 8.62m; Leg 4-10.78m; Leg 5-11.91m

Weaving length: 1-2: 60.42m; 2-3: 34.06m; 3-4: 32.85m; 4-5: 49.73m; 5-1: 31.4m

Entry angle: Leg1-58°; Leg2-53°; Leg3-52°; Leg4-49°; Leg5-59°

4. Conclusion

Designing a roundabout for an intersection requires data on the traffic volume and the geometry of intersection, to understand the suitability of roundabout. The geometry of any intersection can be obtained by modern technique like plotting the google map image of the intersection to the scale on AutoCAD software. After obtaining the dimension, the permissible inscribed circle should be allocated and the reference to that central island diameter can be decided and providing a sufficient circulatory carriageway width. Splitter island plays an important role in directing the traffic through and out of the roundabout. Pedestrian crossing of sufficient width need to be allocated at a safe distance from circulatory carriageway. The designed roundabout should be check for the entry angle and suitability of a design vehicle.

Traffic movement in a roundabout is slow enough to permit visible engagement with pedestrians, encouraging deference in the direction of them. Other advantages consist of decreased driver confusion and decreased queuing related to traffic signals. They permit U-turns inside the regular flow of traffic, which frequently aren't viable at different styles of the junction. Moreover, when you consider that vehicles that run on fuel averagely spend much less time idling at roundabouts than at signalized intersections, the usage of a roundabout undoubtedly results in much less pollution. When entering traffic most effective need to offer way, they do now no longer continually carry out a complete stoppage, as a result, by retaining part of their momentum, the engine will produce much less work to regain the preliminary speed, ensuing in lesser emissions. Research has additionally proven that slow-shifting traffic in roundabouts makes much less noise than traffic that ought to prevent start, accelerate and braking of vehicles.

References

[1] Indian Highway Capacity Manual (Indo - HCM), 2017. CSIR - Central Road Research Institute, New Delhi
[2] Code of Practice, Part 2: Intersections. Institute of Urban Transport. Ministry of Urban Development
[3] Guidelines for planning and design of roundabout. Indian Road Congress:65, 2017
[4] Alex Ariniello and Bart Przybyl, 2011. Roundabouts and sustainable design. Green Streets and Highways 2010 © ASCE.

[5] C.Sawers, 2009. Mini-Roundabout for the United States. ITE Journal February 2009
[6] Danusz Chodur, 2005. Capacity models and parameters for un-signalized urban intersections in Poland. Journal of Transportation Engineering. 131:924-930, ASCE.
[7] Hashem R. Al-Masaeid, 1999. Capacity and Performance of Roundabouts. Canadian Journal of Civil Engineering. Vol. 26, 597-605
[8] Pratelli, 2006. Design of modern roundabouts in urban traffic systems. Urban Transport XII: Urban Transport and the Environment in the 21st Century. Vol 89
[9] Richard A. Retting, Bhagwant N. Persaud, Per E. Garder, Dominique Lord, 2001. Crash and Injury Reduction Following Installation of Roundabouts in the United States. American Journal of Public Health. Vol. 91, No. 4
[10] Brilon W., Vandehey M.,1988. Roundabouts – The state of the art in Germany. ITE Journal, Nov., pp. 48-54
[11] Gardner P., Little Falls, 1999. Gorham reconstruction to a modern roundabout. Transportation Research Record 1658, TRB, pp. 17-24
[12] Austroads, 1993. Guide to Traffic Engineering Practice: Part 6-Roundabouts.Association of Australian State Road and Transport Authorities, Sydney, Australia
[13] Rune Elvik, 2003. Effects on road safety of converting intersections to roundabouts: A review of evidence from non-US studies. Annual Meeting Transportation Research Board, 2003
[14] FHWA-SA-10-006, 2010. Mini-roundabouts: Technical Summary. U.S. Department of Transportation.