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DESIGNING A ROUNDABOUT HAVING CENTRPETAL MOTION WITH PROVISION FOR PEDESTRIAN AND BICYCLE FACILITIES:A CASE STUDY FOR 5 LEGGED INTERSECTION

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ABSTRACT

Roundabout is a one-way circular channelized intersection without traffic signals in which traffic flows clockwise around a central island. To ensure safety and efficiency, a roundabout should be designed properly incorporating all the required parameters. The parameters can be obtained from condition survey and extensive data collection. The collected data should be properly analyzed and compiled in a systematic manner to meet the coherency with the required design parameters of a roundabout. Using these potential data, proposals can be adopted and finally a design can be selected. As an assignment, this paper studied Polashi Intersection, analyzing which it is found that it lacks both safety and facilities for pedestrians and cyclists. In this regard, this paper proposes a detailed innovative design considering the need for safety, efficiency and at the same time economy to construct it, providing all the requierd facilities. The salient features of this proposed design have been illustrated with corresponding figures and the strengths and weaknesses also have been addressed accordingly.

Keywords: *Roundabout, channelized intersection, traffic signal.*

1. INTRODUCTION

A modern roundabout is a one-way circular intersection without traffic signals in which traffic flows around a central island. Roundabouts feature yield control for all entering traffic, channelized approaches and appropriate geometric curvature to ensure that travel speed on the circulatory roadway is typically less than 30 mph. Roundabouts must be designed to meet the needs of all users—drivers, pedestrians, pedestrians with disabilities and bicyclists. While designing roundabouts, special considerations must be given to the needs of pedestrians with visual disabilities who are unable to judge adequate gaps in traffic at roundabouts. Proper location selection and pedestrian channelization are essential to make roundabouts accessible to all users.

In order to design a roundabout providing special facilities for cyclists and pedestrian, a special disign consideration is introduced in this paper with a grade seperation for each types of vehicles and pedestrians. The features of the design along with its advantages and weakness of the proposed design are highlighted. In order to to do so a test site is considered which is a five legged intersection situated at Polashi in Dhaka. Both collected and analyzed data are focused in this paper which has been considered to design the proposed roundabout with provisions of exclusive pedestrian and bicycle facilities (Hoque 2015).

2. LITERATURE REVIEW

In the United States in 1905 with the construction of Columbus Circle in New York City was first introduced as roundabout (FHWA 2000).Alike roundabouts were then built in many cities across the country as well as in Europe. These roundabout were considered for high-speed movement, generally featuring large radius and vehicle capacity. The outcome of the design and guidelines for these roundabouts resulted in high accident rates and traffic congestion (FHWA 2000). ODoT (1998) looked at the evolution of the roundabout and outlined some key design features of the traditional rotary on 1998. Unlike the roundabout, where roads generally intersect the circle at ninety-degree angles, the rotary creates merging lanes and allows high-speed entry and priority to the entering driver.

American Association of State Highway Officials first published the design guidelines in 1942 for the roundabout. These guidelines recommended the general operating speeds within the rotary as 40 to 60 km per hour, which required a central island radius of 270 feet or more (ODoT 1998). Conventional wisdom was that increasing the size of the rotary the capacity and flow would increase, which led to larger and larger rotaries (MDoT 2007).Growing the speed and size of rotaries, roundabout did not lead to increased capacity or efficiency. However, high accident rates and driver confusion were introduced. They fell out of favour and were often replaced by new, coordinated traffic signals by the mid-twentieth century (ODoT 1998).

The United Kingdom established the theory of modern roundabouts in the 1960s. In 1966 they accepted the "give-way" rule at round junctions. This rule needs the drivers to yield to traffic already in the roundabout. The standards of designing roundabout followed the principle. The safety of the roundabout and the traffic flow both were radically improved due to these changes. From the 1960s, the roundabout has gained popularity in the United Kingdom. Many cities in the United States have begun to implement the modern roundabout and it is important to understand the advancement in the design and function of circular junctions since the 1960s have affected and will affect all road users, including automobile drivers, pedestrians, and bicyclists.

3. RESEARCH OBJECTIVE

This paper is based on an undergraduate project work and finds out the existing problems on the desired site and the reasons behind it. Here, the remedial measures of these problems are developed and a complete design of modern roundabout is proposed. It also finds out the drawbacks of conventional multilane roundabout and provides a unique solution. The paper in particular intends to propose an improved design with:

- Proper channelization
- Safety for pedestrian
- Special facity for cyclists
- Adequate traffic control

In this design, maximum priority is given to the pedestrians, then cyclists, then other NMV (i.e. rickshaw) and lastly to the motorized vehicle.

4. TEST SITE AND EXISTING CONDITION

For the purpose of design, Polashi intersection is chosen as the test site. It is a five legged intersection as shown in the Figure1.This intersection connects links coming from Dhaka University, Bangladesh University of Engineering and Technology, Dhakeshwari, Azimpur and Nilkhet.

In order to propose an effective design for constructing roundabout at Polashi intersection, at first the current condition of the field has to be observed. And we went there to find out about existing facilities and lacking of traffic system. In order to do so we recorded a 15 min video clip of Polashi intersection just to observe the traffic system and its deficiencies and eventually we found some which will be reported below in brief. Apart from the video clip, we took some photos (Figure 1-7) that show the ineffectiveness of footpath, traffic sign and side friction which reduce the traffic capacity.

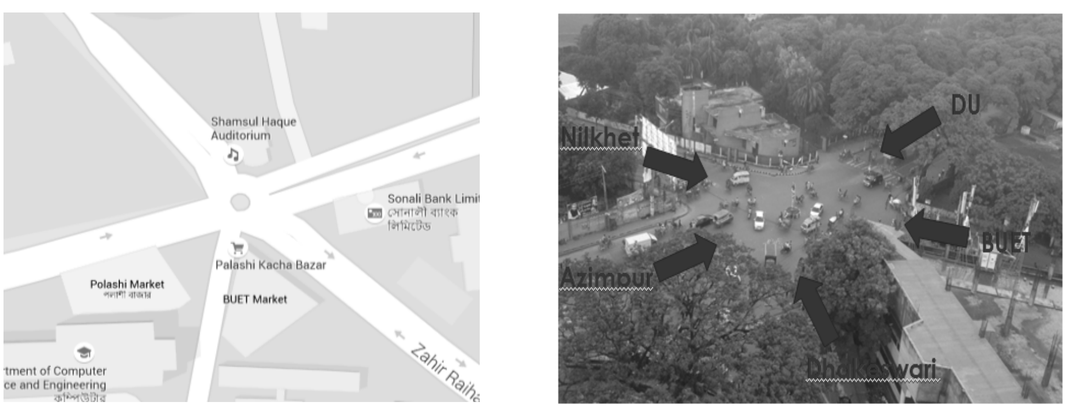


Figure 1: Test Site: Polashi Intersection

Figure 2: Heterogeneous Traffic System

Figure 3: Tendency of taking anticlockwise rotation

Figure 4: Absence of Channelization

Figure 5: Pedestrian Safety Hazards

Figure 6: Side Friction

Figure 7: Ineffective Footpath

4.1 Heterogeneous Traffic System

In Figure 2, it is seen that 8 types of vehicle comprising both NMV and motorized vehicles clogged together in the middle making congesion at the intersection, which is a major issue.

4.2 Tendency of Taking Anticlockwise Rotation

At roundabout, there has to be clockwise rotation in circular path for all traffics. But in the Polashi intersection we found that some drivers have a tendency to take shortcut by rotating in anticlockwise direction (Dark arrow) making congestion by blocking the traffic that is rotating in clockwise direction (Bright arrow), shown in Figure 3. A circular path of larger diameter may solve this problem.

4.3 Absence of Channelization and facility for bicycle

Both NMV and motorized vehicles are moving atPolashi intersection in a haphazard manner. There is no channelization for particular traffic which makes it more accident and congestion prone intersection as shown in Figure 4. Also there is no special facility for bicycle.

4.4 Pedestrian Safety Hazards

Pedestrians are the most vulnerable road users yet they are the most ignored in the existing traffic system. They were crossing the intersection risking their own lives as shown with the marked pedestrian with white t-shirt in Figure 5.No foot over bridge or any other facility was seen in Polashi intersection.

4.5 Side Friction

In all approaches, due to lack of law enforcement there was unauthorized parking especially of Rickshaws, shown in Figure 6, reducing the capacity of the approaches by a large extent. It was also boosted by introduction of some roadside shops attracting buyers, making congestion for moving vehicles in the link.

4.6 Ineffective Footpath

Roadside shops are situated on footpath making it ineffective and forcing pedestrians to use the road instead of footpath. Figure 7 shows the extent of footpath width which is reduced by these frictions.

4.7 Ineffective Signs

Although there were proper traffic signs at Polashi intersection, widespread non-compliance of these signs wasparticularly absence on the spot. Some were hidden behind the shops on footpath making it ineffective.

5. METHODOLOGY

Roundabout has several features i.e. number of lanes, size of the Central Island, design vehicle, turning path characteristic, splitter island size, etc. To design these features, extensive field data is required which should be collected at the desired site. For this purpose, site study, geometric condition study, direction-wise volume study, classified speed study, queue measurement, pedestrian movement recording are needed. All of these studies have been done on 04/10/15 at polashi intersection. The site study has been done incorporating video camera and Google map. The geometric study has been done incorporating odometer and Google map. The odometer has been utilized to take road measurement and the Google map has been used to measure the angle among the roads. The direction wise volume study has been done using manual counting method for half an hour at 5 min interval. The Classified speed study has been done applying manual '88 ft' method. Queue has been measured upto 40 ft upstream at 5min interval.

To maintain coherency with the methodology several data has been collected. It includes road width of the existing roads, foot paths width, drain width, gutter with, median width, entry width, existing central island diameter, location of the permanent structures, traffic markings and traffic signs. Besides speed of different vehicle, pedestrian crossing per hour at every leg has also been measured for justifying the pedestrian facility which will be utilized in our design. The inflow and outflow of bicyclist, another vulnerable road user, has also been measured. Depending on this, facilities will be proposed at a reasonable extent in alternative design.

6. DATA COLLECTION AND ANALYSIS

6.1 Road Geometry of Polashi and the Area

Road geometry of different legs was measured by odometer. All road width is shown in the following Figure 8. To find out the area available at the intersection, required length was measured. These lengths are mentioned in the Figure 9. From our calculation, we found that the area is 1869 square meter.

6.2 Vehicle Composition

The number of different vehicles was counted to find out the composition. The maximum percentage of vehicles is of rickshaws, which is around 60% of total vehicles. Car, bicycle, motorcycle are small in number (14 %, 11% respectively). Buses/minibuses were seen rarely, being only 1% of the total vehicles.

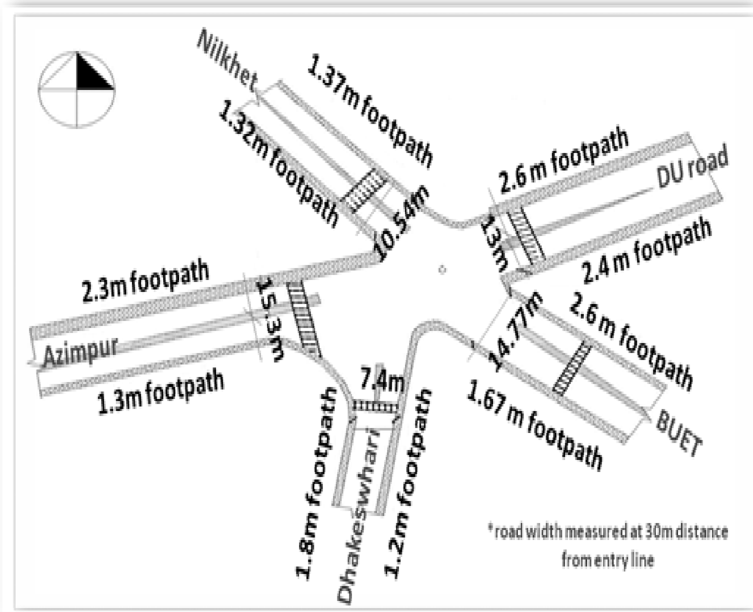
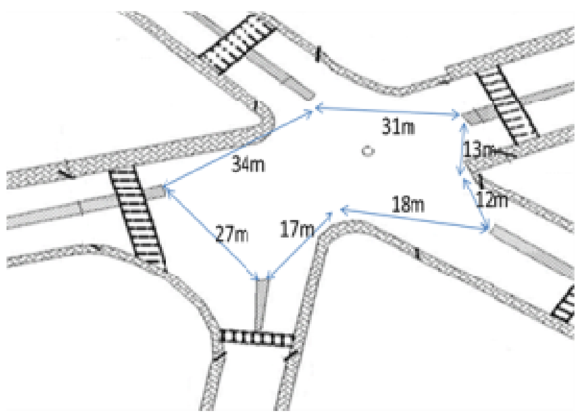


Figure 8: Road Geometry of Polashi



Total Available Area 2365.30 sq m

Figure 9: Area Survey

6.3 Directional Flow

On the second day of our survey, directional flow from each direction to other directions was measured and it was found that the maximum percentage of vehicles go to the through direction in every case. Sample size to find out directional flow is given in Table 1. Total number of vehicle is also provided in corresponding Figures 10~14.

Table 1: Sample Size to find Directional Flow

Name of roads	Vehicle Sample size
Nilkhet	917
Azimpur	697
Dhakeshwari	274
BUET	701
DU	622

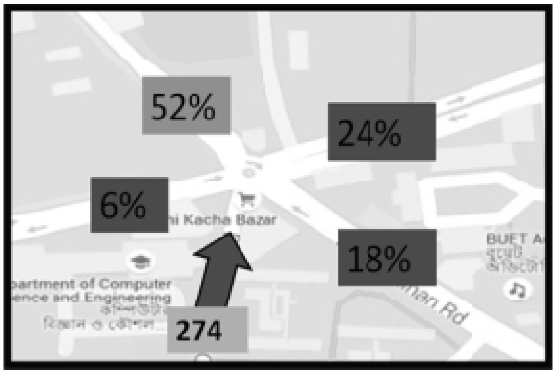


Figure 10: From Dhakeshwari to other directions

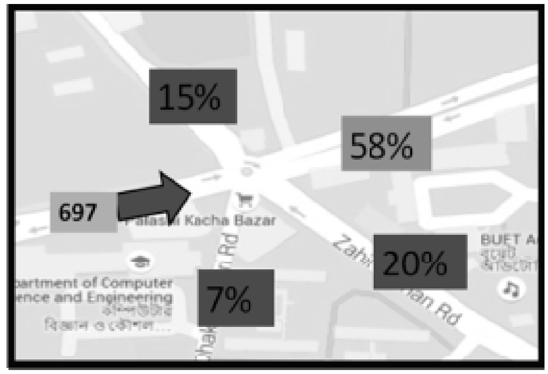


Figure 11: From Azimpur to other directions

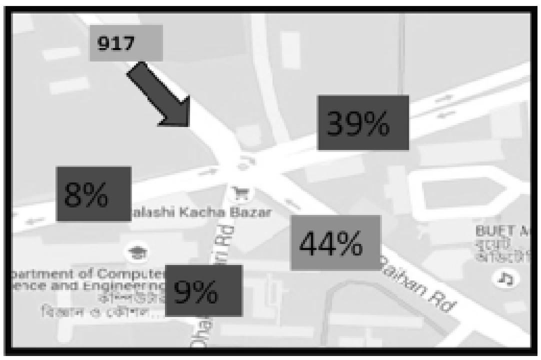


Figure 12: From Nilkhet to other directions

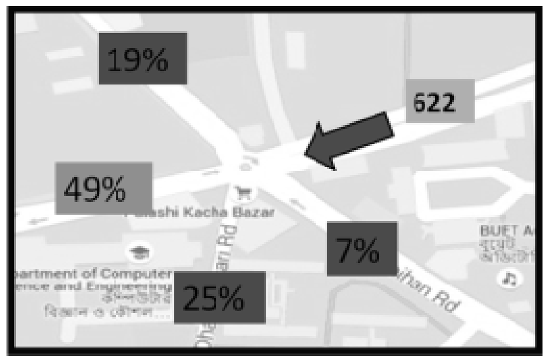


Figure 13: From DU to other directions

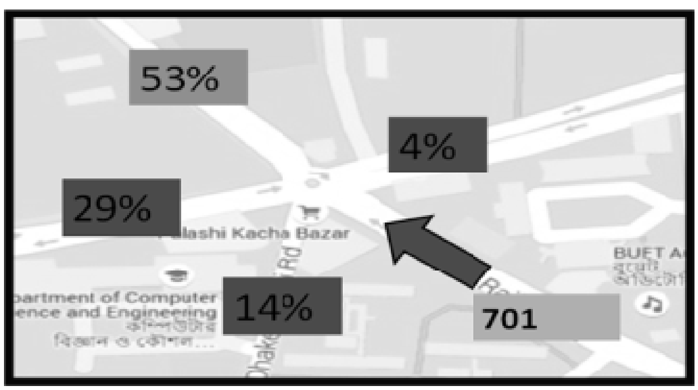


Figure 14: From BUET to other directions

6.4

6.5 Variation of Speed with Vehicle Type

To calculate the average speed of different type of vehicles, several samples of particular types were taken. As the number of rickshaw is huge in this road, 51 were used for calculating speed. As the percentage of Bus/ Truck is lower, fewer samples are used in calculation. As heterogeneous vehicles are present in all roads, there is quite variation in the speed. The speed of motorcycle was found to be maximum at 26 kmph (see Figure 15).

Table 2: Sample Size for Calculating Average Speed

Vehicle Type		Vehicle Sample Size
Non-Motorized Vehicle	Rickshaw	51
	Bi-Cycle	11
Motorized Vehicle	Car	23
	Truck/Bus	3
	CNG	30
	Motorcycle	17
	Tempo	14
	Micro	17

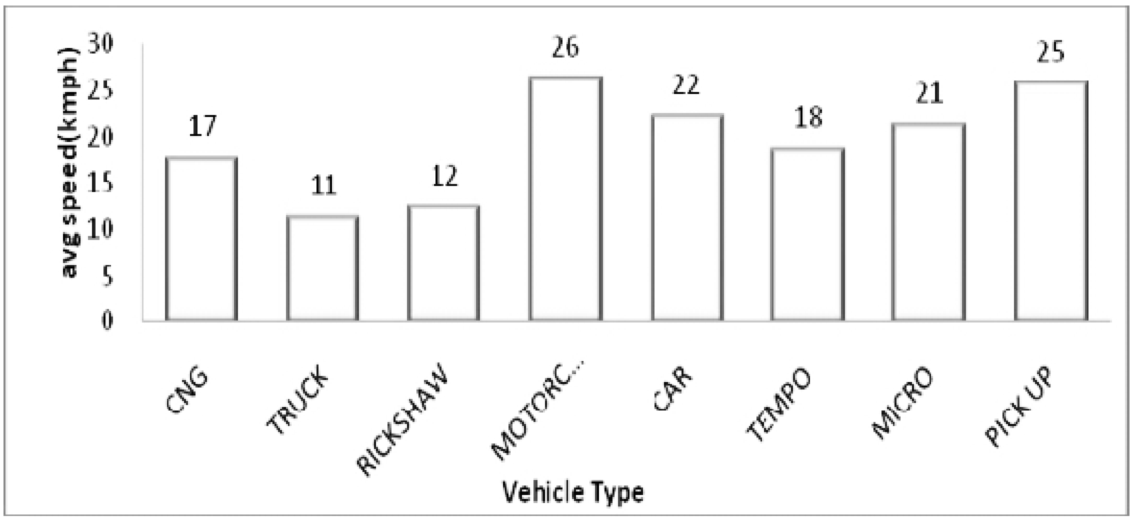


Figure 15: Speed of different types of vehicles

6.6 Bicycle % in every direction

Cyclists are one of the most vulnerable of all types of road users. So their percentage was observed. The percentage of bicyclists from different roads is given below in the Table 3:

Table 3: Bicyle % in every direction

Name of roads	% of bicycle
Dhakeswari	2
Azimpur	2
Nilkhet	3
DU	3
BUET	4

6.7 Pedestrian Crossing per Hour

Pedestrians are the most vulnerable users of road. The numbers of pedestrian crossing different roads per hour are given in the Figure 16. In BUET road, there are many students crossing the road. Average number of pedestrian crossing in all roads is 528, which is very alarming. This is the reason for providing special facility for pedestrians.

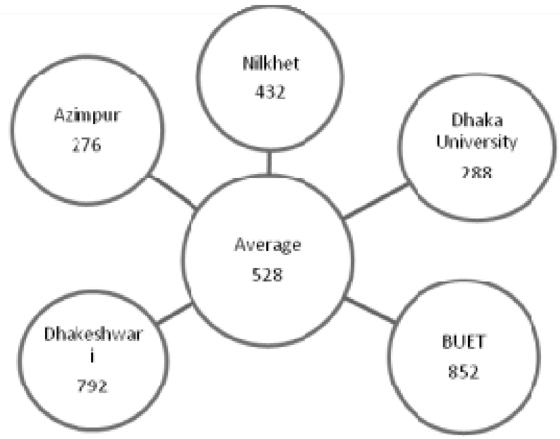


Figure 16: Pedestrian Crossing per Hour in each link

7. PROPOSED DESIGN

In this section, a robust design model will be proposed for Polashi intersection which incorporates and considers all the factors and data analysis mentioned in the previous section. In this regard, the salient features, strengths and weaknesses of the proposed model have been discussed with proper illustration and explanation

7.1 Design Considerations

7.2.1 Roundabout Type

Multilane. Number of circulating lane should be at least equal to approach lane. In this site four of the five legs have two approach lanes. So, design will be of two circulating lane.

7.2.2 Critical Vehicle

From data analysis, it is seen that the number of rickshaw is much higher. But if design is proposed for rickshaw or second highest percentage, CNG, roundabout might fail when large sized vehicle enters. As the largest vehicle in Polashi is Bus, it is considered as the critical size in design.

7.2.3 Lane Width

Normally, the width of bus is 8-10 ft. While turning it occupies a greater width. Assuming sixty degree turning angle, turning width is found to be 13 ft. With a factor of safety of 2 ft with 1 ft at each side the design lane width is decided to be 15ft.

7.2.4 Circulating carriageway

Two lanes of 15 ft make the carriageway 30 ft.

7.2.5 Central Island

Larger Central Island ensures higher flow. At present, a 10 ft diameter central island is available, which is not adequate. From available area of existing intersection and with some acquisition of land, an inscribed circle of 70 ft radius can be drawn. With 30 ft carriageway a central island of 40 ft diameter can be inserted.

7.2.6 Channelization and Speed

From speed study, the speed of motorized vehicle (20-30 kmph) is found much higher than non-motorized vehicle (10-15 kmph). For enabling them to move with their own desirable speed, channelization is done.

7.2.7 Others

For convenience and safety issues, a 6 ft wide footpath, pedestrian barrier, splitter island, road marking, road sign, lane divider, proper lighting etc. are provided.

7.2 Salient Features of the Proposed Design

The proposed design (Figure 17 and Figure 18) is a multi-storeyed roundabout. The main concept of the model came from the uniqueness of separating road users having different speed at different elevation. In this regard, the motorized vehicles have been guided to circulate on an elevated roundabout (Figure 18). The guiding is done by narrowing the road width at grade, where another roundabout (Figure 23) has been provided for the Non Motorized Vehicles (NMV) i.e. rickshaw, bicycle. And for the pedestrians an underpass roundabout has been provided.

To elevate the motorized vehicles i.e. car, bus, truck, pickup or CNG, ramp facility having 1:20 slope and 15 ft width has been provided at each leg. Figure 19 shows the on ramp facility which will be provided. And also off-ramp facility will be provided for elevated roundabout. Generally, the exit of a roundabout is located at the outer circumference. However, in this design the vehicles will be exited through inner circumference to ensure more safety to the users.

The main reason of keeping this exit point inside the roundabout is the drawback of the conventional multilane roundabout. In a roundabout when a vehicle circulating in the inner lane wants to take exit, it needs to cross the vehicles of the outer lane. And the flow in the outer lane reduces. This phenomena introduces a conflicting point within the roundabout and the conflicting angle between the vehicles at inner lane and outer lane becomes a great safety factor. Figure 20 illustrates the drawback of the conventional multilane roundabout marking the possible conflicting point.

To solve this problem, the concept of "Centripetal Motion" has been introduced. This concept focuses on the safety of the roundabout users and elimination of the confliction point as well. It also reduces the conflict angle among the circulating vehicles and ejecting vehicles. The concept conveys that any vehicle trying to eject have to come to exit lane which is situated at the inner circumference of the roundabout. An additional lane is provided inside the roundabout to facilitate the exit of the circulating vehicle. Figure 21 shows the concept of the centripetal motion and Figure 22 shows the implementation of the concept on the elevated round about. It should be noted that to apply this concept the traffic control structure should be comprised of at least 2 stories. It can be a combination of 'elevated and at grade' or 'at grade and subway'. In this proposal the 'elevated and at grade' combination has been used as the pedestrians have been given the underpass facility.

At grade, the facilities for non-motorized traffic have been provided. Flared triangle and properly marked splitter islands have been provided(Figure 23). Where the ramp starts, the lanes at grade have been narrowed so that motor vehicles are discouraged to go through at grade.

The last user of this model is the pedestrians. An underpass facility has been provided for the pedestrians. The main problem of the underpass is lack of lighting. In this regard, proper lighting facility has been provided so that any types of anti-social activities are less likely to occur. An escalator has been provided so that elderly and disable persons can also use the underpass. The underpass is also a roundabout but people don't need to maintain clockwise circulating flow, as it may discourage the users from using underpass. Pedestrians have been given maximum freedom and safety as the pedestrians are the most uncontrollable and hence unsafe road user.

7.3 Advantages of the design

- Motorized, NMT and pedestrians share different path, so the conflicts have been minimized.
- No traffic controller is needed.
- Bicyclist is safe as there is no motorized vehicle at grade.
- NMT doesn't share the motorized vehicles pathway, which ensures less hindrance to the path of the motorized vehicle.

7.4 Limitations of the design

- Need massive land acquisition.
- Need to re-route utility services to ensure pedestrian crossing.
- Drainage of underpass.
- Lack of tools to minimize merging of motorized and NMT at grade.
- Costly

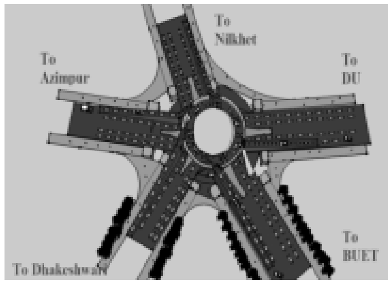


Figure 17: Plan view of the roundabout

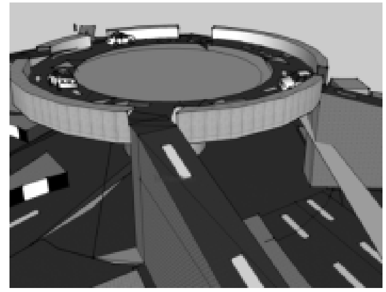


Figure 18: Side view of the roundabout

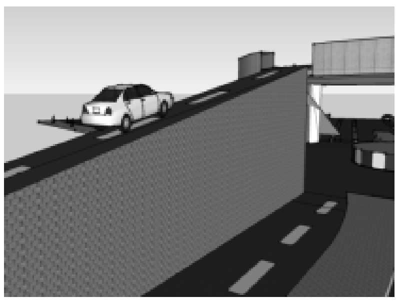


Figure 19: Ramp facility for elevated roundabout

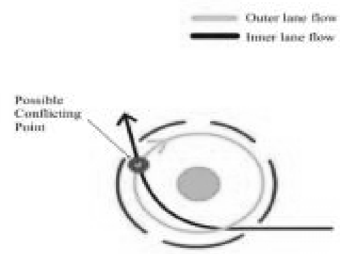


Figure 20: Drawback of the conventional roundabout

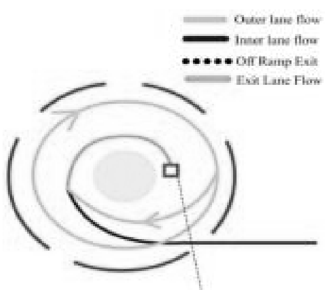


Figure 21: Concept of the centripetal motion

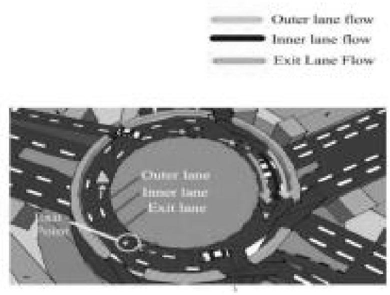


Figure 22: Implementation of centripetal motion in real

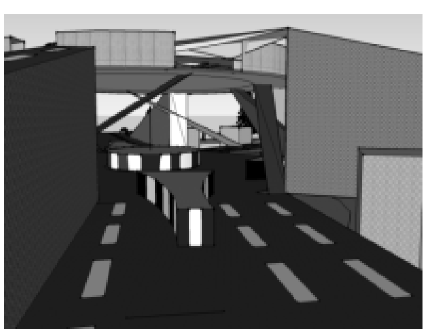


Figure 23: At grade facility for NMT

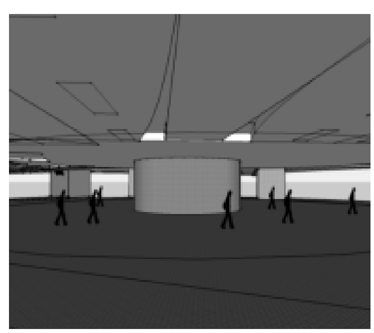


Figure 24: Underpass facility for Pedestrians.

8. CONCLUSIONS

Roundabout is an essential element to ensure safety at intersections. In a roundabout signals are not necessary. To design a roundabout, greater emphasis should be given on study of existing condition such as prevailing problems, survey of geometric properties including the total available area and most importantly the traffic studies. In this regard, we have collected data of existing geometric and transport condition and data analysis is done to discover the limitations of the conventional multilane roundabout. The survey of existing condition includes study on heterogeneity and circulation direction of traffic, existing channelization and pedestrian facility, traffic signs and lastly the side friction. The study has brought about the deficiency of existing facilities such as no channelization, acute heterogeneity of traffic, no pedestrian safety, ineffective footpath and ineffective sign and also marked the points on which the paper is focused on. The vehicle composition study shows that the rickshaws dominate over all. The directional flow analysis shows that the through movement is greater than all other movements. The speed study has also brought out the fact that NMT have lower speed than the motorized vehicles whereas the speed of the motorized vehicles is influenced greatly by the NMT. The intersection faces on an average 3% bicycle flow, which means that the roundabout needs added pedestrian facility. Based on all these considerations, this paper gives a unique design in which all the existing limitations have been addressed by providing different right of way for different users having different speed. The pedestrians have been given the safest place by offering them to use the underpass. Although the design is costly, it meets all the present needs and requirements to a great extent. Further studies and investigations in this regard to improved and safer design of roundabout should be carried.

9. ACKNOWLEDGEMENTS

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REFERENCES

Hoque, MM (2015). Personal Communications. Department of Civil Engineering, BUET.

Federal Highway Administration (2000). Roundabouts: An Informational Guide. Report No. FHWARD-00-067. p 2.

Oregon Department of Transportation (1998). Modern Roundabouts for Oregon.

Michigan Department of Transportation (2007). Evolution of Roundabout Technology: A History-BasedLiterature Review. p 3.