BE CIVIL ENGINEERING
PROJECT REPORT

Safety and Operational Analysis of At Grade Unsignalized Intersections

Project submitted in partial fulfilment of the requirements for the degree of

SUBMITTED BY

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MILITARY COLLEGE OF ENGINEERING

NATIONAL UNIVERSITY OF SCIENCES & TECHNOLOGY

RISALPUR, PAKISTAN

(2018)

This is to certify that the

BE Civil Engineering project entitled

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Has been accepted towards the partial fulfilment of requirements for BE Civil Engineering Degree

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Lt Col Dr. Anwaar Ahmed

Syndicate Advisor

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"In the name of Almighty Allah, the Most Beneficent, the Most Merciful"

First and foremost, all thanks and praises to ALLAH Almighty for the strength, patience, knowledge and His blessings to complete this project. We are obliged to our respected supervisor, Lt. Col. Dr. Anwaar Ahmed, who gave us his precious time and shared his life-long hard-earned knowledge and experience. It would never have been possible for us to work on this project without his supervision, constant support and instructions.

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ABSTRACT

Intersections in our country are seldom designed according to standards which results in traffic congestion and accidents. The best way to control an intersection is to control it without traffic signals. An intersection should guide the road user through it, with appropriate signings and geometry. Thus, it is important to carry out a road safety audit of uncontrolled intersections in the light of design standards and identify the shortcomings.

An intersection needs to be analyzed in terms of intersection sight distance and other necessary measures such as crosswalks and stop line etc. an alternate to an intersection is a roundabout. A roundabout allows the traffic to flow smoothly through the intersection with the help of deflections in geometry and signage. Thus, well planned, sensible and efficient intersection designs are needed. Our study aims to identify intersection design problems in two simple intersections and two roundabouts. All of them are in Risalpur. For the analysis and redesign, the standards of FHWA and AutoCAD Civil 3D (Vehicle Tracking) Software was used.

Chapter 1

INTRODUCTION

1.1 Background

Transportation and communication infrastructure are an important component of the economy and a common tool used for economic progression and enhancing production capacity of a country. Quantity and quality of transportation facilities and economic growth are directly related to each other. It has been universally acknowledged that countries with efficient transportation and communication infrastructure are more economically competitive and vibrant as compared to those having inefficient system. Communication network is an expression of the human aspiration to live in harmony and peace with other people. Roads and routes serve this purpose effectively.

If conditions allow, it is always preferred to keep an intersection unsignalized. Which means that traffic should be controlled only with signings and geometry. To control traffic in this manner either we keep the intersection unsignalized or provide a roundabout.

The advanced roundabout was conceived in the United Kingdom to take care of the issues related with the traffic circles. In 1966, Britain embraced an obligatory "give-way" control at all the roundabout crossing points, which require the entering movement to give way, or yield, to flowing traffic. This administer kept round intersections from locking up, by not enabling vehicles to enter the convergence until there were sensible gaps in the flowing activity. What's more, smaller round crossing points were additionally suggested that required adequate horizontal curvature of vehicle ways to accomplish slower passage and coursing speeds.

1.2 Problem Statement

- Most complex individual locations within any street and highway system are at-grade intersections.
- Uncontrolled intersection is a common phenomenon on any highway network.
- For safe and efficient movement of traffic it is extremely necessary that all intersections are appropriately designed.
- Failure to ensure accurate intersection design would not only result in poor traffic operations (congestion) but would also result in loss of valuable lives.
- There is need to carry out safety and operational analysis of common uncontrolled intersections, so that geometric and safety deficiencies can be identified.

1.3 Study Objective

The main objective is to do a road safety audit of unsignalized intersections in our vicinity. Study the standards and analyze our candidate sites in light of these standards. Then identify the problems and recommend their solution. The following objectives are to be achieved:

- To carryout safety and operational analysis of unsignalized intersections (Level-1 and Level-2)
- To identify safety and geometric deficiencies
- To suggest suitable measures to enhance safety and operations

1.4 Scope of the Study

The scope of the study includes safety and operational analysis of unsignalized intersections and roundabouts in the light of AASHTO standards, identifying the shortcomings in sites under consideration and proposing new designs according to standards.

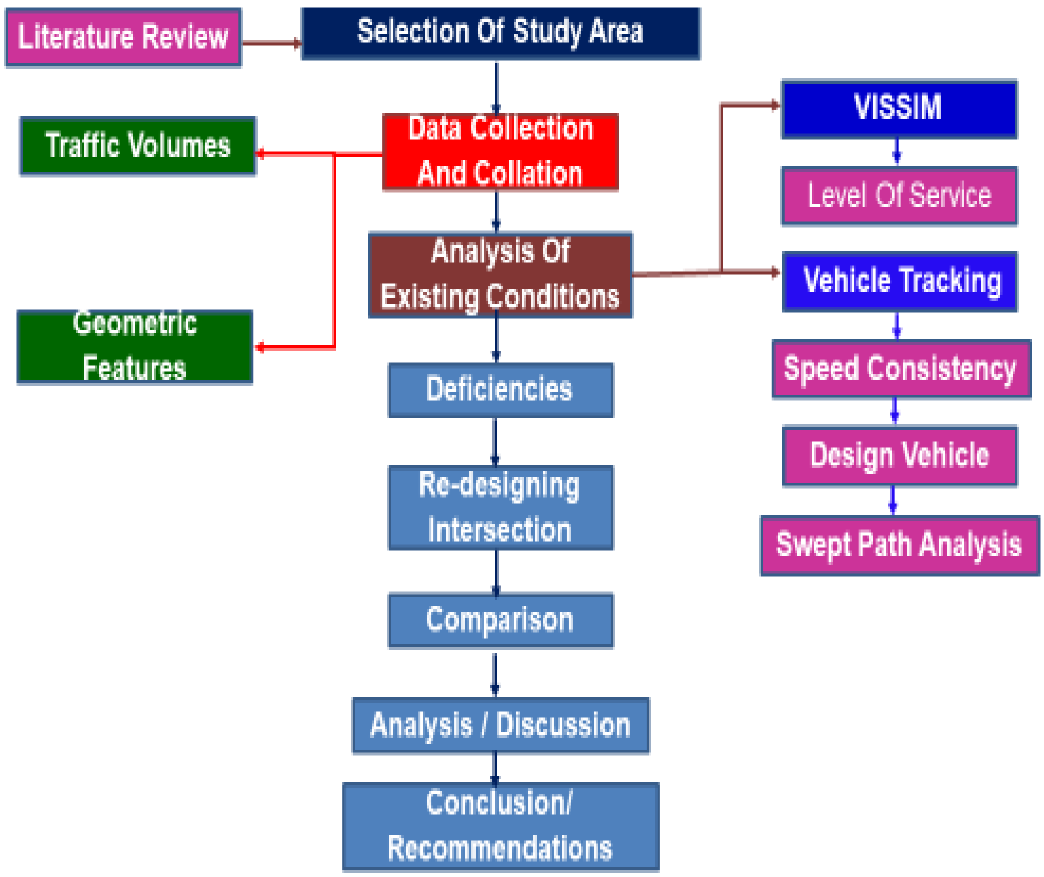
At grade unsignalized intersections:

1. North Colony Intersection, Risalpur Cantt
2. MCE Intersection (at entrance of MCE), Risalpur Cantt

Roundabouts:

1. Urban Double Lane Roundabout (Rashakai Roundabout-South), on N-45, Rashakai
2. Mini Roundabout (between Gate#3 and Jamia Masjid), Risalpur Cantt

1.5 Generalized Study Methodology



1.6 Organization of the Report

The project is ordered in five chapters; brief description of each is as follows

Chapter 1 gives a short overview to unsignalized intersection, scope and objectives of the study and organization of report.

Chapter 2 comprises of review of the past researches and case studies that have been carried out on similar type of intersections.

Chapter 3 describes the methods used for collection and collation of data.

Chapter 4 uses the results of chapter 3 to recommend changes for improving the intersection and roundabout efficiency and effectiveness to make them safe.

Chapter 5 concludes the study on intersections and roundabouts and recommends the solutions to the issues pertaining to our candidate sites.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

A lot of research has been done on various aspects of unsignalized intersections. Studies on roundabouts are discussed first then intersections will be discussed.

There are three basic levels of control that can be implemented

at an intersection:

- *Level* I-Basic rules of the road
- *Level* 2- Downright assignment of right-of-way using STOP or YIELD signs
- *Level* 3 -Traffic signalization

2.2 Level I Control: Basic Rules of the Road

Basic rules of road apply to an intersection where right of way is not defined using yield or stop signs. Every state has its own basic rules of road and drivers are expected to know them. Most of the intersections are controlled using basic rules of road where there is no intersection sight distance limitation.

2.2.1 Intersection Sight Distance

Intersection sight distance is that distance before which a motorist can see an approaching vehicle before its line of sight is blocked by obstruction adjacent to the intersection. Insufficient sight distance can lead to crashes and fatalities, if provided sight distance at intersections is not sufficient then an intersection cannot operate according to basic rules of road. Intersection sight distance is calculated using posted speed limit for an intersection and stopping sight distance.

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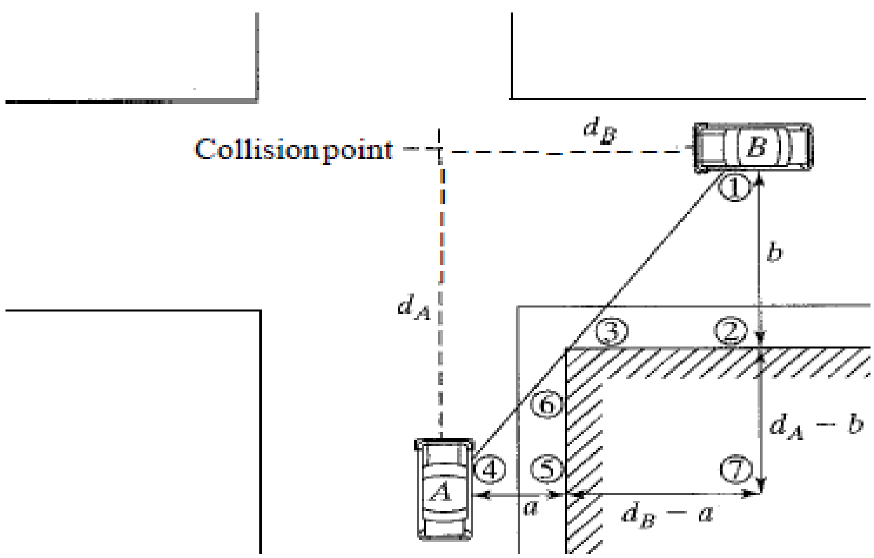

Figure 1 Clear sight triangles used in Intersection sight distance calculation.

the safe stopping distance is given by:

$$d_{B\,min} = 1.47S_i t + \frac{s_i{}^2}{30(.548+.01G)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

$d_{B\,min}$ = intersection safe stopping distance, ft.

$\boldsymbol{S_i}$ = initial speed of vehicle, mi/h

G = grade, %

t = reaction time for stopping maneuvers

minimum design Intersection sight distance is given by

$$d_{b\,act} = \frac{a d_{B\,min}}{d_A - b} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

$d_{b\,act}$ = existing intersection sight distance.

a = distance of vehicle A from obstruction.

b = distance of vehicle B from obstruction.

If

$d_{b\,act} > d_{B\,min}$ intersection can operate under basic rules of road.

$d_{b\,act} < d_{B\,min}$ intersection cannot operate under basic rules of road.

According to design standards the most important factors in intersection design are intersection sight distance if this factor is justified on site then traffic can be regulated following basic rules of road but if not, then adjustments should be made accordingly.

2.3 Level II Control: YIELD and STOP Control

Level II of traffic control is used for following reasons:

- Requirement of design intersection distance is not satisfied.
- Signalized area containing unsignalized intersection.
- Intersection of some minor street with a primary street where utilization of typical right-of-way govern would not give sensibly safe activity.
- High traffic volume roads where signalization will cause unnecessary delays and provision of yield control is a better alternative i.e. Roundabouts.

2.4 Level 3 Control: Traffic Control Signals

Traffic signal is a definitive type of convergence control as it on the other hand allocates right-of approach to particular movements, in this manner it can considerably lessen the number and nature of conflicts contrasted with other type of control.

2.5 Intersections

The most complex areas inside road and thruway are at level Intersections. Intersections have 12 legal vehicular movements and 4 legal pedestrian movements creating about 16 conflicts. If improperly controlled, it can lead to accidents and deaths.

Important factors defining safety of an intersection include:

1. intersection sight distance
2. Traffic control measures
3. Pedestrian safety and markings
4. Signage

2.6 Uncontrolled Intersections

Uncontrolled crossing points need signs and signals (once in a while a warning sign might be given). right-of-way rules differ by nation: on a 4-way intersection movement drawing closer from left regularly has priority; on a 3-way crossing point again either activity from the left has priority, or activity on the proceeding with street. For movement originating from the inverse or same direction, priority is given to straight going activity over activity turning left.

Yield-controlled crossing points might have "YIELD" signs (known as "GIVE WAY" signs in a few nations).

Stop-controlled crossing points utilize at least one "STOP" signs. Two-way stops are more typical, while a few nations additionally utilize four-way stop sign

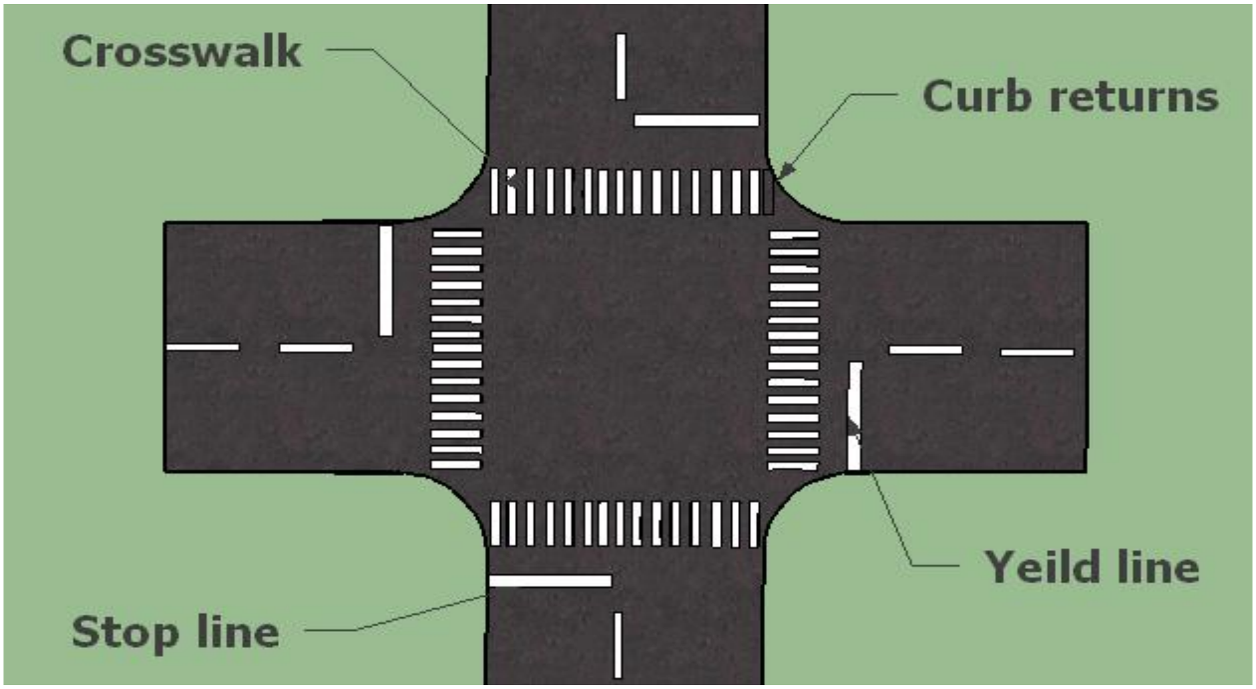

Figure 2: Elements of an intersection

2.7 Roundabouts

2.7.1 Components of a Roundabout:

For design purposes and operation analysis, it is useful to define several main dimensions. Following figures will show them briefly:

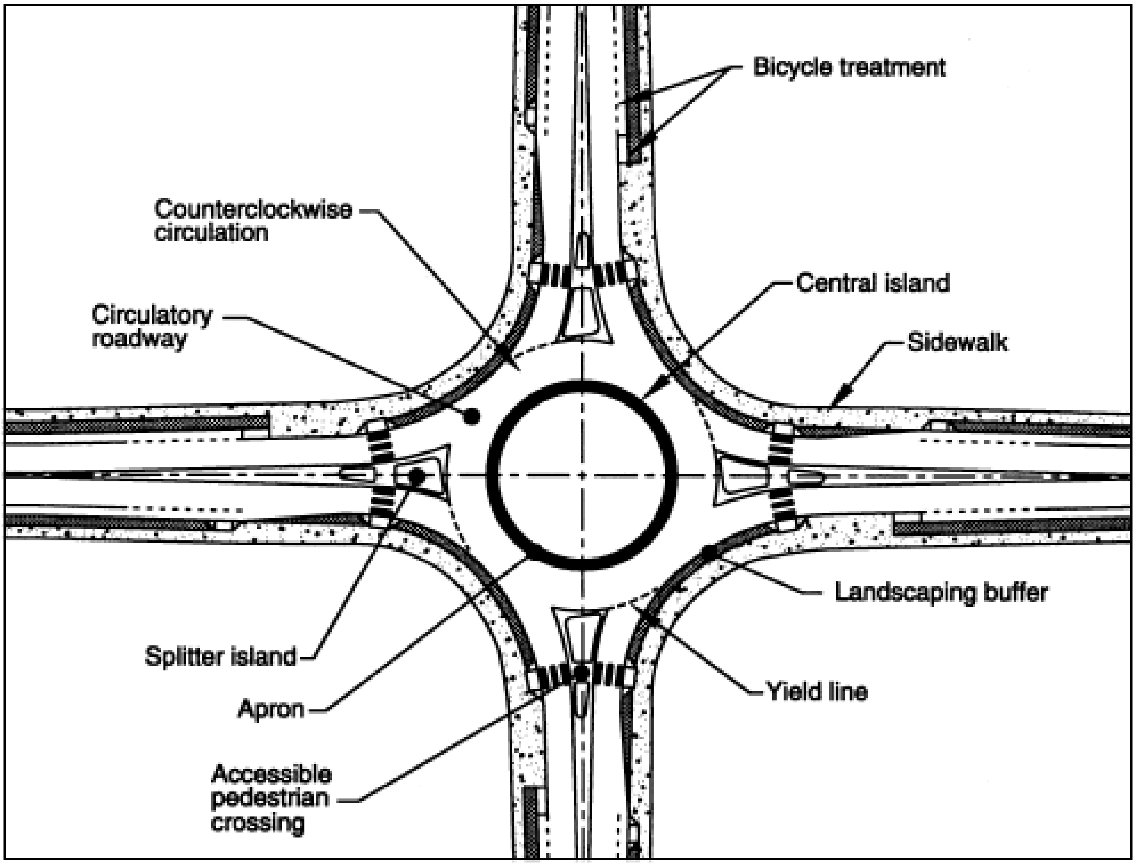

Figure 3 Key features of a roundabout.

Table 1: Description of Key Roundabout Elements.

Features	Description
Central island	Central island is the highland area at the center of roundabout around which Traffic rotates.
Splitter island	Splitter Island is an elevated area or marked on an approach used to distinguish the entry from exit traffic, slipping and entering slow traffic, and also providing storage space for pedestrians crossing the road in two phases.
Circulatory roadway	Circulatory roadway is the curved path which is used by vehicles to travel in a counterclockwise movement around the central island

Apron	If required it might be utilized on smaller roundabouts to oblige the wheel following of extensive vehicles, an apron is the mountable part of the central island adjoining the circulatory roadway.
Yield line	A yield line is a pavement marking which is used to mark the point of entry from an approach into the circulatory roadway and it is generally marked along the inscribed circle. Entering vehicles must yield to any circulating traffic coming from left before crossing this line into the circulatory roadway.
Accessible pedestrian crossings	Open passerby crossings ought to be given at all roundabouts. The crosswalk area is set back from yield line, and the splitter island is trimmed so people on foot, wheelchairs, strollers, and bikes can go through.

2.7.2 Comparison of a Roundabout and a Simple Intersection

A roundabout has 75% less points of conflict than a typical intersection. This phenomenon is shown in the following figures:

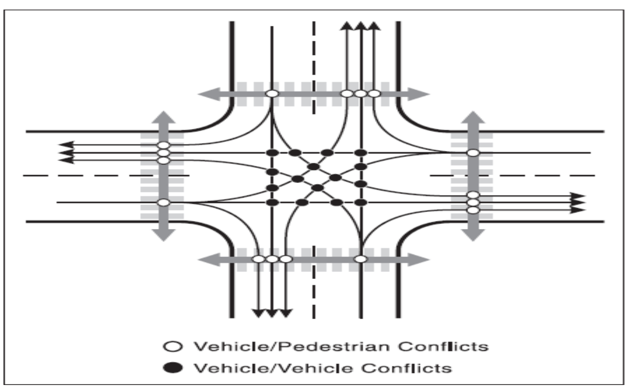

Figure 4 Conflicting points on an intersection

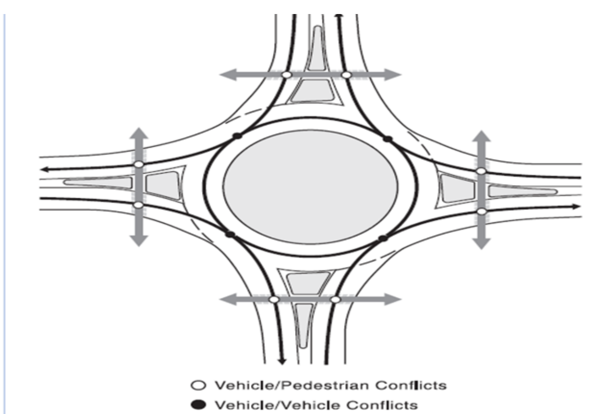

Figure 5 Conflicting points on roundabout.

2.7.3 Types of Roundabouts

Roundabouts have been classified by condition and size to encourage talk of particular execution or configuration issues. There are six fundamental classifications in view of number of paths, condition, and size:

Table 2: Key Design Elements of a Roundabout.

Design Element	Mini-Roundabout	Urban Compact	Urban Single lane	Urban Doublelane	Rural Single lane	Rural Double Lane
Speed Limit	25kmph (15mi/h)	25km/h (15mi/h)	35km/h (20mi/h)	40km/h (25mi/h)	40km/h (25mi/h)	50km/h (30mi/h)
Number of approach Lanes	1	1	1	2	1	2
Inscribed Circle Diameter	23m to 25m	25m to 30m	30m to 40m	45m to 55m	35m to 40m	55m to 60m
Splitter Island	Raised if possible	Raised	Raised	Raised	Raised	Raised
Daily Service Volume	10,000	15,000	20,000 13	-	20,000	-

Studies show that roundabouts have following three major advantages:

1. Reduces automobile accidents and fatalities at an intersection.
2. It has a positive effect on traffic flow.
3. Significant effect on safety of pedestrians and bicyclists using the road.

Roundabout is a modified form of a rotary or a traffic circle. In fact, a conventional rotary has evolved into a modern roundabout as research was done on the issues of congested traffic and high crash rates on rotaries.

2.7.4 Comparison of a Roundabout to a Traffic Circle

Some of the major differences are shown here in this table.

Table 3: Comparison of a Roundabout to a Circle.

Roundabout	Traffic Circle
They work on the principle of "entering traffic yields for the circulating traffic"	They work on the principle of "circulating traffic yields to entering traffic"
Small diameters	Usually have large diameters
All vehicles move in a clockwise manner and pass to the left of the central island.	Some neighborhood has traffic circles that allow right-turning vehicles to pass to the right of central island
It is not permissible to Park within the circulatory roadway or at the entries	It is permissible to park within the circulatory roadway
Pedestrians are allowed to cross only at the start of the legs of the roundabout, before the yield line	Some traffic circles allow the use of central island by the pedestrians.
Sufficient deflection and signage to reduce speed	Insufficient deflection and signage to reduce speed

Figure 4 Traffic Circle

Figure 5 Roundabout

2.7.5 Analysis Done on Vehicle Safety

"A study of traffic safety at roundabouts in Minnesota, Derek Leuer P.E gave the following conclusions by analysing 144 roundabouts:

- An 86% reduction in the fatal crash rate.
- An 83% reduction in the severe injury crash rate.
- A 69% reduction in the Right-Angle crash rate at intersections where Single Lane Roundabout have been installed.
- An 83% reduction in the Left Turning crash rate at intersections where Single Lane Roundabout have been installed.
- A 61% reduction in the injury crash rate at intersections where Single Lane Roundabout have been installed.
- A 42% reduction in the injury crash rate at intersections where Single Lane Roundabout have been installed."

"NCHRP Report 572, titled "Roundabouts in United States" was published in 2007. This report analysed 55 sites where traditional intersections were converted to roundabouts and concluded that:

- There was a 35% reduction in crashes from 1122 to 726 per year.
- A 76% reduction in severe injury crashes from 296 to 72.
- 60% reduction in severe injury crashes.
- At suburban signalized intersections, a dramatic 67% reduction in overall crashes.
- At rural intersections, there was a remarkable decrease of 87% in severe injury crashes."

2.7.6 Positive Effect on Traffic Flow, Environment and Operating Cost

2.7.6.1 Reduced Delays

- "The insurance Institute of Highway Safety (IIHS) reported a 13% to 36% reduction in delays at three roundabouts studied."
- "The NCHRP reported 75% reduction in peak hour delays at studied roundabouts".
- The IIHS reports that a study of 11 intersections in Kansas found a 65% reduction in delays and 52% reduction in vehicle stops."

2.7.6.2 Reduced Environmental Impact

- "Various IIHS reports estimate reductions of carbon mono-oxide emissions by 21% to 42% and 30% reduction in fuel consumption."
- "A study by NYSDOT Intern, using a SIDRA software predicted "6.36% reduction in nitrous oxide and a 26.05% reduction in hydrocarbons compared to traffic signal"

2.7.6.3 Reduced Operating Costs

- "The Alaska Department of Transportation Estimates a $13,000 per year reduction in maintenance cost."
- "The IIHS states that a roundabout eliminates the estimated $3000 per year in electricity costs of a traditional traffic signals".
- "Other cost reduction is associated with reduction in collisions, particularly injury and fatality collisions reduced due to construction of a roundabout".

2.7.6.4 Safety of Pedestrians and Bicyclists

- "Quoting a Dutch Study, the report states that roundabouts have been shown to reduce pedestrians/vehicle crashes by 73% and injury crashes by 89%."
- "In case of bicyclists behaviour of roundabout is not very encouraging".
- "A French study found a 16% increase in two-wheel vehicle crashes at roundabouts, and crashes were also generally more severe".
- "Thus, it is advised that bicyclists should negotiate a roundabout as a driver because separate bicycle lanes have proved to be the cause of crashes".

Chapter 3

DATA COLLECTION AND COLLATION

3.1 Introduction

We intend to perform a safety and operational analysis of unsignalized at grade intersections and roundabouts. Controlling traffic without traffic signal or traffic police, requires an intersection to have sufficient traffic controlling and guiding features. Such as geometric deflections, intersection sight distances, signings and pavement markings. These features will be provided according to widely accepted standards. So that an intersection achieves the objectives for which it is built.

We will be separately analyzing intersections and roundabouts. Intersections will be analyzed for sight distances and other important aspects. Roundabouts will be analyzed for design speed, vehicle path, speed consistency and design vehicle.

3.2 Types of Data

The data collected can be broadly classified into two categories:

1. Inventory Data
2. Traffic Volume Data

Inventory data includes details of the geometry at roundabout like diameter of central island, approach width, entry width, circulatory width etc. This inventory data was collected using google earth as well as a measuring tape for minor details on site.

Traffic volume data was collected according to category of vehicles at the entry of an approach and on the circulatory roadway, giving Insight of total traffic volume and its composition.

3.3 Types of Intersections

Generally, we have selected two unsignalized intersections and two roundabouts.

Table 4: Description of Candidate Sites

Candidate Sites	
Intersections	
1.	North Colony Intersection (4 approaches)
2.	MCE Entrance Intersection (4 approaches)
Roundabouts	
1.	Urban Double Lane Roundabout (Rashakai Roundabout-South) on N45, Rashakai (3 approaches or a T-Junction)
2.	Mini Roundabout (between Gate#3 and Jamia Masjid), Risalpur Cantt (4 approaches)

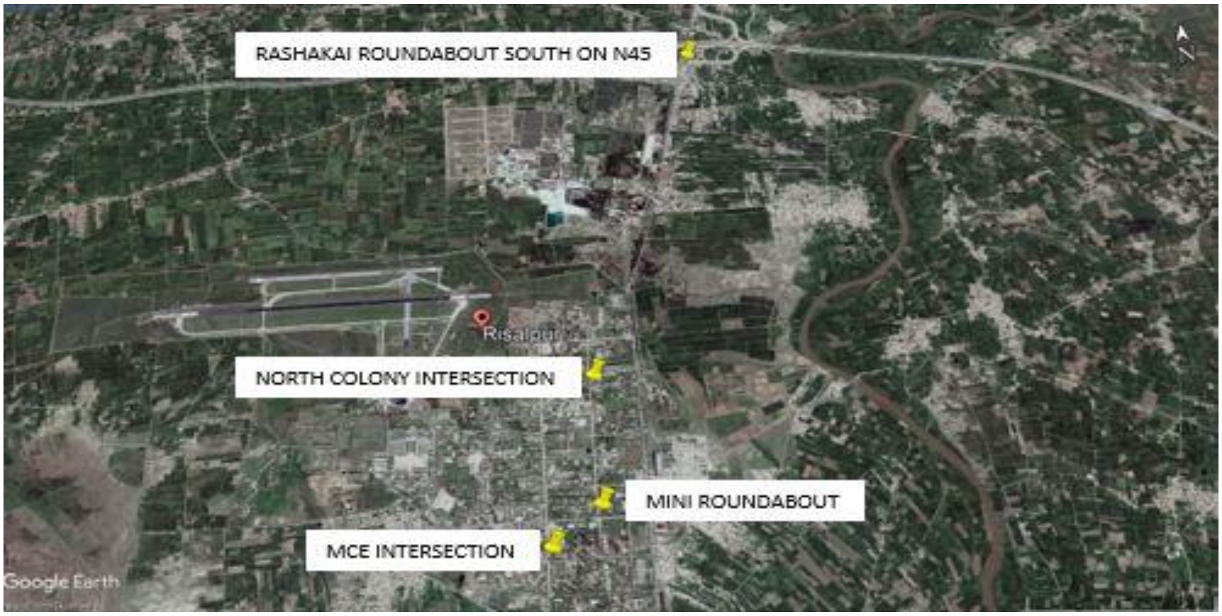

Figure 6 Google Imagery of Candidate Site

3.4 Introduction to Selected Intersections

3.4.1 Urban double lane Roundabout (RASHAKAI ROUNDABOUT-SOUTH)

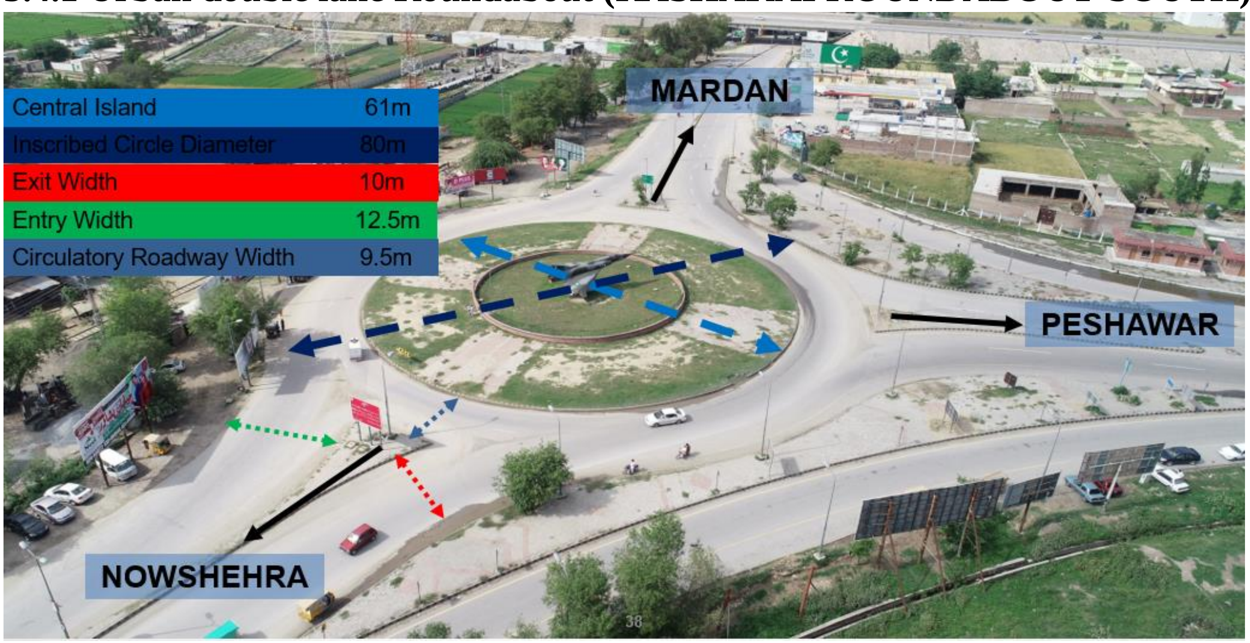

Figure 7 Dimensions of urban double lane round about.

This roundabout is at a T-Junction located on GT Road between Nowshera and Mardan. Where three roads intersect. One from Nowshera, one from Mardan and one from Rashakai Interchange.

All roads are double lane with all types of traffic from two wheelers to long vehicles. The roundabout is also a double lane roundabout.

3.4.1.1 Inventory Data

Table 5: Inventory Data for Rashakai Roundabout-South

Geometric Element	Dimension(m)
Central Island Diameter	61
Inscribed Circle Diameter	85
Entry Width	12.5
Exit Width	10
Approach Width	10
Circulating Roadway Width	9.5

Configuration of our candidate roundabout:

1. It is having three approaches.
2. Approach road and Circulatory Roadway both are double lane.
3. All approaches are approximately at 90 degrees to each other.

3.4.1.2 Traffic Volume Data

Table 6: Traffic Data for Rashakai Roundabout-South Chowk.

Direction	**Entry Volume (veh/h)**			**Total Entry (veh/h)**	**Circulating Volume (veh/h)**
	LT	TH	RT		
Mardan Bound	0	1612	321	1933	321
Nowshera Bound	132	1880	0	2012	417
Peshawar Bound	356	0	96	452	2201

- This is the peak hour traffic data.
- Peak hour occurs after 2pm when offices and schools are closing, which adds to the normal traffic.
- Data was collected in the morning from 7am to 9am and in afternoon from 1pm to 3pm on Monday, Friday and Sunday.
- Traffic counts were done manually at a rate of 15-minute intervals.

This data was used to determine the total entry and circulating flows. As these two factors determine the capacity of roundabout. Approach capacity graph from *Roundabout Design Guidelines* by State of Maryland Department of Transportation shows that two lane roundabouts is appropriate for this traffic volume.

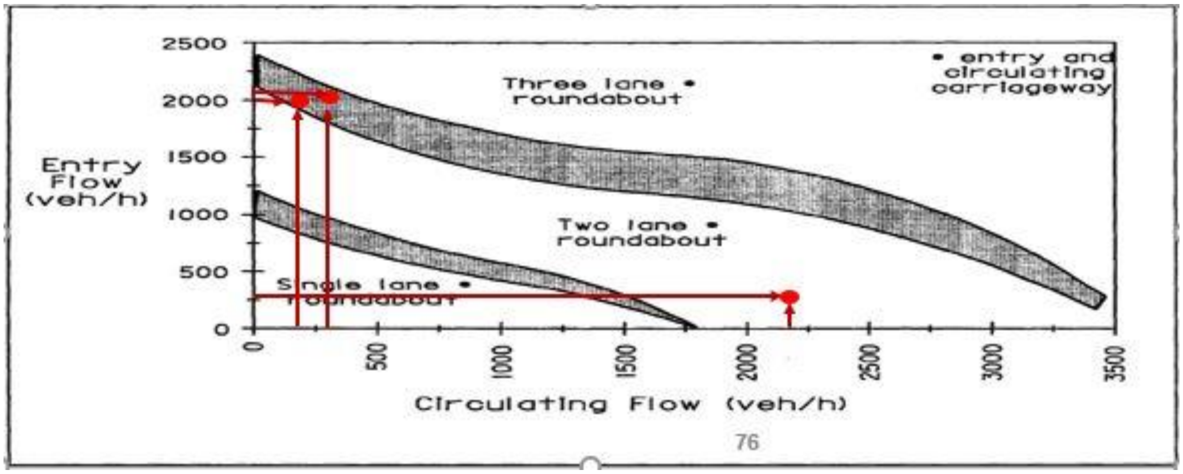

Figure 8 Roundabout approach capacity graph.

3.4.1.3 Signings and Markings

No significant signing or marking is provided.

3.4.2 Mini Roundabout - Jamia masjid/Gate3:

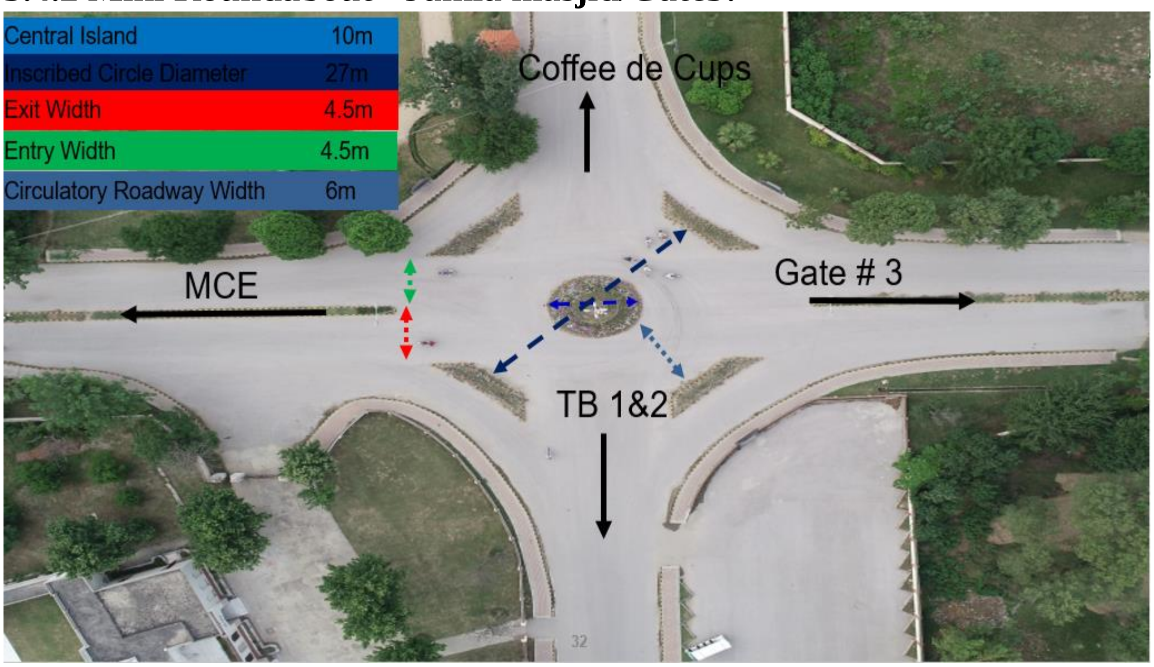

Figure 9 Dimensions of a Mini Roundabout

This roundabout has four approaches and is in front of the Jamia Masjid in Risalpur Cantt. Four roads coming from Gate#3, MCE, BTB 1 and Engrs Centre Mess, intersect here. All roads are single lane road with dividers dividing opposite traffic. The geometry and traffic conditions match to that of a mini roundabout, so it was analyzed as a mini roundabout.

Mini-Roundabouts usually operate well above their capacity. So is the roundabout we are studying. As the traffic flow is negligible so there was no need to analyze it. Thus, only the geometric design was studied for which only inventory data was collected to design it on civil 3d.

3.4.2.1 Inventory Data

Table 7: Inventory Data for Mini Roundabout

Geometric Element	Dimension(m)
Central Island Diameter	9
Inscribed Circle Diameter	27
Entry Width	4.5
Exit Width	4.5
Approach Width	4.5
Circulatory Roadway Width	6

Configuration of our candidate roundabout:

1. It has four approaches.
2. Approach road and circulatory roadway both are single lane.
3. All approaches are approximately at 90 degrees to each other.

3.4.3 North Colony Intersection

North colony intersection is located between Professor Munir Road (minor road) and Cantonment Board Road (major road) at (34° 4'3.44"N, 71°59'51.81"E) opposite to Cantt Board Office in Risalpur cantonment. Traffic setting in this intersection include Military trucks (Hino FG8J) WB 15 and other passenger vehicles. It consists of two lane divided roadway in North south alignment and one lane divided in East west direction. The lane width at intersection is 8.5 ft. the intersection geometry is as follows.

3.4.3.1 Geometric Details

Our candidate site is a four-legged intersection with all of its approaches making a 90-degree angle with each other. A two-lane divided roadway of 34 ft. cuts a single lane divided roadway having 16 ft. width. Lane width for all legs is 8.5ft. major road is having a side walk of 6 ft. on each side.

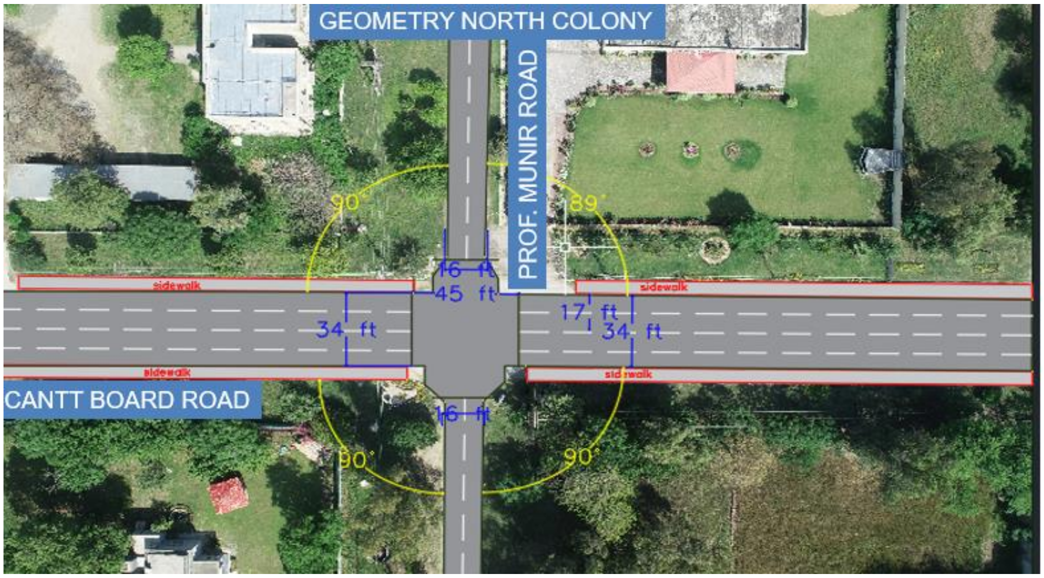

Figure 10 Geometry of North Colony Intersection.

Table 8: Key Dimensions of North Colony Intersection.

Feature	Existing	Standard
Lane width (Major)	8.5 ft.	8-12 ft.
Lane width (Minor)	8 ft.	-do-
Intersection angle	90 deg	90 deg preferable

3.4.4 MCE Intersection

MCE intersection is located between Scholar’s avenue and South Avenue in Risalpur Cantonment. Traffic setting in this intersection include Hino Bus (Hino FG8J) WB 15 and other passenger vehicles. It consists of two lane divided roadway in North south alignment and one lane divided in East west direction. The lane width at intersection is 11 ft. and 8 ft. the intersection location is as follows.

3.4.4.1 Geometric Details

Our candidate site is a four-legged intersection with all of its approaches making a 90-degree angle with each other. A two-lane divided roadway of 44 ft. cuts a double lane divided roadway having

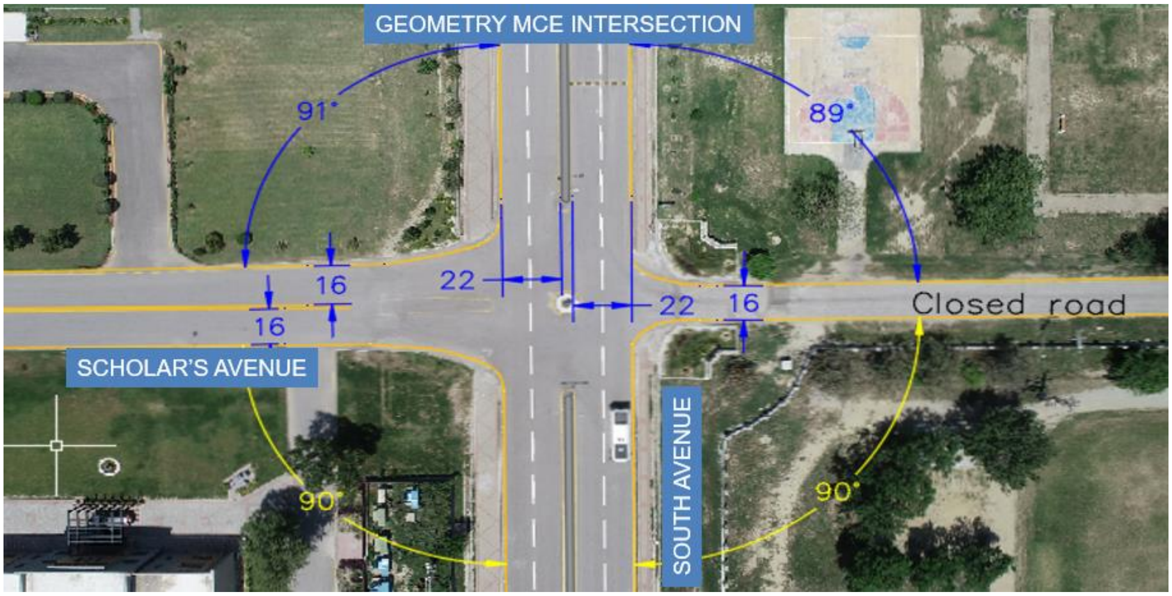

Figure 11 Geometry of MCE Intersection.

32 ft. width. Lane width for all legs is 8.5ft. major road is having a side walk of 6 ft. on each side.

Table 9: Inventory Data for MCE Intersection.

Feature	Existing	Standard
Lane width (Major)	11 ft.	8-12 ft.
Lane width (Minor)	8 ft.	-do-
Intersection angle	90 deg	90 deg preferable

Chapter 4

RESULTS AND ANALYSIS

All the roundabouts and intersections were analyzed for their deficiencies in respective software. Geometrics were analyzed in Civil 3D and traffic operations were analyzed in VISIM.

4.1 Software Used

Two software were used:

4.1.1 AutoCAD Civil 3D-Vehicle Tracking

It is an add on software in Civil 3D, specially programmed for roundabouts. It is an intelligent software which calculates vehicle paths, radii and speeds according to the conditions provided by the user.

4.1.2 VISSIM

This software is used to analyze traffic conditions and provide solutions. The plus point is that it also depicts results in video form.

4.2 Rashakai Roundabout-South on N-45

4.2.1 Geometric Analysis

In current conditions following deficiencies were encountered:

1. Design Entry Speed is 57 km/h which should be below 40 km/h.

Table 10: Head Up Displays (HUD's) Show Critical Design Values Related to Each Arm.

Peshawar	Mardan	Nowshehra
R1 / V1: N/A	R1 / V1: 155.21 m / 53.68 km/h	R1 / V1: 173.90 m / 57.56 km/h
R2 / V2: N/A	R2 / V2: 30.85 m / 29.22 km/h	R2 / V2: 33.59 m / 30.14 km/h
R3 / V3: N/A	R3 / V3: 168.78 m / 56.70 km/h	R3 / V3: 181.57 m / 58.81 km/h
R4 / V4: 28.86 m / 28.43 km/h	R4 / V4: N/A	R4 / V4: 23.68 m / 26.56 km/h
R5 / V5: 55.14 m / 36.15 km/h	R5 / V5: 36.47 m / 31.05 km/h	R5 / V5: N/A
Deflection: 0.00 m	Deflection: 0.00 m	Deflection: 0.00 m

2. Speed Difference b/w entry and circulatory traffic is greater than 20km/h i.e. 27km/h.
3. No deflection has been provided.

4. The design vehicle which is a WB 20 interstate semitrailer is climbing the central island because of absence of truck apron.
5. No signings and cross walk have been provided at any single approach way except chevron sign.

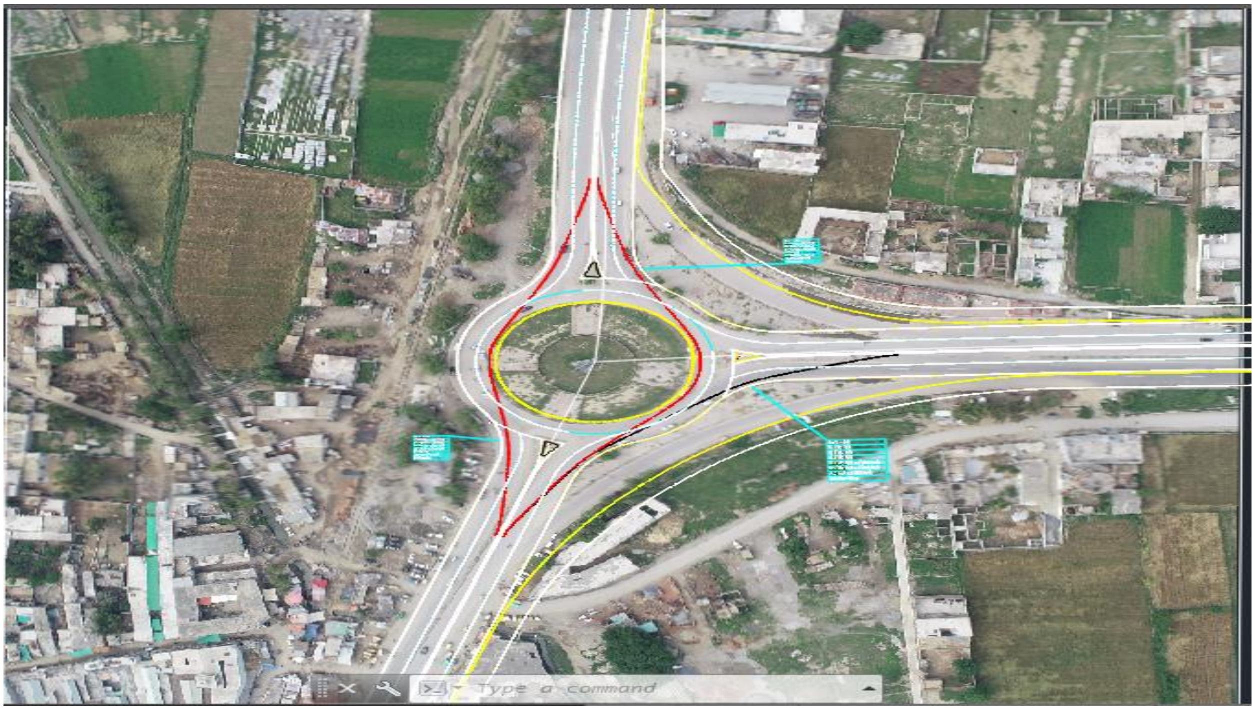

Figure 12 Shows Existing Design of Rashakai Roundabout South

Reasons of these deficiencies:

1. A roundabout reduces the speed of entering vehicles with help of deflections but here Inadequate deflection is provided at entry.

2. As the entry speed is high so speed difference between circulating and entering vehicles exceed 20 km/h.

3. As the diameter of central island is very big which is not consistent with any standards and there is no provision of Truck apron, so the vehicle climbs the central island in its through and right turning movements.

Objectives we want to achieve in a roundabout geometry, as guided in standards are:

1. Design entry speed should be less than 40 km/h.

2. Speed Difference b/w entry and circulatory traffic should be less than 20km/h.

3. The design vehicle should easily negotiate the roundabout while maintaining its lane and without climbing the curb stones.

4. Remedies for these issues:

1. Providing a 6m deflection at all entries.

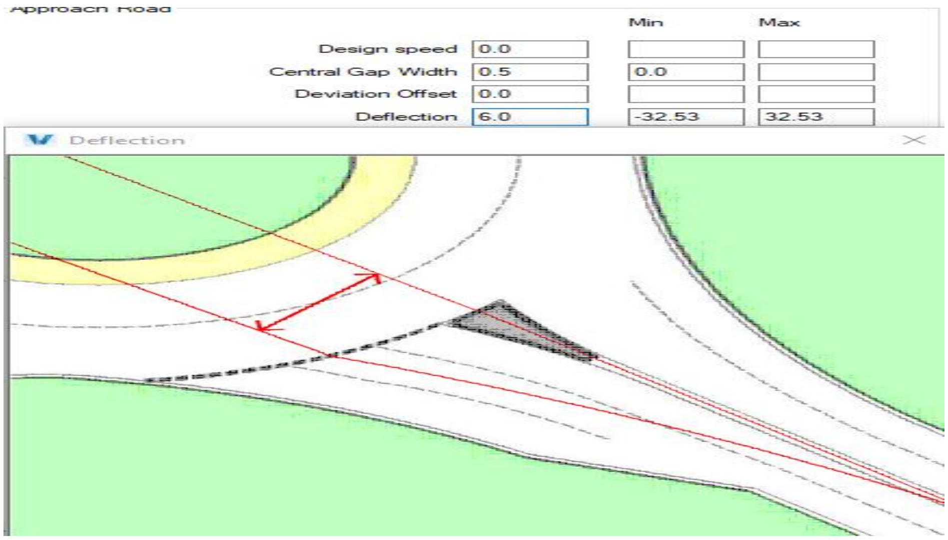

Figure 13 Shows Deflection W.R.T Centerline of Splitter Island.

2. Reducing the central island diameter to 35 which is according to standards.
3. Providing a truck apron around the central island which allows design vehicle to use it while maintaining its lane.

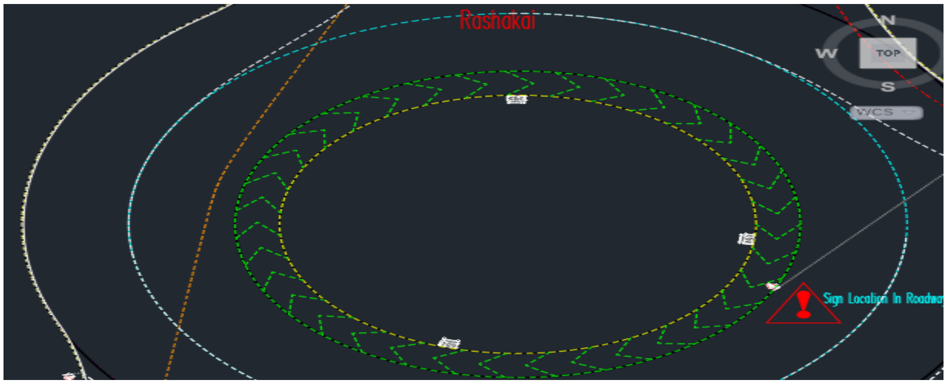

Figure 14 Truck Apron

Results of changes in proposed design:

1. Design Speed is below 40km/h on all approaches.

Table 11: Head Up Displays (HUD's) Show Critical Design Values Related to Each Arm

Mardan	Arm 1 – Nowshehra	Peshawar
R1 / V1: 68.07 m / 39.11 km/h	R1 / V1: 72.05 m / 39.95 km/h	R1 / V1: N/A
R2 / V2: 20.14 m / 25.07 km/h	R2 / V2: 52.76 m / 35.56 km/h	R2 / V2: N/A
R3 / V3: 170.12 m / 56.95 km/h	R3 / V3: 171.69 m / 57.19 km/h	R3 / V3: N/A
R4 / V4: N/A	R4 / V4: 19.42 m / 24.74 km/h	R4 / V4: 19.42 M / 24.74 KM/H
R5 / V5: 31.60 m / 29.47 km/h	R5 / V5: N/A	R5 / V5: 61.91 m / 37.74 km/h
Deflection: 6.00 m	Deflection: 6.00 m	Deflection: 6.00 m

2. Speed difference is below 20km/h.
3. By providing truck apron the design vehicle is negotiating smoothly as shown in the video on next slide.
4. Other deficiencies such as pavement markings and signage have also been fulfilled using civil 3d.

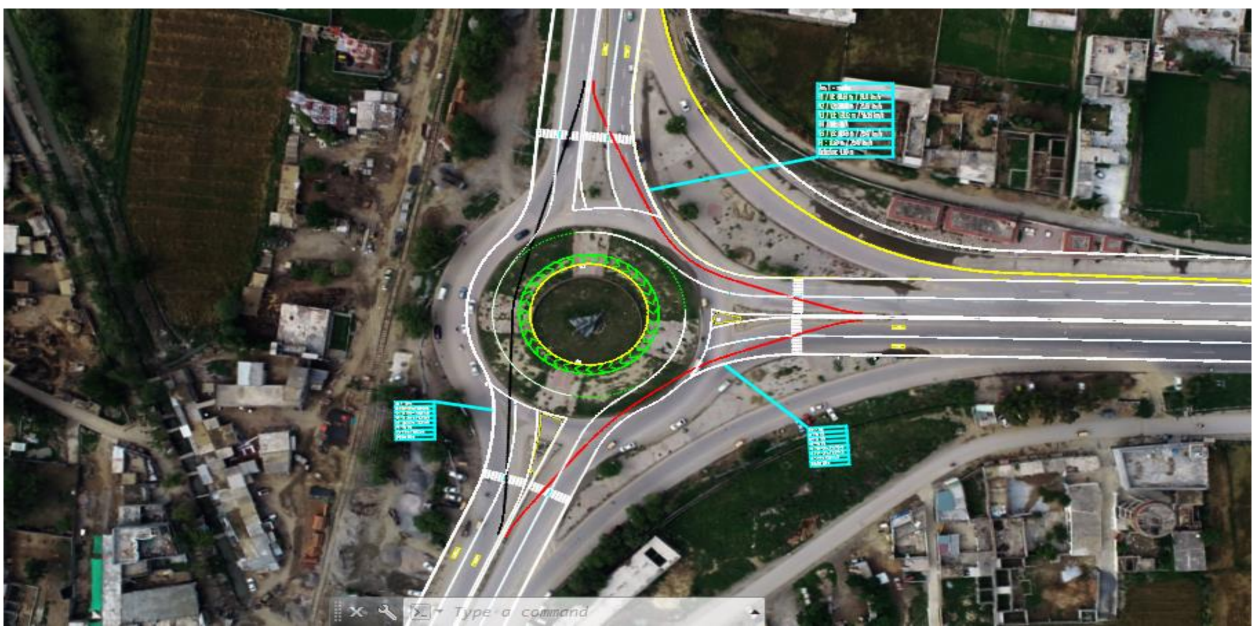

Figure 15 Proposed Design of Rashakai Roundabout South

4.2.2 Traffic Analysis

First this roundabout was made in VISSIM according to the on-ground configuration the traffic data was inserted. When the simulation was run, the result was that for all approaches, level of service came out to be A. So, in terms of traffic operations roundabout is operating perfectly.

4.2.3 Comparison between Existing, Designed and Standard Values

Table 12: Comparison with Design Standards (Rashakai Roundabout-North).

Sr No.	Design Element	Existing Value	Proposed Value	FHWA 2000
1.	Central Island	61	35	35
2.	Inscribed Circle	85	55	55
3.	Truck Apron	Non-existent	1.5m width	1.5m width
4.	Entry Width	12	12.5	
5.	Circulating Width	9.5	14.9	120% of entry width
6.	Crosswalk	Non-existent	22m from yield line	22m from yield line
7.	Splitter Island	20m in length	40m in length	40m in length

4.2.4 Signings and Markings

We have provided signings and markings according to the MUTCD and FHWA.

Figure 16 Signage Plan for Rashakai Roundabout South.

4.3 Mini Roundabout - Jamia Masjid/Gate#3

4.3.1 Geometric Analysis

In current conditions following deficiencies were encountered:

1. Design Entry Speed for all approaches is above 50 km/h > 25 km/h.

Table 13: Head Up Displays (HUD's) Show Critical Design Values Related To Each Arm.

COFFEE DE CUPS	Gate # 3
R1 / V1: 141.60 m / 51.78 km/h	R1 / V1: 143.67 m / 52.07 km/h
R2 / V2: 41.91 m / 32.67 km/h	R2 / V2: 42.46 m / 32.82 km/h
R3 / V3: 143.59 m / 52.06 km/h	R3 / V3: 144.34 m / 52.17 km/h
R4 / V4: 9.17 m / 18.96 km/h	R4 / V4: 9.17 m / 18.96 km/h
R5 / V5: 15.80 m / 22.99 km/h	R5 / V5: 16.04 m / 23.11 km/h
Deflection: 0.00 m	Deflection: 0.00 m

TB1 & TB2	MCE
R1 / V1: 137.13 m / 51.13 km/h	R1 / V1: 146.42 m / 52.46 km/h
R2 / V2: 41.44 m / 32.53 km/h	R2 / V2: 42.44 m / 32.82 km/h
R3 / V3: 143.73 m / 52.08 km/h	R3 / V3: 144.19 m / 52.15 km/h
R4 / V4: 9.14 m / 18.94 km/h	R4 / V4: 9.14 m / 18.93 km/h
R5 / V5: 16.03 m / 23.11 km/h	R5 / V5: 15.80 m / 22.99 km/h
Deflection: 0.00 m	Deflection: 0.00 m

2. Speed Difference b/w entry and circulatory traffic is greater than 20km/h i.e. 21km/h.
3. No deflection has been provided.
4. No splitter islands.
5. The design vehicle which is an SU 12 truck is unable to pass through the roundabout because of absence of truck apron.

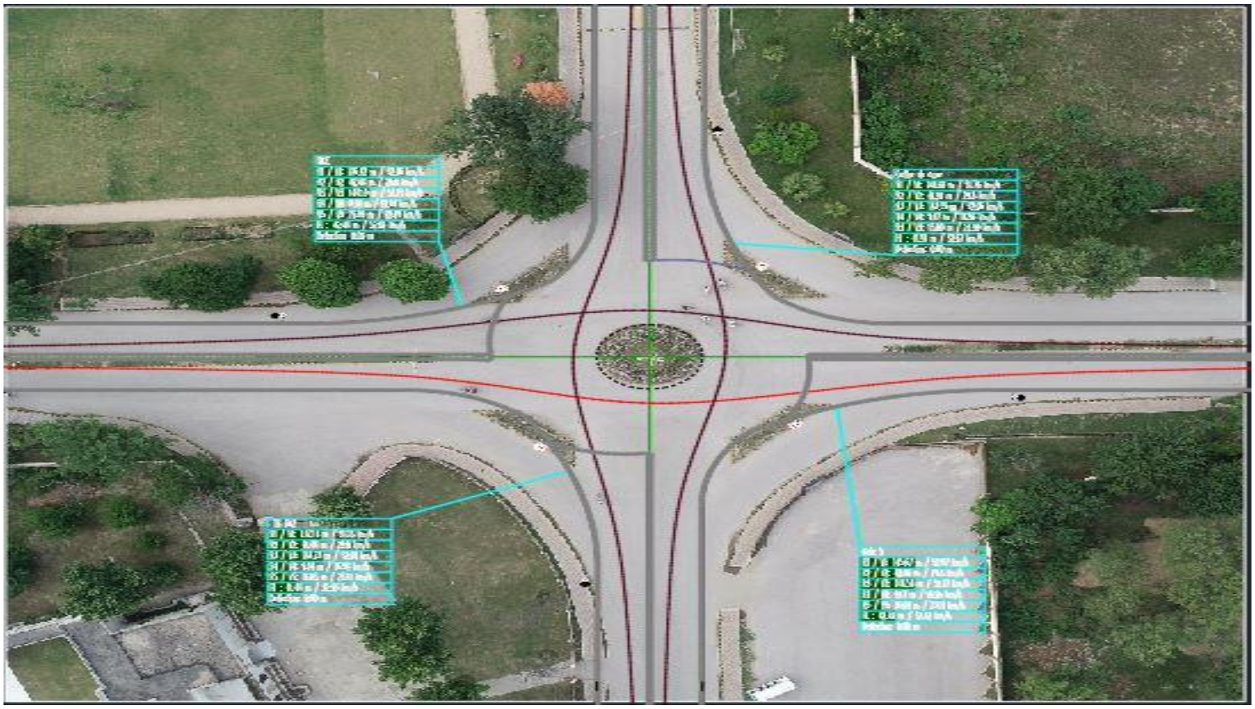

Figure 17 Existing Design of Mini Roundabout

Reasons of these issues:

1. A roundabout reduces the speed of entering vehicles with help of deflections but here inadequate deflection provided at entry.
2. As the entry speed is high so speed difference between circulating and entering vehicles exceed 20 km/h.
3. As the diameter of central island is very big which is not consistent with any standards and there is no provision of Truck apron, so the vehicle climbs the central island in its through and right turning movements.

Remedies for these issues:

1. Providing a 5m deflection at all entries.
2. Reducing the central island diameter to from 27m to 25m which is according to standards.
3. Providing a truck apron around the central island.

Objectives we want to achieve in a roundabout as guided in standards are:

1. Design Entry Speed should be less than 25 km/h for an urban roundabout as discussed before.
2. Speed Difference b/w entry and circulatory traffic should be less than 20km/h.
3. Placement of markings and signings at correct locations

Results of the changes in proposed design:

1. Design Speed is below 25km/h on all approaches.

Table 14: Head Up Displays (HUD's) Show Critical Design Values Related to Each Arm.

COFFEE DE CUPS	MCE
R1 / V1: 26.6 m / 24.95 km/h	R1 / V1: 26.6 m / 24.95 km/h
R2 / V2: 44.12 m / 33.29 km/h	R2 / V2: 44.31 m / 33.34 km/h
R3 / V3: 386.98 m / 85.86 km/h	R3 / V3: 390.92 m / 86.30 km/h
R4 / V4: 9.47 m / 19.17 km/h	R4 / V4: 9.64 m / 19.29 km/h
R5 / V5: 14.26 m / 22.16 km/h	R5 / V5: 14.07 m / 22.06 km/h
Deflection: 5.00 m	Deflection: 5.00 m

Gate # 3	TB 1&2
R1 / V1: 26.6 m / 24.95 km/h	R1 / V1: 26.6 m / 24.95 km/h
R2 / V2: 42.27 m / 33.33 km/h	R2 / V2: 44.12 m / 33.29 km/h
R3 / V3: 417.82 m / 89.22 km/h	R3 / V3: 386.98 m / 85.86 km/h
R4 / V4: 9.47 m / 19.17 km/h	R4 / V4: 9.47 m / 19.17 km/h
R5 / V5: 14.37 m / 22.23 km/h	R5 / V5: 14.26 m / 22.16 km/h
Deflection: 5.00 m	Deflection: 5.00 m

2. Speed difference is below 20km/h.
3. A deflection of 5m.
4. Provision of truck apron.
5. Provision of splitter island.
6. Other deficiencies such as pavement markings and signage have also been fulfilled using civil 3d.

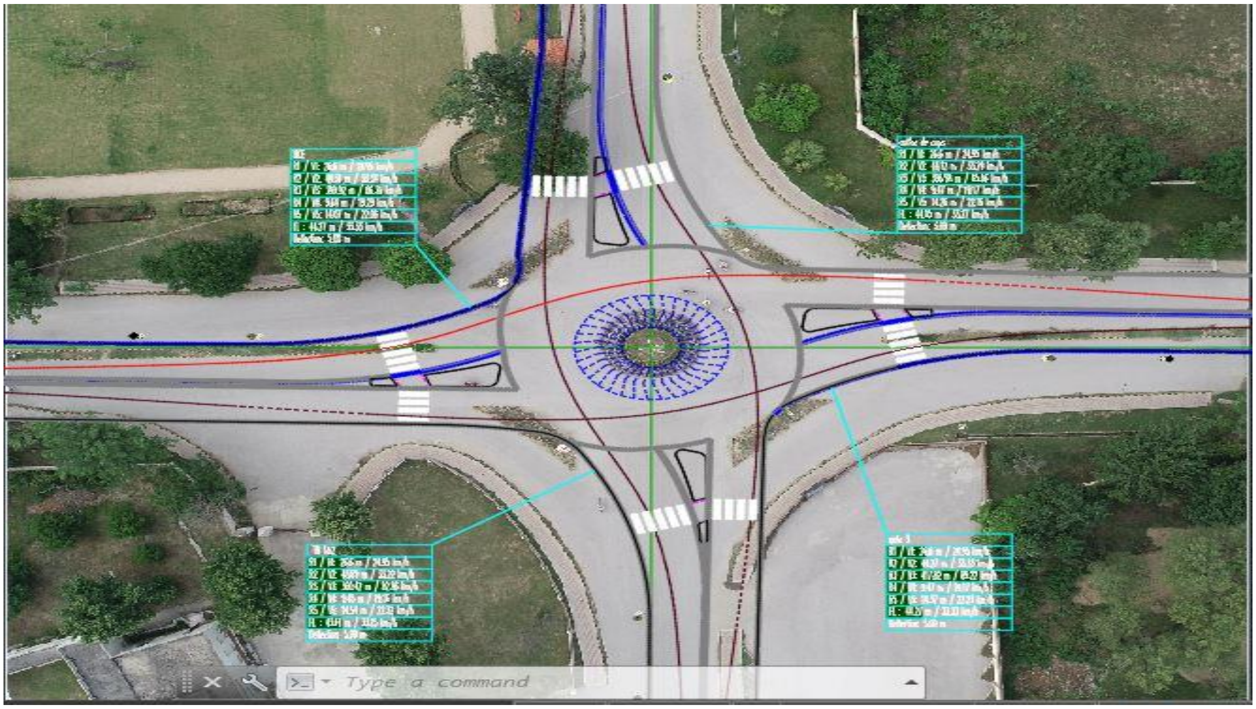

Figure 18 Proposed Design of Mini Roundabout.

4.3.2 Comparison between Existing, Designed and Standard Values

Table 15: Comparison with Standards (Mini Roundabout).

Sr No.	Design Element	Existing Value	Proposed Value	FHWA 2000
1.	Central Island	9	5	3-5
2.	Inscribed Circle	27	25	13-25
3.	Truck Apron	Non-existent	4m width	4m width
4.	Entry Width	4.5	5	Slightly greater than approach width
5.	Circulating Width	9	7	120% of entry width
6.	Crosswalk	Non-existent	7.5m from yield line	7.5m from yield line
7.	Splitter Island	Non-existent	20m in length	20m in length

4.3.3 Signings and Markings

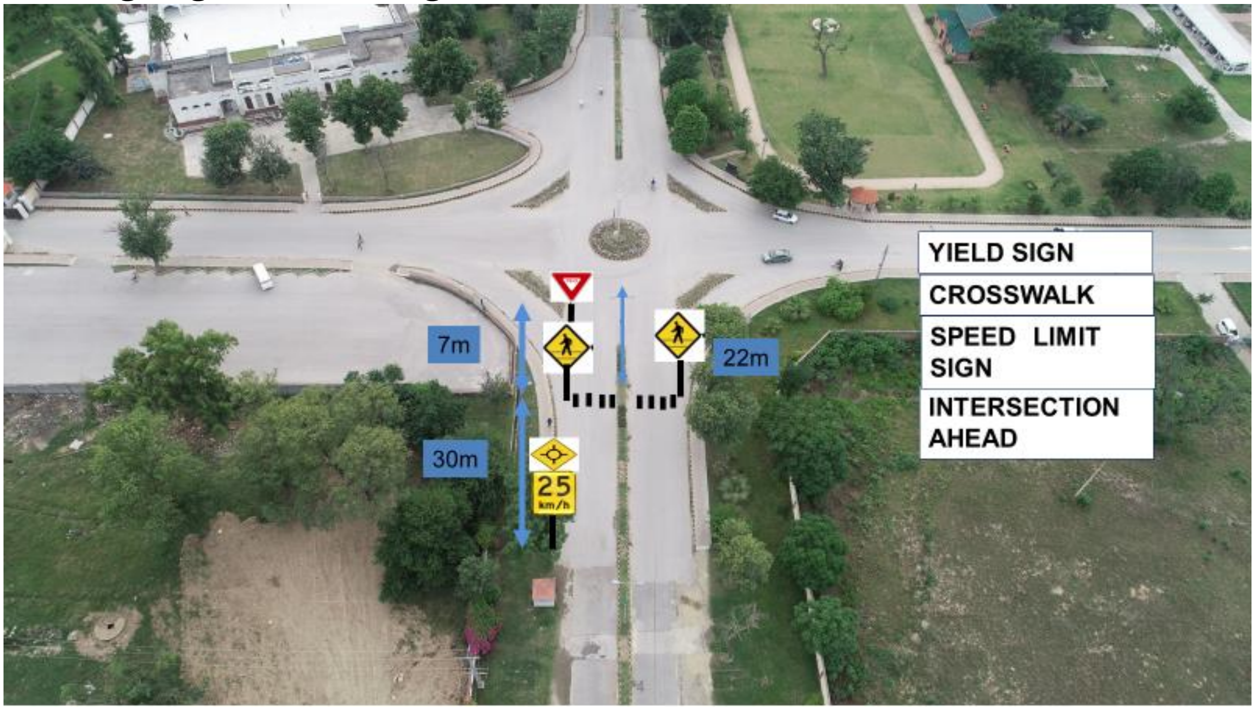

Figure 19 Signage plan for Mini Roundabout.

4.4 North Colony Intersections

4.4.1 Design problems encountered at north colony intersection

- Improper intersection sight distance thus traffic cannot regulate under basic rules of road.
- No cross walk provided
- No signage
- No yield or stop lines as per standards

4.4.1.1 Reasons for these problems

1. Intersection sight distance is limited due to obstructions like trees and buildings.
2. For speed of 40 km/h minimum intersection sight distance should be 152 ft.
3. Intersection sight distance provided on all approaches is less than 152 ft.

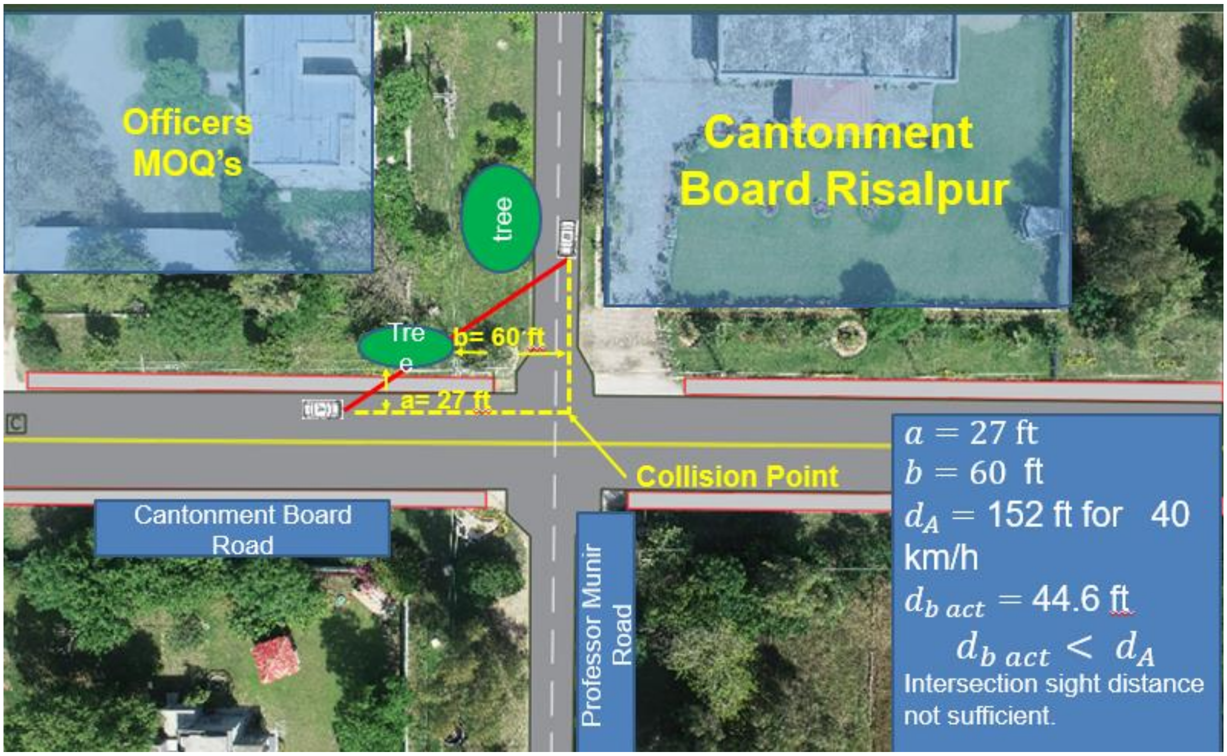

Figure 20 Sight Triangle from East Approach.

Calculations:

$$d_{b\ act} = \frac{a d_A}{d_A - b} = \frac{27*152}{152-60} = 44.6\ ft \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

$$d_{B\ min} = 1.47 S_i t + \frac{{s_i}^2}{30(.548 + .01G)} = 1.47 * 152 * 2.5 + \frac{40^2}{30(.548 + .1 * 0)} = 152\ ft$$

$$d_{b\ act} < d_{B\ min}$$

Road cannot operate under basic rules of road.

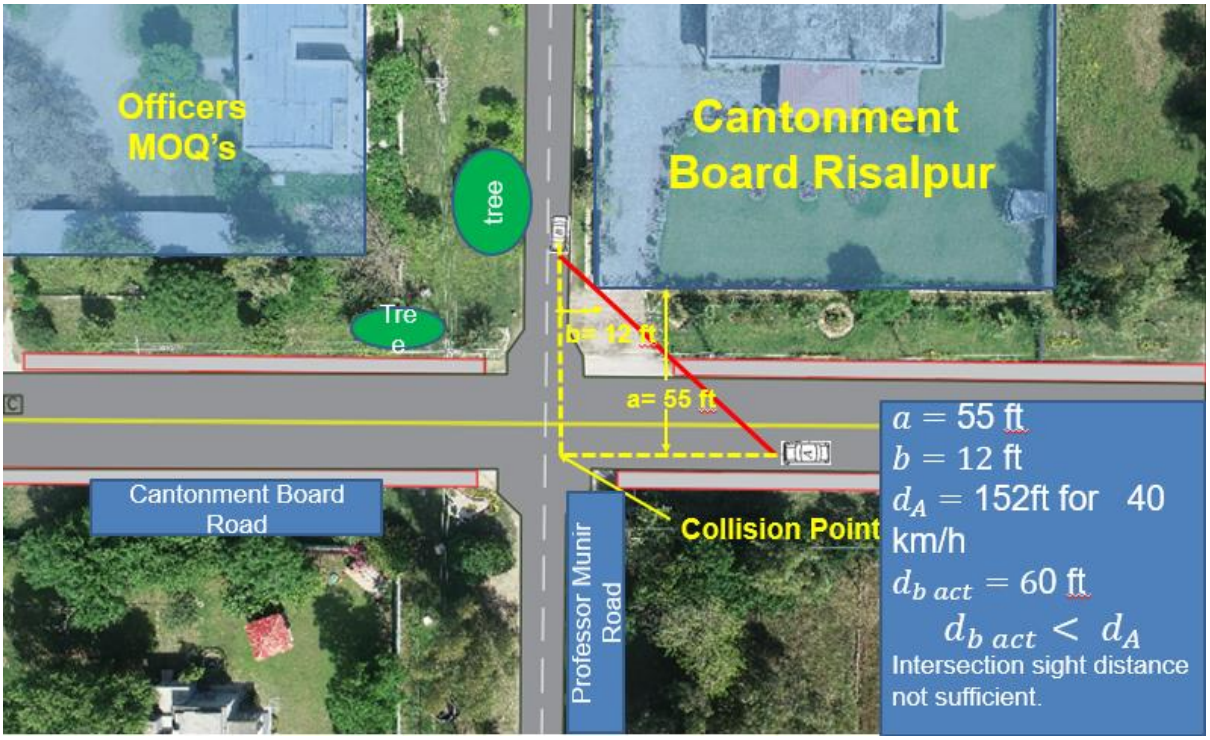

Figure 21 Sight Triangle from East Approach.

Calculations:

$$d_{b\ act} = \frac{a d_A}{d_A - b} = \frac{55*152}{152-12} = 60\ ft \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

$$d_{B\ min} = 1.47 S_i t + \frac{{s_i}^2}{30(.548+.01G)} = 1.47*152*2.5 + \frac{40^2}{30(.548+.1*0} = 152\ ft$$

$$d_{b\ act} < d_{B\ min}$$

Road cannot operate under basic rules of road.

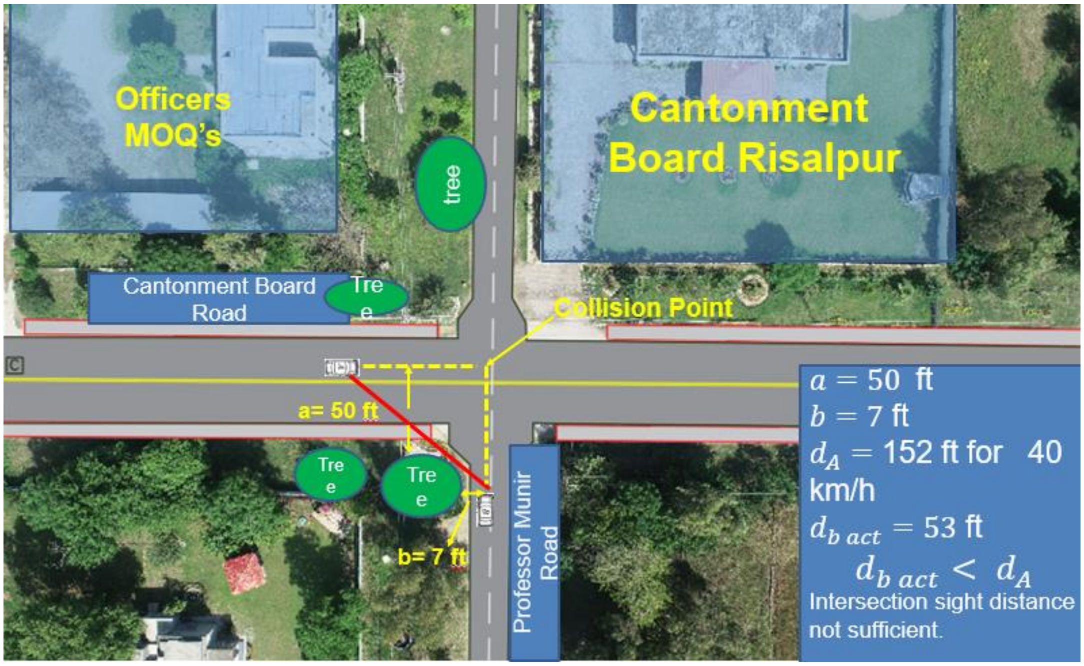

Figure 22 Sight Triangle from West Approach.

Calculations:

$$d_{b\ act} = \frac{ad_A}{d_A - b} = \frac{50*152}{152-7} = 53\ ft \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3)$$

$$d_{B\ min} = 1.47S_i t + \frac{{s_i}^2}{30(.548 + .01G)} = 1.47 * 152 * 2.5 + \frac{40^2}{30(.548 + .1 * 0} = 152\ ft$$

$$d_{b\ act} < d_{B\ min}$$

Road cannot operate under basic rules of road.

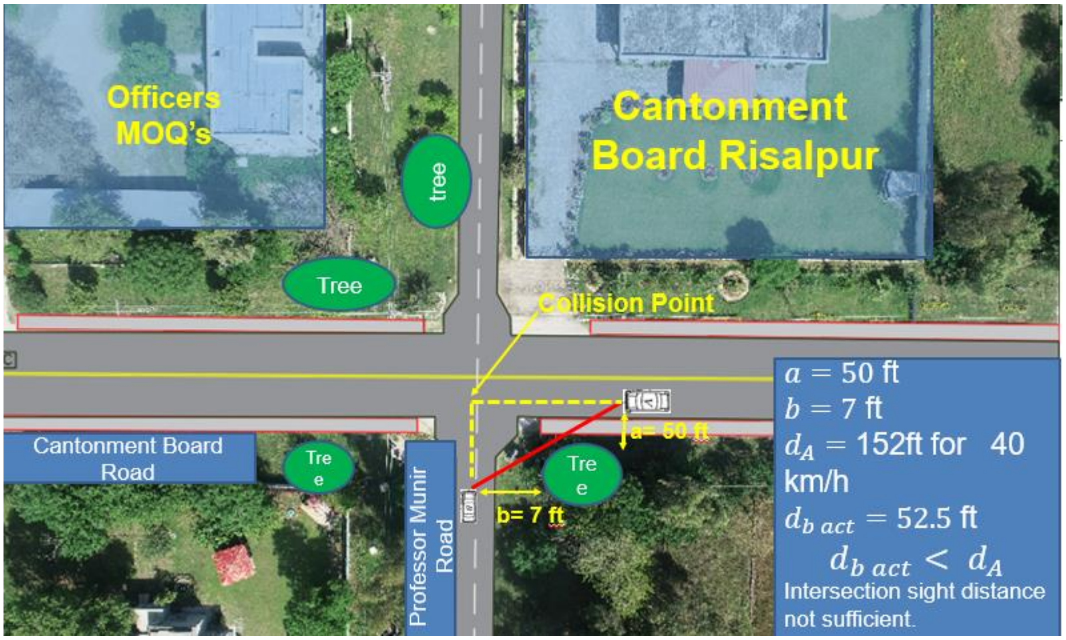

Figure 23 Sight Triangle from West Approach.

Calculations:

$$d_{b\ act} = \frac{ad_A}{d_A - b} = \frac{50*152}{152-12} = 52.5\ ft \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$d_{B\ min} = 1.47S_i t + \frac{{s_i}^2}{30(.548 + .01G)} = 1.47 * 152 * 2.5 + \frac{40^2}{30(.548 + .1 * 0} = 152\ ft$$

$$d_{b\ act} < d_{B\ min}$$

Road cannot operate under basic rules of road.

4.4.2 Signage

As no signs were encountered at north colony intersection and intersection sight distance is not sufficient this brings us at level 2 of intersection control hierarchy by controlling intersections using yield and stop signs.

4.4.3 Necessary Interventions

1. Removal of obstructions to clear up sight distance
2. Provision of crosswalk for pedestrians
3. Provision of yield line/sign at major legs
4. Provision of stop line/sign at minor legs
5. Removal of speed humps from major legs and placing them at minor legs.

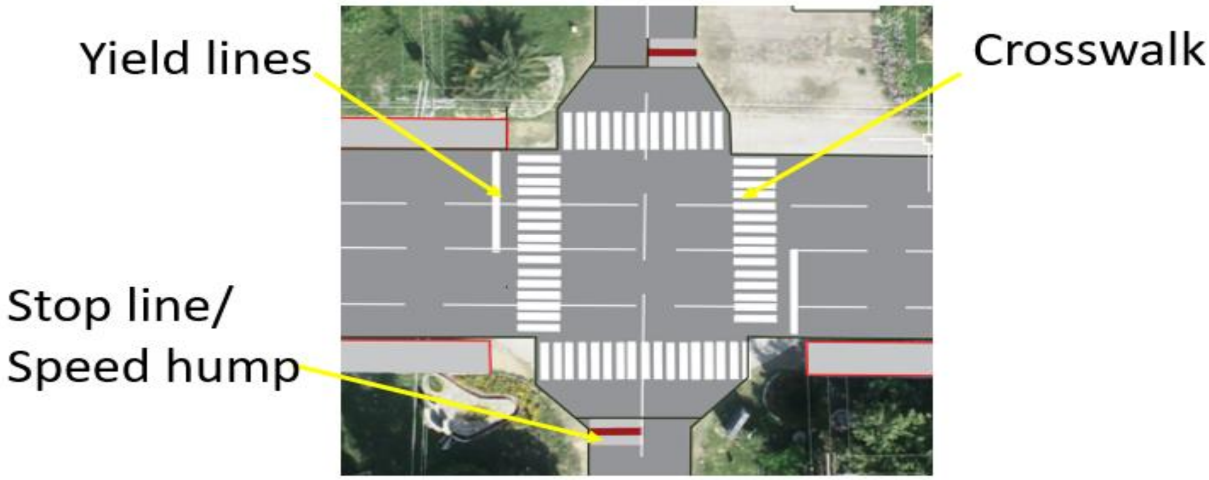

Figure 24 Provision of Intersection Elements on North Colony Intersection.

Figure 25 Provision of Stop Sign/Stop Line At East And West Approach.

Figure 26 Provision Of Yield Signs / Yield Lines On North And South Approach.

4.5 MCE Intersection

4.5.1 Design Problems Encountered At MCE Intersection

- Improper intersection sight distance thus traffic cannot regulate under basic rules of road.
- No cross walk provided
- No signage
- No yield or stop lines as per standards

4.5.1.1 Reasons for these problems

1. Intersection sight distance is limited due to obstructions like trees and buildings.
2. For speed of 30 km/h minimum intersection sight distance should be 102 ft.
3. Intersection sight distance provided on all approaches is less than 102 ft.

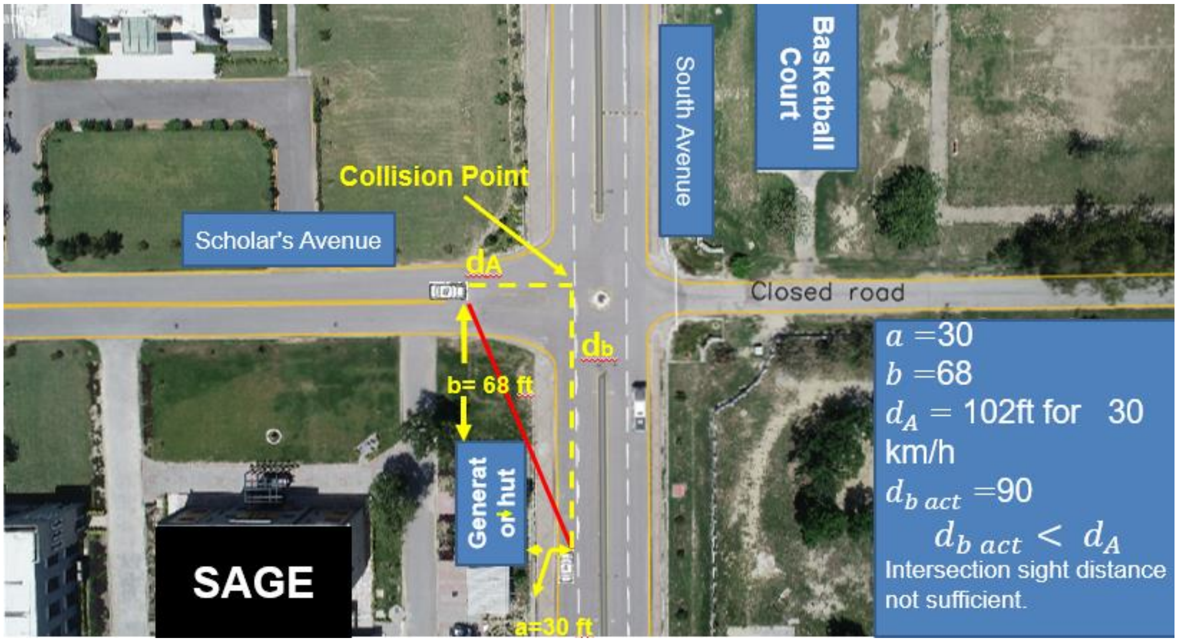

Figure 27 Sight Triangle At MCE Intersection.

Calculations:

$$d_{b\ act} = \frac{ad_A}{d_A - b} = \frac{30*152}{152-68} = 90\ ft \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5)$$

$$d_A = 1.47S_i t + \frac{{s_i}^2}{30(.548 + .01G)} = 1.47 * 18.75 * 2.5 + \frac{18.75^2}{30(.548 + .1 * 0} = 102\ ft$$

$$d_{b\ act} < d_A$$

Road cannot operate under basic rules of road.

4.5.2 Necessary Interventions

- Provision of crosswalk for pedestrians
- Provision of yield line/sign at major legs
- Provision of stop line/sign at minor legs

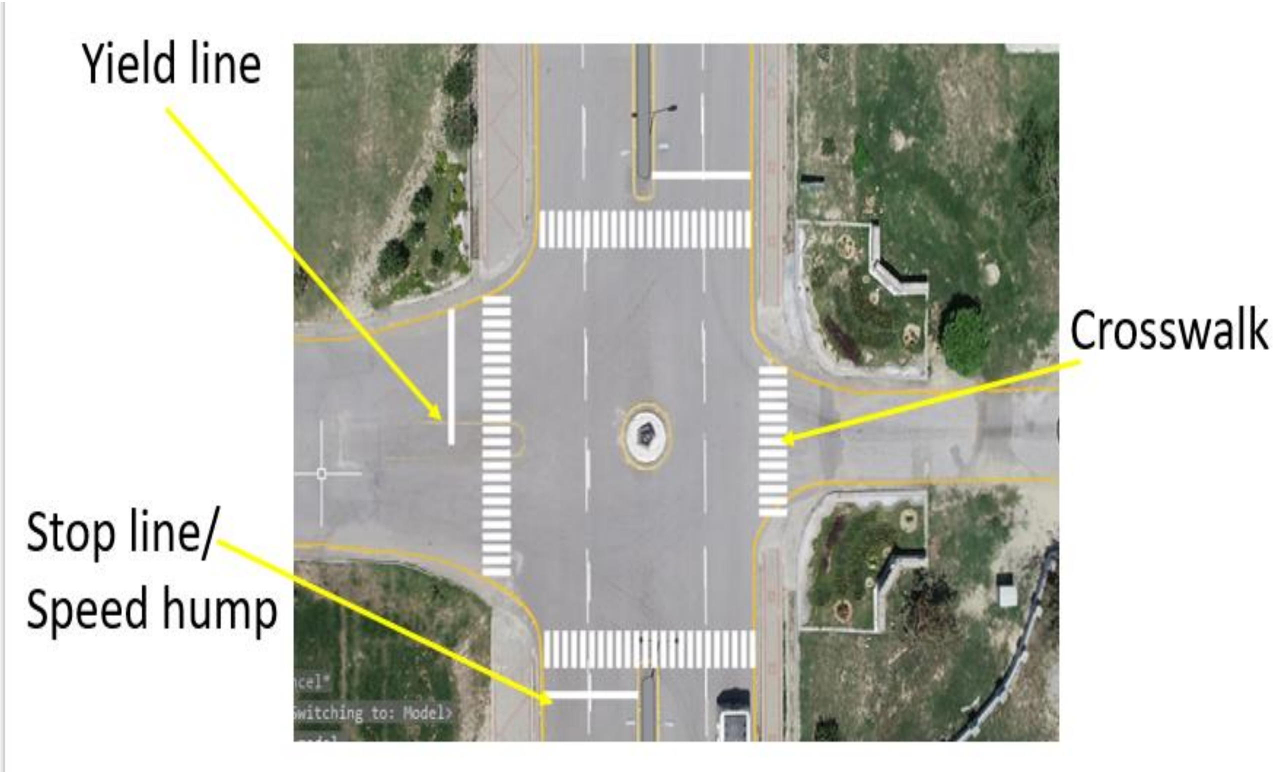

Figure 29 Provision of Intersection Elements at MCE Intersection

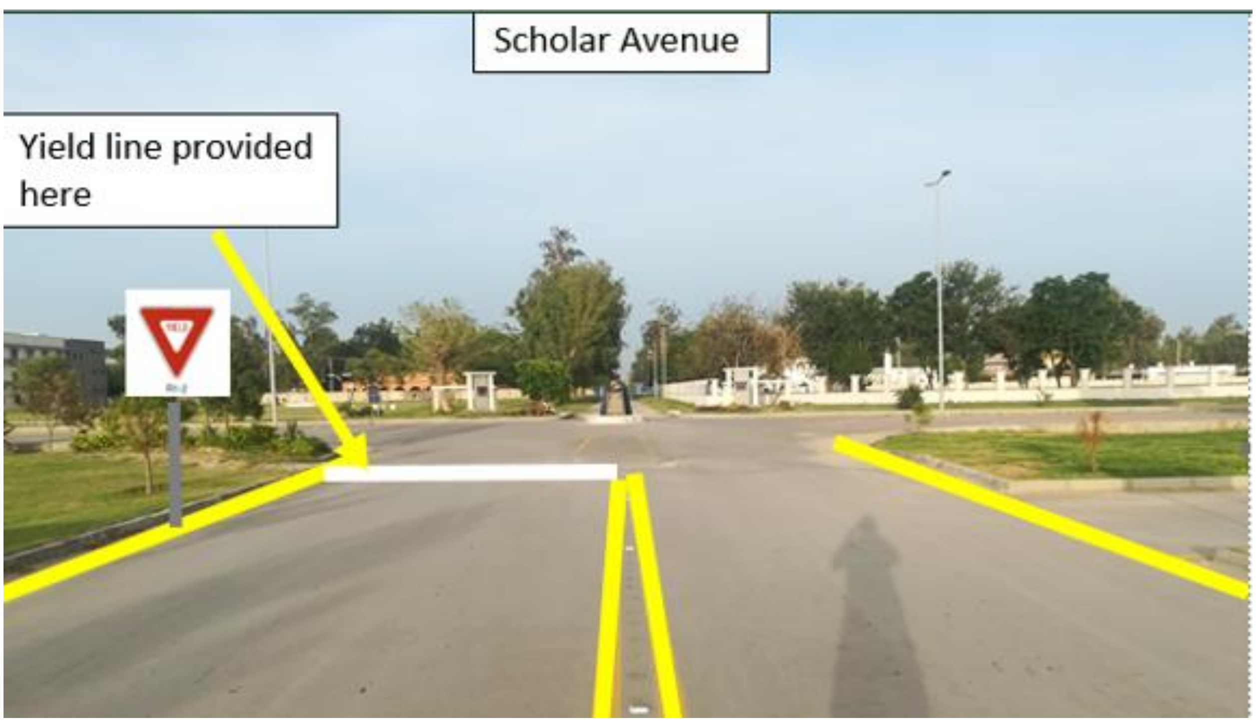

Figure 28 Provision of Yield Line/ Yield Sign On Scholar's Avenue.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Two intersections and two roundabouts were analysed from both geometric and traffic point of view. In analysis of roundabout key features which were analysed are approach widths, entry widths, circulatory roadway widths, splitter islands and central island. Other features such as swept path of design vehicle and speed consistency. When all these features are in confirmation with standards of FHWA 2000 and MUTCD then they are analysed in the VISSIM and Civil 3D software. The Level of Service came out to be A for all links. Geometry of sites had a lot of deficiencies such as in entry speed, central island, design vehicle paths and intersection sight distances. They were rectified using the guidance given in standards with the help of software. This was an iterative process which was aimed at achieving balance between safety and capacity. Finally, this balance was achieved, after making a few changes in geometry, in the form of speed consistency and smooth flow of design vehicle. In analysis of simple intersections, we kept our analysis under Level 1 and Level 2 of intersection control. Which says that intersection sight distance should be satisfied and if not than proper yield and stop signs should be provided. Both the intersections failed in terms of intersection sight distance thus stop bars, stop signs and yield signs and crosswalks were provided according to standards.

5.2 Conclusions

At grade intersections have serious geometric and safety deficiencies. Neither intersection sight distance is enough nor is there appropriate signage provision on our candidate intersections. Roundabouts design need revision and appropriate signage. That candidate roundabouts are not fulfilling the standard design criteria. They are just placed on the locations not designed for those locations. Roundabout is always a better choice than a simple intersection.

5.3 Recommendations

Unsignalized intersections and roundabouts are being implemented all over the world. They have proved to be very efficient intersection control designs. In Pakistan everyday accidents take place due to over speeding and lack of knowledge. Intersection sight distances must be satisfied while making unsignalized intersections. Roundabouts should be preferred on all new intersection sights and old intersections must be replaced by it. Complete road safety audit of Risalpur Cantt covering all streets and intersections. Study of other types of intersections and roundabouts on other facilities to identify deficiencies. Development of national guidelines for geometric design of streets and highways. This study should be used as a basis for future studies on intersections of Risalpur. This study should also be shared with NHA so that high capacity roundabouts can perform efficiently for all types of traffic. Signage and markings should be given importance as they can reduce fatal accidents. Basic rules of road should be taught at intermediate level to young generation. So that our road networks are properly used by our drivers. Laws and regulations must be formulated to ensure that drivers follow the rules.

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