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ORT12A Study on Sight Distance at Urban Uncontrolled Intersections: A Case Study in Bauchi State-Nigeria

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Abstract
The safe operation at intersection or driveways requires adequate sight distance so drivers can enter the roadway safely. Sight distance is the length of roadway visible to the driver.
This study compares standards and current practice on intersection sight distance within Bauchi metropolis for a four-way and 'T' intersections respectively. Primary emphasis being on the traffic operation conditions, drivers' behavior and vehicle operation characteristics that influence the required intersection sight distance.
Keywords: intersection, sight distance, sight triangle, closure.

1.1 Introduction

In the field of road transport, an intersection is a road junction where two or more roads either meet or cross at grade. Such road junction may also be called across road.

Intersections may be classified either as 3-way, 4-way, 5-way, 6-way etc depending on the number of road segments (arms) that come together at the intersection.

4-way intersection is the most common because they usually involve a crossing over of two streets or roads. The crossing streets or roads are perpendicular to each other. However, two roads may cross at a different angle. In a few cases, the junction of two roads segment may be offset from each other when reaching an intersection, even though both ends may be considered the same streets. This study considered a 3-way and 4-way intersections respectively.

The study also considered an uncontrolled intersection, which is a road intersection where no traffic lights, or control signs are used to indicate the right-of-way. Mostly, uncontrolled intersections are unmarked. However, in some locations, motorists may be warned by road signage or warning light.

The intersection sight distance is a major control for the safe operation of roadways. It is of particular concern for access management with numerous drive ways and approach roads that must be safely accommodated. All intersecting driveways and roadways must have adequate intersection sight distance. The three types of sight distance common in roadway design are intersection sight distance, stopping sight distance and passing sight distance. This study focused on sight distance at intersections.

The driver of a vehicle approaching or departing an intersection should have an unobstructed view of the intersection, including any traffic control devices, and sufficient lengths along the intersecting highway to permit the driver to anticipate and avoid potential collisions. Maize and Plazak (2000). These unobstructed views form triangular areas known as sight triangle. A typical intersection is divided into areas between each leg known as quadrants. There may be three quadrants, such as for a 'T' intersection, or four quadrants for a four-legged intersection.

Sight triangles are the specified areas along an intersections approach legs and across the included corners. These areas should be clear of obstructions that might block a driver's view of conflicting vehicles or pedestrians. The two types of sight triangle are: approach sight triangles and departure sight triangles

Approach Sight Triangles

Approach sight triangles provide the driver of a vehicle approaching an intersection an unobstructed view of any conflicting vehicle or pedestrians. These triangular areas should be large enough that drivers can see approaching vehicles and pedestrians in sufficient time to slow or stop and avoid a crash.

Departure Sight Triangles

Departure sight triangles provide sight distance for a stopped driver on a minor roadway to depart from the intersection and enter or cross the major roadway.
Intersection sight distance presents a complex and difficult issue.
It requires a somewhat involved analysis. The best criteria to determine a safe intersection sight distance are not clear. Numerous conditions influence the intersection sight distance, conditions and operations vary on different highways by urban versus rural, speed expectations, and volume levels.
The question to be answered in this study would include:

1. If the coefficient of friction is used to determine the minimum distance to stop before an intersection, should it represent a comfortable or an emergency deceleration rate? Should they be

the same as far as the design stopping sight distance?
2. What height of eye should be used? Likely, this will not significantly change from AASHTO's current standard of 1.07m (3.5 ft)
3. The 1990/1994 height of object, according to AASHTO criteria is 1300mm (4.25 ft). This is assumed to be the top of a car. The question is, how much of the approaching car does a driver need to see to judge the speed and closure rate?
4. If the 1990/1994 AASHTO Green Book method is used , a perception reaction time of 2 seconds for the entering driver is assumed for both left turns and right turns. Should the perception reaction time change for various classes of facilities, speeds, volume levels and urban versus rural?
5. Should the same intersection sight distance criteria be used for all roadways, regardless of speed, volume, class of facility? Do the safeties "rises" and effect on traffic, such as platoon flow, differs for certain conditions?
6. Should sight distance for trucks be considered, if so, how, where, when and why?
7. Should the perception reaction times for intersection sight distance criteria be modified at complex locations?
8. Should perception reaction time for elderly drivers be considered in the criteria?
9. Should the "human factors" limit for drivers to see and judge vehicle speed and rate of closure be used to set the intersection sight distance criteria?
10. Is an intersection sight distance based on minimum required gap, i.e. the 2001/2004 Green Book criteria adequate for high volume high speed criteria's?

1.2 Problem

Among the several consequences of inadequate sight distance at uncontrolled intersections include:

1. Change in perception reaction time for various classes of facilities speeds, volume levels and urban versus rural.
2. Emergency deceleration.
3. Wrong judgment of speed and closure rate.
4. Traffic conflict.

There is no research that adequately quantifies the effectiveness of improving sight distance at unsignalized intersections. A group of safety experts reviewed the literature and estimated that if the available sight distance in any Quadrant of an intersection is less than or equal to the design sight distance for a speed of 20km/h less than the actual 85^{th}- percentile speed of the approach, then the frequency of related crashes at the intersection would be increased by 5% (Harwood et al. 2000).

AASHTO, Green Book observed that, to determine whether an object is a sight obstruction, consider both the horizontal and vertical alignment of both roadways, as well as the height and position of the object.
The primary, changes in intersection sight distance arose from changes in vehicle acceleration characteristics.

Height of Eye

The 1990/1994 standard for height of eye was 1080mm (3.5 ft). The 2001/2004 height of eye for the 2001/2004 Green Book policy is retained at 1080mm (3.5ft). The height of eye for design for trucks has been increased to 2330mm (7.6ft).

Height of Object

The 1990/1994 standard for height of object was 1300mm (4.25 ft) for intersection sight distance.
The new height of object for the 2001/2004 Green Book is 1080mm (3.5 ft) for automobile and 2330mm (7.6 ft) for trucks.

2.0 Materials and Methods

Bauchi metropolis, a city in northeast Nigeria, the capital of Bauchi state, located on the northern edge of the Jos Plateau, at an elevation of 616 m, coordinates: 10°18′57″N 09°50′39″E, with a population of 316,173 (2004). Bauchi town covers an area of 3,687 km^2 and had a population of 493,810 at the time of the 2006 census, was selected for the study, owning to the underlying factors:

a) The city is crossed with several road networks
b) At grade intersections with uniform carriage way width
c) Approach roads to the intersection with two lanes
d) Traffic movement not influenced by bus stop, hawkers and crossing pedestrians
e) Freedom from signs or signalized traffic control

The 'New Government Restricted Area and Old GRA' within the metropolis were the two locations selected having three (3) cross- intersections and five (10) T- intersections combined.
Four key steps were employed for this study.

1. Determine the minimum recommended sight distance.
2. Obtain or construct sighting and targets rods.

3. Measure current sight distances and record observations.
4. Perform sight distance analysis.

Determine the Minimum Recommended Sight Distance
The minimum sight distance for the posted or operating speed at the intersecting roadway is determined from table 1.

Construct Sighting and Target Rods
The target rod is constructed out of a 2- inch by 0.75 inch wood. The target rod is 1080mm tall do represent the vehicle height and is painted fluorescent orange on both the top portion and bottom 540mm of the rod.

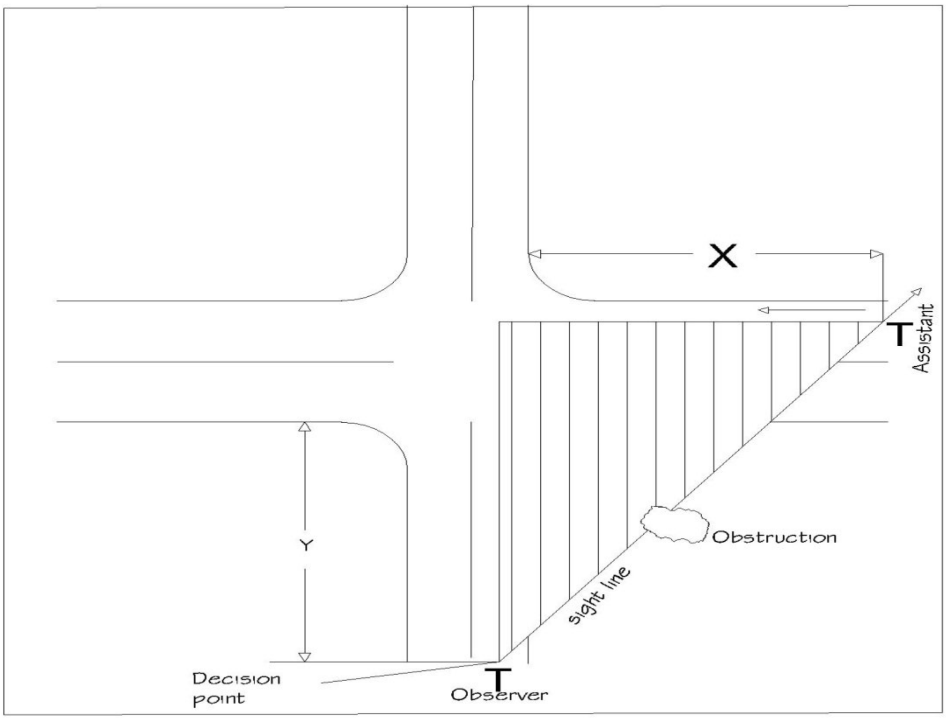
The bottom 540mm portions represent the object height for measuring stopping sight distance. The sighting rod is also 1080mm tall according to the 2001/2004 AASHTO Green Book to represent the drivers' eye height. The sighting rod is constructed out of the same material as the target rods are used in measuring sight distances.

Measure Sight Distance and Record Observations.
Sight distance measurement was gathered for all legs of the uncontrolled intersections. Traffic approaching from both the left and right were considered for measurements on the sight distance intersection diagram. The date and time, posted or operating speed, sight location and whether conditions were recorded.

The observer holds the sighting rod, and the assistant holds the target rod. They position themselves on two intersecting approaches at the appropriate stopping sight distances taken from Table 1. These are the X and Y dimensions. The observer represents the approaching vehicle and is located at the decision point. The observer uses the 1080mm sighting rod, which represents the drivers' eye height. The assistant represents the intersecting vehicle. The assistant uses the 1080mm target rod, which represents the height of the approaching vehicle. The observer sights from the top of the sighting rod to the target rod.

If the target rod is visible, the assistant holding the target rod walks toward the intersection along the center line of the intersecting lane until the observer can see the target rod. When the target rod is visible, the position is marked and the distance to the intersection is measured along the centerline of the roadway. This is the X dimension.

Figure 1. Sight distance measurement at uncontrolled intersection.



Sight Distance measurement at uncontrolled Intersection

Vehicle Position for Sighting

The vehicle is assumed to be positioned 3.0m (10 ft) behind the extension of the pavement edges or curb lines, according to the Green Book. This places the drivers' eye about 4.5-6.0m (15-20 ft) from the pavement edge, or curb lines extended.

Perform Sight Distance Analysis

The analysis of intersection sight distance consisted of comparing the recommended sight distance to the measured sight distance. The measured sight distance should be equal to or greater than the recommended stopping sight distance. If the measured sight distance is less than the recommended sight distance, some remedial measures may be required.

Vehicles Adjust Speeds

The uncontrolled intersection sight distance requires that drivers approaching an uncontrolled intersection on a cross street must have sufficient sight distance across the intersection corners to:

I. At least be able to adjust speeds to avoid a collision
II. Desirably, be able to stop.

The case for vehicles to adjust speed provides 2 seconds of perception- reaction time plus one second for breaking, accelerating or maneuvering. The distances travelled by the vehicles approaching the intersection in 3 second generate the sight triangle shown in figures 3.

The distance the vehicle travels on approach is defined by:

$$\frac{db}{da} = \frac{a}{da-b}$$

$$db = \frac{(a)(da)}{da-b}$$

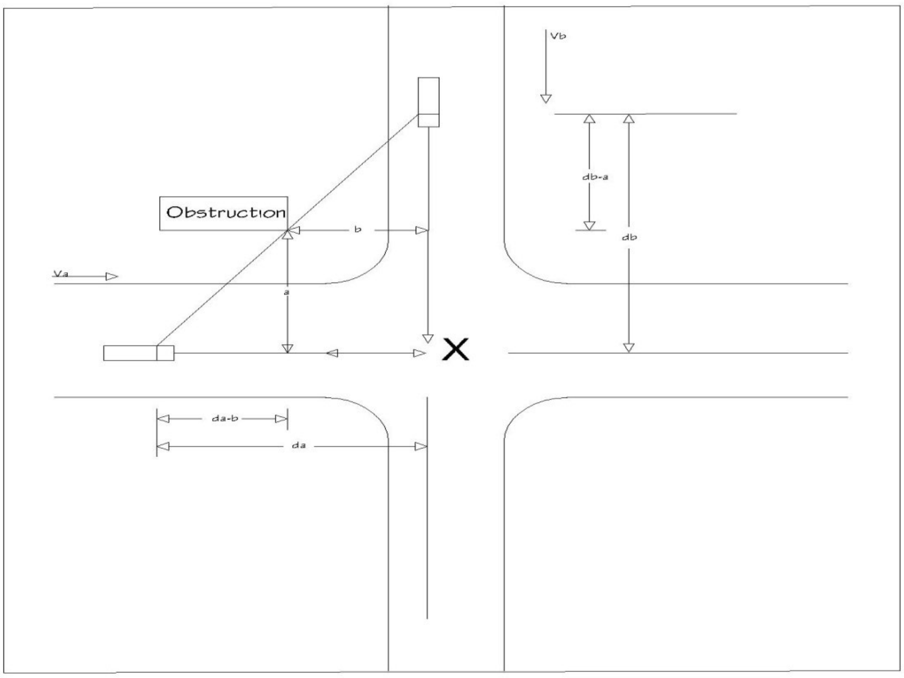
$$da = \frac{(b)(db)}{db-a}$$

Where:

da and db = distance travelled at speed to perceive and react, and brake, accelerate or maneuver

a and b = distance from vehicle path to obstruction

Figure 2 – Sight distance at intersections



Sight Distance at Intersections. No stop control - Enabling vehicles to adjust speed

The next instance under this, allows the vehicle on either or both approaches to stop before reaching the point of impact. Thus, the stopping distance for the critical approach speeds are calculated from the stopping sight distance equation:

$d_b = 0.278vt + \frac{v2}{254f}$ ' f is taken as 0.53

db = 0.278vt + 0.0074 $v2$

The formula is used to determine the slopping sight distance for the 'T' intersections.

From table 3, average speed = 37.51km/h

Since db = 0.278vt + 0.0074 $v2$

Db = safe stopping distance + 5m

t from table 4 = 0.855 (by interpolating)

db = + $0.0074v^2$ + 0.278 vbt + 5

5 = clearance distance.

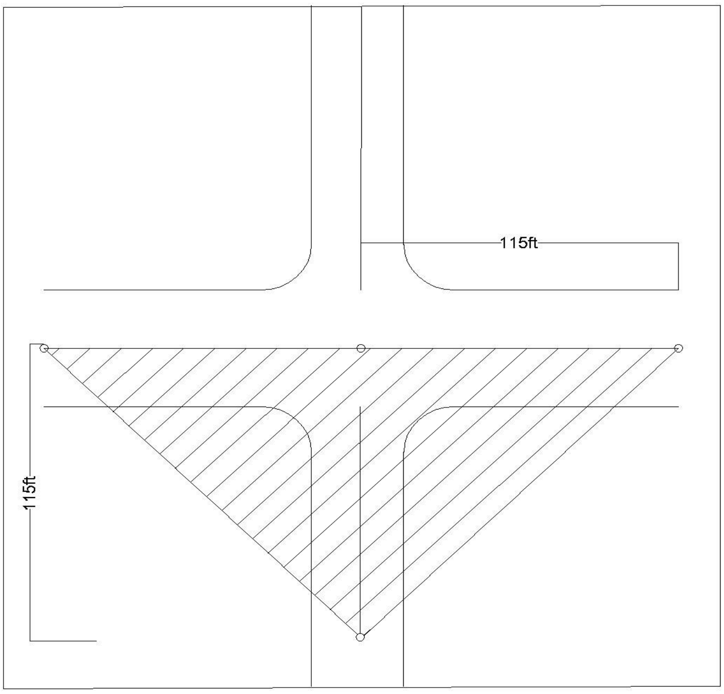
$d_b = [0.0074(37.51)^2 + 0.278(37.51 * 0.855)] + 5$

$d_b = 10.41+8.94 + 5$

$d_b = 24.33m = 25m$

This stopping sight distance is used for the uncontrolled 'T' intersection sight distance measurement.

Figure 3, Sight distance Triangle.



Sight Distance Triangle
(Uncontrolled 4-way Intersection)

3.0 Discussion of Analysis

Table 4, presents from the analysis, the required and measured sight distance for the four legs of the 4- way uncontrolled intersections while, ***table 5*** presents the sight distance of both the required and measured right-turn and left-turn maneuver for the uncontrolled T-intersections.

The bar chart in figure 4 and 5 presents the 3 four-way and 10 "T" uncontrolled intersections measured summarizes the analysis of data presented.

From figure 4, *(the red horizontal line on the bar chart represents the minimum recommended sight distance for the four-way intersection*). For intersection 1, only the south approach satisfied the minimum recommended sight distance.

For the second 4-way intersection, none of the four legs of the quadrant satisfied the minimum recommended sight distance. While for the final third uncontrolled 4-way intersection, only the south approach sight distance measured satisfied the minimum recommended sight distance and was measured to be 48.6m which is sufficient.

From figure 5, for the uncontrolled T-intersections, (red horizontal line on the bar chart represents the minimum recommended sight distance for left-turn maneuver, while the green horizontal line on the bar chart represents the minimum recommended sight distance for right-turn maneuver).

It was observed that out of the 10-intersections measured, intersection 1,2,3,4,5,6,7,8 and 10 failed to satisfy the minimum recommended sight distance for both left and right-turn maneuver. But intersection 9, satisfied the minimum recommended sight distance for both left and right turn maneuver.

4.0 Conclusion

Based on the study conducted, of the thirty-two (32) legs of the quadrants investigated, only 4 legs (12.5%) satisfied the minimum recommended sight distance which is unsatisfactory.

5.0 Recommendations

Owing to the unsatisfactory results (sight distance measured) obtained, the following recommendations are proffered;

Relevant authorities are adequately informed on such intersections with inadequate sight distances to:

a) Remove the obstructions.
b) Modify/lower the height of obstructions.
c) Reduce traffic speeds.
d) Install traffic control devices.

This study was conducted by **(Shimfe Mamshong)**. I hold a B.Engr degree in civil engineering from Abubakar Tafawa Balewa University, Bauchi, Nigeria. I currently work as a Project Engineer with the Taraba State Road Construction and Maintenance Agency (TARCMA), Jalingo, Nigeria. I am responsible for: Planning, design, organising and coordinating plant, site facilities and the activities of the construction team, ensuring the execution of projects in accordance with the contract document.

LIST OF TABLES AND FIGURES

Table 1. Minimum Recommended sight Distance

Design Speed		Sight Distance	
Km/h	Mph	M	ft
20	15	20	70
30	20	25	90
40	25	35	115
50	30	45	140
60	35	55	165
70	40	65	195
80	45	75	220
90	50	90	245
100	55	105	285
110	60	120	325
120	65	135	365

Table 2. Minimum Recommended sight Distance based on vehicle maneuver

Vehicle Speed Km/h	Stopping Sight Distance Left-Turn maneuver (m)	Stopping Sight Distance for Crossing & Right-Turn maneuver (m)
20	52	44
30	75	59
40	85	73
50	102	88
60	119	102
70	136	117
80	152	131
90	169	146
100	186	162

Table 3, Determination for average speed for the 10 'T' intersections

'T' Intersection	Vehicle	Distance Traveled (m)	Time (s)	Average Time (s)	Speed (V=d/t) m/s	Speed (km/h)
1	1	142.8	13.56	13.32	10.32	38.59
	2		12.92			
	3		14.08			
2	1	142.8	13.70	14.43	9.89	35.62
	2		15.66			
	3		14.00			
3	1	142.8	12.33	12.93	11.04	39.75
	2		12.46			
	3		14.01			
4	1	142.8	13.21	13.44	10.63	38.25
	2		14.30			
	3		13.11			
5	1	142.8	15.60	15.02	9.51	34.23
	2		14.91			
	3		14.55			
6	1	142.8	13.13	13.27	10.76	38.74
	2		11.55			
	3		12.13			
7	1	142.8	16.70	14.20	10.06	36.20
	2		11.30			
	3		14.60			
8	1	142.8	15.11	12.79	11.16	40.19
	2		12.01			
	3		11.25			
9	1	142.8	13.33	13.75	10.36	37.38
	2		12.59			
	3		15.33			
10	1	142.8	14.40	14.22	10.04	36.15
	2		13.19			
	3		15.09			
			AVR	13.74	**AVR**	37.51

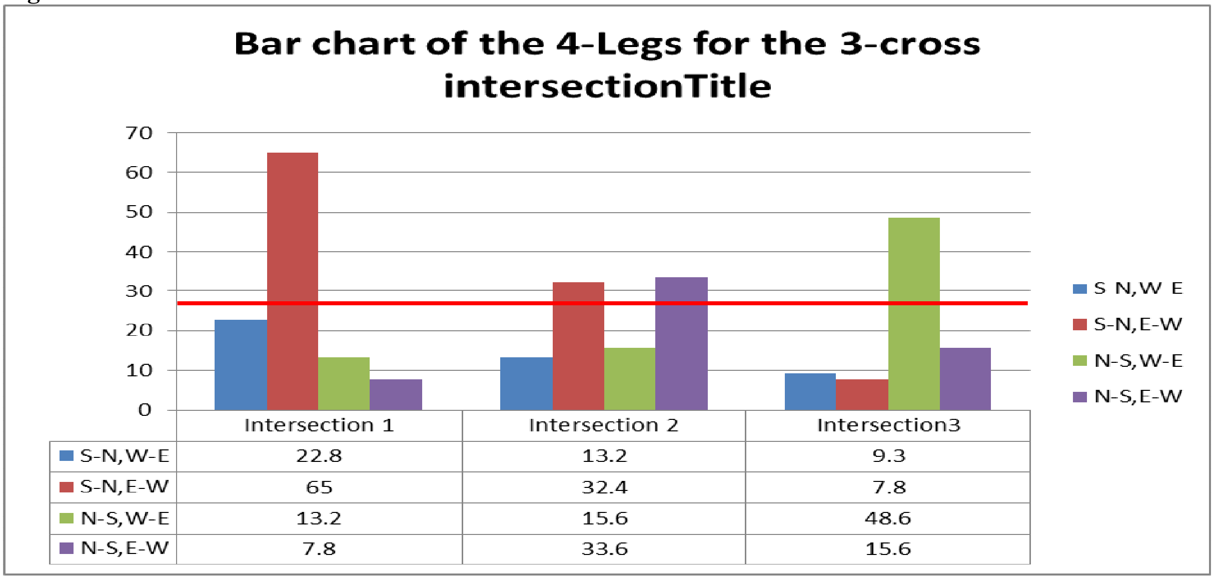
Table 4. Required and Measured sight distance for the 4-legs of 4-way uncontrolled intersection

APPROACH	REQUIRED SIGHT DISTANCE (m)	MEASURED SIGHT DISTANCE		
		1	2	3
S-N, W-E	35	22.8	13.2	9.3
S-N, E-W	35	100.0	32.4	7.8
N-S, W-E	35	13.2	33.6	48.6
N-S, E-W	35	7.8	15.6	15.6

Table 5. Sight distance for Right-Turn and Left-Turn maneuver for 'T' uncontrolled intersection

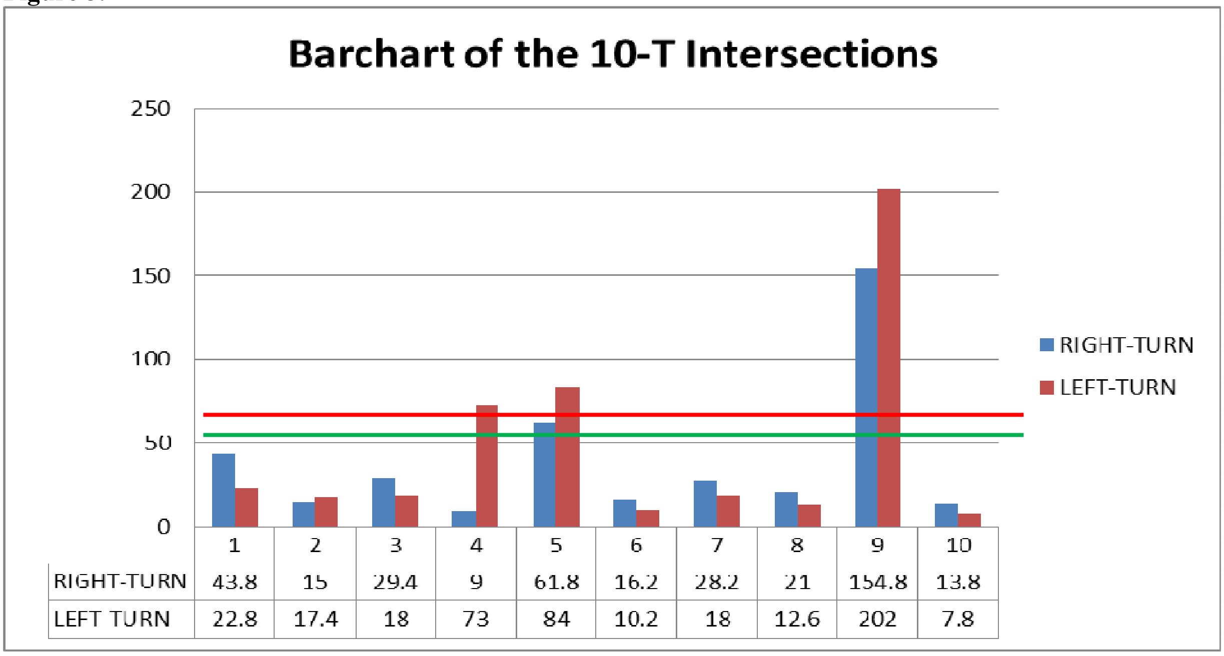
MANEUVER	REQUIRED SIGHT DISTANCE (M)	MEASURED SIGHT DISTANCE (M)									
		1	2	3	4	5	6	7	8	9	10
RIGHT-TURN	73.0	43.8	15.0	29.4	9.0	61.8	16.2	28.2	21.0	154.8	13.8
LEFT-TURN	85.0	22.8	17.4	18.0	73.0	84.0	10.2	18.0	180.8	180.8	7.8

Figure 4.



	Intersection 1	Intersection 2	Intersection3
S-N,W-E	22.8	13.2	9.3
S-N,E-W	65	32.4	7.8
N-S,W-E	13.2	15.6	48.6
N-S,E-W	7.8	33.6	15.6

Figure 5.



	1	2	3	4	5	6	7	8	9	10
RIGHT-TURN	43.8	15	29.4	9	61.8	16.2	28.2	21	154.8	13.8
LEFT TURN	22.8	17.4	18	73	84	10.2	18	12.6	202	7.8

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