

## Operational Evaluation of Road 2 – Road 6 Intersection at Obafemi Awolowo University, Ile – Ife, Osun State, Nigeria.

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### Abstract

Over the recent years traffic at the Road 2 – Road 5 intersection has been observed to be high at peak hours. This situation sometimes becomes frustrating as a result of long queues. Accidents have even occurred in some instances. The need to proffer solution to this problem, therefore becomes imperative, hence this study. The geometric characteristics and the traffic and the signalized conditions of the intersection were determined using standard procedures. The intersection geometrics show that, there are two lanes on all approaches, with an average width of 3.65 m. The terrain is level and there is no storage bay. Raised islands are provided to separate the traffic streams. There are no lane and pedestrian markings. The saturation flows (s), for the East Bound (EB), West Bound (WB), North Bound (NB) and South Bound (SB) traffic, were, 2306, 1948, 1561 and 1569 veh. / h respectively, while the critical v/c ratio value for the intersection was, 0.54. The uniform delay,  $d_1$ , for EB and WB, and NB and SB, were 10 and 26 sec. / veh. respectively; while the values for their incremental delays,  $d_2$ , were, 0.44, 0.56, 0.41 and 0.47 sec. / veh. respectively. The average intersection delay is, 13 sec / veh., which put the level of service (LOS), at B. It can therefore be concluded that, there is a slight delay at the intersection, which could probably be attributed to the inadequate geometrics of the intersection. A new geometric configuration was therefore proposed to eliminate this delay.

**Keywords:** Intersection, Geometrics, Saturation Flow, Critical v/c Ratio, Average delay and Level of Service (LOS).

### 1. Introduction

An intersection is an area shared by two or more roads, whose main function is to provide for the change of route directions. Intersections vary in complexity from a simple intersection: which may have only two roads crossing at a right angle to each other, to a more complex intersection at which three or more roads cross within the same area. Drivers, therefore have to make a decision at an intersection concerning which of the alternative routes they wish to take. This effort which is not required at non-intersection areas of the road, is the part of the reason why intersections tend to have a high potential for crashes (Garber and Hoel, 2010)

An intersection is an important part of a road because, to a good extent, the efficiency, safety, speed, cost of operation and capacity depends on its design (Oguara, 2006).

Intersection channelization is used mainly to separate turn lanes from through lanes. A channelized intersection consists of solid white lines or raised barriers which guide traffic within a lane so that vehicles can safely negotiate a complex intersection. When raised islands are used, they can also provide a refuge for pedestrians. One of the most effective ways of controlling traffic at an intersection is the use of traffic signals. Traffic signals can be used to eliminate many conflicts because different traffic streams can be assigned the use of the intersection at different times. Since these results in a delay to vehicles in all streams, it is important that traffic signals be used only when necessary. The most important factor that determines the need for traffic signals at a particular intersection is the intersection's approach traffic volume (Garber and Hoel, 2010).

The operation of an intersection is influenced by its geometric layout and the type of traffic control which affects its accident potential and capacity. Queue lengths and delays at an intersection are a function of the inadequate capacity at an intersection, volume of traffic and vehicle operating characteristics (FMT, 2007). In developing an intersection design AASHTO recommends the consideration of the following elements – traffic consideration, physical elements, economic factors and functional intersection area. One of the most critical aspects of intersection design is the determination of the number of lanes needed on each approach. Furthermore, considerations of capacity, safety, and efficiency, all influence the desirable number of lanes (Roess *et al.*, 2004). According to Federal Ministry of Transportation (Woks), 2007, the design of an at grade intersection is based on traffic volume and turning movements, the time and duration of peak traffic volumes, traffic distribution and composition of vehicular traffic during peak hours. Design is further influenced by the extent of control required as determined by factors such as vehicle speeds, design capacities, pedestrian movements and accidents data. It added that, an intersection is considered to be safe when it is perceptible, comprehensible and manoeuvrable..

Signal timing at an intersection, reduces the average delay of all vehicles and the probability of crashes; which are achieved by minimizing the possible conflict points when assigning the right of way to different traffic streams at different times. Consequently, delay is an important measure of effectiveness to use in the evaluation of a signalized intersection (Garber and Hoel, 2010). For signalized intersection, capacity and level of service are

analyzed separately, and unlike other types of facilities, the two are not related to each other. It is however necessary that both capacity and level of service be fully considered in the evaluation of the overall operation of a signalized intersection. Capacity is based on the concept of saturation flow rates. Saturation flow rate is the maximum rate of flow that can pass through a given intersection approach or lane group under prevailing traffic and roadway conditions, assuming that the green phase was always available to the approach. The flow ratio for a given approach or lane group is defined as the ratio of the actual flow rate to the saturation flow rate (Ogura, 2006). Level of service may be based on such things as travel times (or speed), total delay, probability of delay, comfort, and safety amongst others (Banks, 2004).

The tasks involved in an operational analysis of an intersection include; identifying and recording the geometric characteristics, identifying the traffic and signalized conditions, lane grouping and demand flow rate, saturation flow rate, capacity analysis ( $v/c$ ), and performance measures (Garber and Hoel, 2010).

The input data for an intersection analysis is as shown on Table 1.

Level of service criteria for signalized intersection is shown in Table 2.

Over the recent years traffic at this intersection has been observed to be horrendous at peak hours. This situation sometimes becomes frustrating as a result of long queues. Accidents have even occurred in some instances. The need to proffer solution to this problem, therefore becomes imperative, hence this study.

## 2. Materials and Methods

The intersection studied is the road 2- road 6 junctions at Obafemi Awolowo University, Ile – Ife, Osun State of Nigeria. Figure 1 shows Osun State, Nigeria, while Plate 1 shows the intersection location.

The geometric characteristics and the traffic and the signalized conditions of the intersection were determined using standard procedures.

The following parameters were thereafter determined using appropriate equations (Highway Capacity Manual, 2000):

$$(i) \quad v = V/PHF \quad \text{Equation 1}$$

Where,  $v$  = demand flow rate (veh./h),  $V$  = demand volume (veh./h) and  $PHF$  = peak-hour factor

$$(ii) \quad s = S_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{RT} f_{LT} f_{Rpb} f_{Lpb} \quad \text{Equation 2}$$

Where:

$S$  = saturation flow rate (veh./h)

$S_o$  = base saturation flow rate per lane (pc/h/ln)

$N$  = number lanes in lane group

$f_w$  = adjustment factor for lane group

$f_{HV}$  = adjustment factor for heavy vehicles in the stream

$f_g$  = adjustment factor for approach grade

$f_p$  = adjustment factor for existence of parking lane and parking activity adjacent to lane group

$f_{bb}$  = adjustment factor for blocking effect of local buses that stop within intersection area

$f_a$  = adjustment factor for area type

$f_{LU}$  = adjustment factor for lane utilization

$f_{RT}$  = adjustment factor for right turns in lane group

$f_{LT}$  = adjustment factor for left turns in lane group

$f_{Rpb}$  = pedestrian – bicycle adjustment factor right-turn movement

$f_{Lpb}$  = pedestrian – bicycle adjustment factor left-turn movement

$$(iii) \quad c = s_i g_i / C \quad \text{Equation 3}$$

where

$c_i$  = capacity of lane group  $i$  (veh./h)

$s_i$  = saturation flow rate

$g_i$  = effective green ratio for lane group

$C$  = cycle length (s)

$$(iv) \quad X_i = v_i C / s_i g_i \quad \text{Equation 4}$$

where

$X_i = (v/c)_i$  = ratio for lane group  $i$

$v_i$  = actual or projected demand flow rate for lane group (veh./h)

$s_i$  = saturation flow rate for lane group (veh./h)

$g_i$  = effective green time for lane group (veh./h)  
 $C$  = cycle length (s)

$$(v) \quad X_c = \sum \left( \frac{v_i}{c} \right) c t_i \left( \frac{c}{c-L} \right) \quad \text{Equation 5}$$

where

$X_c$  = critical v/c ratio for intersection

$\sum \left( \frac{v_i}{c} \right) c t_i$  = summation of flow ratios for all critical lane groups  $i$

$C$  = cycle length (s)

$L$  = total lost time per circle, computed as lost time,  $t_l$  for critical path of movement

$$(v) \quad d = d_1(PF) + d_2 + d_3 \quad \text{Equation 6}$$

where

$d$  = control delay per vehicle (s/veh.)

$d_1$  = uniform control delay assuming uniform arrivals (s/veh)

PF = uniform delay progression adjustment factor, which accounts for effects of signal progression

$d_2$  = incremental delay to account for effect of random arrivals and oversaturation queues, adjusted for duration of analysis period and type of signal control.

$d_3$  = initial queue delay

Assumptions: arrival time type – AT 3, PF = 1

No initial queue,  $d_3 = 0$

Therefore,

$$d = d_1 + d_2 \quad \text{Equation 7}$$

where:

$$d_1 = \frac{0.5C(1 - \frac{X_c}{c})^2}{1 - \left[ \frac{\min(1, X_c/c)}{c} \right]} \quad \text{Equation 8}$$

$$d_2 = 900T [(X-1) + \sqrt{(X-1)^2 + 8KIX/cT}] \quad \text{Equation 9}$$

take  $K = 0.5$  and  $I = 1$

$$d_A = \frac{\sum d_i v_i}{\sum v_i} \quad \text{Equation 10}$$

where

$d_A$  = delay for approach A (s/veh.)

$d_i$  = delay for lane group  $i$  (veh./h)

$v_i$  = adjusted flow for lane group  $i$  (veh./h)

### 3. Results and Discussion

The intersection configuration is as shown on Figure 2 and is of cross road type (Slinn *et al.*, 2006). The intersection geometrics show that, there are two lanes on all approaches, with an average width of 3.65 m. The terrain is level. There is no storage bay, which means that there is no provision for left turn vehicles. In addition the single lane configuration indicates that there is no provision for right turn vehicles either. Raised islands are provided to separate the traffic streams. There are no lane and pedestrian markings.

The traffic count and signal parameters are as shown in Table 3. The demand volume (veh. / h), for the East Bound (EB), West Bound (WB), North Bound (NB), and South Bound (SB) traffic were 364, 405, 44 and 66 respectively. The larger volumes of East Bound and West Bound traffic recorded are typical of collector roads as aptly indicated on the location map. The peak hour factors (PHF), for EB, WB, NB and SB were, 0.72, 0.82, 0.56 and 0.74 respectively. Random arrival of vehicle was adopted for the intersection, which put arrival type (AT) at 3 (Garber and Hoel, 2010). There are no provisions for pedestrian crossing, bicycle approach and parking. Zero (0) was therefore, entered for, parking maneuvers,  $N_m$ , bus stopping,  $N_B$  (buses / h), and min. timing for pedestrian,  $G_p$  (S). The green timings for EB and WB, and NB and SB are 30 seconds and 10 seconds respectively. While their yellow timing are 3 seconds and 5 seconds respectively. Their cycle timings are 70 seconds and 63 seconds respectively. The volume adjustment and saturation flow rate are as shown on Table 4. The adjustment flow rate,  $v_p$  (veh. / h), for EB, WB, NB and SB, were 506, 494, 79 and 89 respectively. Same values were adopted for adjustment flow rate in lane group,  $v$  (veh. / h), since there was no provision for either left turn or right turn vehicles. The resulting saturation flows (s), for EB, WB, NB and SB, were therefore, 2306, 1948, 1561 and 1569 veh. / h respectively.

The critical v/c ratio value for the intersection was, thereafter determined to be 0.54, which indicates that, the intersection is operating at under capacity. It also means that, the cycle length provided is adequate for all critical movements. (Garber and Hoel, 2010)

The uniform delay,  $d_1$ , for EB and WB, and NB and SB, were 10 and 26 sec. / veh., respectively, as shown on Table 5, while the values for their incremental delays,  $d_2$ , were, 0.44, 0.66, 0.41 and 0.47 sec. / veh., respectively, as shown in Table 6. The approach lane group delay,  $d$ , for EB, WB, NB and SB, were, 10, 11, 26 and 26 sec. / veh., respectively as shown on Table 7; while their level service (LOS), were, B, B, C and C, respectively. The average intersection delay was therefore determined to be, 13 sec / veh., which put the level of service (LOS), at B. This indicates a slight delay.

Since the intersection is operating at under capacity, this slight delay can be eliminated, by a reconfiguration of the geometrics of the intersection as shown in Figure 3. This new geometrics provides for all turn movements by creating additional lanes and storage bays.

## 5. Conclusion

The operational evaluation of road 2 – road 6 intersection was carried out.

The geometric configuration showed that, there is no provision for turning movement, and no lane and pedestrian markings.

The critical v/c ratio was 0.54, average intersection delay 13 sec / veh., and level of service of, B.

It can therefore be concluded that, there is a slight delay at the intersection, which could probably be attributed to inadequate geometrics of the intersection.

A reconfiguration of intersection is hereby proposed, to eliminate its under capacity operation and slight delay.

## 6. Acknowledgement

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Source: <http://www.ngex.com/nigeria/places/states/osun.htm>

Figure 1: Map of Nigeria Showing Osun State

State



Plate 1: Intersection Location

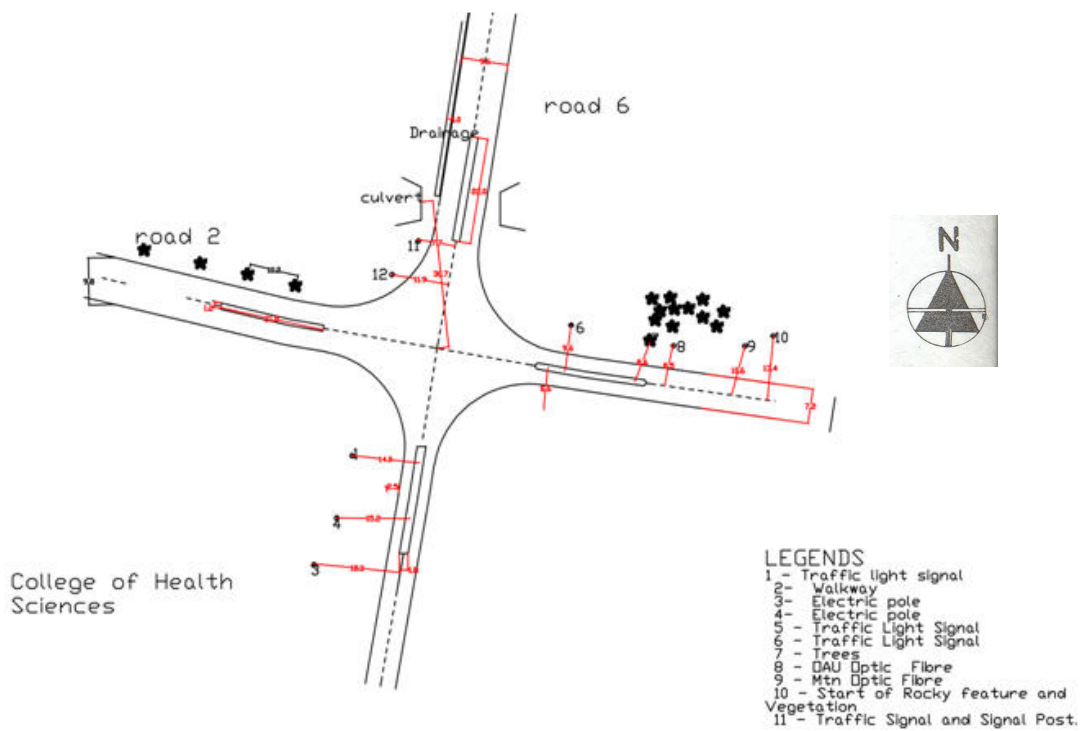


Figure 2: Intersection Configuration

Table .1: Input Data Needs for Each Analysis Lane Group

| Type of Condition        | Parameter   |
|--------------------------|---|
| Geometric conditions     | Area Type   |
|                          | Number of lanes, $N$                                  |
|                          | Average lane width, (m)                               |
|                          | Grade, $G$ (%)  |
|                          | Existence of exclusive LT or RT lanes                 |
|                          | Length of storage bay, LT or RT lane, $L_s$ (m)       |
|                          | Parking   |
| Traffic conditions       | Demand volume by movement, $V$ (veh/h)                |
|                          | Base saturation flow rate, $s_0$ (pc/h/ln)            |
|                          | Peak-hour factor, $PHF$                               |
|                          | Percent heavy vehicles, $HV$ (%)                      |
|                          | Approach pedestrian flow rate, $v_{ped}$ (p/h)        |
|                          | Local buses stopping at intersection, $N_B$ (buses/h) |
|                          | Parking activity, $N_m$ (maneuvers/h)                 |
| Arrival type, $AT$       |   |
| Signalization conditions | Cycle length, $C$ (s)                                 |
|                          | Green time, $G$ (s)                                   |
|                          | Yellow time, $Y$ (s)                                  |

Source: Garber and Hoel, 2010.

Table 2: Level-of-Service Criteria for Signalized Intersections

| Level of Service | Control Delay Per Vehicle (sec) |
|------------------|---------------------------------|
| A                | $\leq 10.0$                     |
| B                | $>10.0$ and $\leq 20.0$         |
| C                | $> 20.0$ and $\leq 35.0$        |
| D                | $> 35.0$ and $\leq 55.0$        |
| E                | $> 55.0$ and $\leq 80.0$        |
| F                | $> 80.0$                        |

Source: Garber and Hoel, 2010.

Table 3: Volume and Timing Input

| Parameter                                      | EB |               |    | WB |      |    | NB |               |    | SB |      |    |  |
|--|----|---------------|----|----|------|----|----|---------------|----|----|------|----|--|
|  | LT | TH            | RT | LT | TH   | RT | LT | TH            | RT | LT | TH   | RT |  |
| Volume, $V$ (veh./h)                           |    | 364           |    |    | 405  |    |    | 44            |    |    | 66   |    |  |
| % heavy vehicles, % HV                         | 4  | 2             | 2  | 0  | 2    | 2  | 0  | 3             | 1  | 1  | 4    | 1  |  |
| Peak hour factor, PHF                          |    | 0.72          |    |    | 0.82 |    |    | 0.56          |    |    | 0.74 |    |  |
| Arrival type, AT                               |    | 3             |    |    | 3    |    |    | 3             |    |    | 3    |    |  |
| Approach pedestrian volume, $v_{ped}$ (p/h)    |    | N             |    |    | N    |    |    | N             |    |    | N    |    |  |
| Approach bicycle volume, $v_{bic}$ (bicycle/h) |    | N             |    |    | N    |    |    | N             |    |    | N    |    |  |
| Parking (Y or N)                               |    | N             |    |    | N    |    |    | N             |    |    | N    |    |  |
| Parking maneuvers, $N_m$ (maneuvers)           |    | 0             |    |    | 0    |    |    | 0             |    |    | 0    |    |  |
| Bus stopping, $N_B$ (buses/h)                  |    | 0             |    |    | 0    |    |    | 0             |    |    | 0    |    |  |
| Min. timing for pedestrians, $G_p$ (s)         |    | 0             |    |    | 0    |    |    | 0             |    |    | 0    |    |  |
| Timing   |    | G = 30, Y = 3 |    |    |      |    |    | G = 10, Y = 5 |    |    |      |    |  |
| Cycle length                                   |    | 70            |    |    |      |    |    | 63            |    |    |      |    |  |

Table 3 : Volume adjustment and Saturation Flow Rate

| Parameters  | EB   |       |      | WB   |       |      | NB  |       |      | SB   |       |      |
|---|------|-------|------|------|-------|------|-----|-------|------|------|-------|------|
|   | LT   | TH    | RT   | LT   | TH    | RT   | LT  | TH    | RT   | LT   | TH    | RT   |
| Volume, V(veh./h)   |      | 364   |      |      | 405   |      |     | 44    |      |      | 66    |      |
| Peak hour factor, PHF   |      | 0.72  |      |      | 0.82  |      |     | 0.56  |      |      | 0.74  |      |
| Ajustment flow rate, $v_p = V/PHF$ (veh./h)   |      | 506   |      |      | 494   |      |     | 79    |      |      | 89    |      |
| Ajustment flow rate in lane group, $v =$ (veh./h)   |      | 506   |      |      | 494   |      |     | 79    |      |      | 89    |      |
| Proportion of LT or RT ( $P_{LT}$ or $P_{RT}$ )   | 0.14 | 0.82  | 0.04 | 0.04 | 0.85  | 0.04 | 0.5 | 0.06  | 0.46 | 0.49 | 0.03  | 0.48 |
| Base flow, $s_0$ (pc/h/ln.)   |      | 1900  |      |      | 1900  |      |     | 1900  |      |      | 1900  |      |
| Number of lanes, N  |      | 1     |      |      | 1     |      |     | 1     |      |      | 1     |      |
| Lane width adjustment factor, $f_w$   |      | 1.12  |      |      | 1.13  |      |     | 1     |      |      | 1.13  |      |
| Heavy vehicle adjusment factor, $f_{HV}$  |      | 0.994 |      |      | 0.994 |      |     | 0.994 |      |      | 0.994 |      |
| Grade adjusment factor, $f_g$   |      | 0.993 |      |      | 0.993 |      |     | 0.993 |      |      | 0.993 |      |
| Parking adjusment factor, $f_p$   |      | 1     |      |      | 1     |      |     | 1     |      |      | 1     |      |
| Bus blockage adjusment factor, $f_{bb}$   |      | 1     |      |      | 1     |      |     | 1     |      |      | 1     |      |
| Area adjusment factor, $f_a$  |      | 0.9   |      |      | 0.9   |      |     | 0.9   |      |      | 0.9   |      |
| Lane utilization adjusment factor, $f_{LU}$   |      | 1.225 |      |      | 1.175 |      |     | 0.908 |      |      | 0.908 |      |
| Left-turn adjusment factor, $f_{LT}$  |      | 0.994 |      |      | 0.984 |      |     | 0.931 |      |      | 0.928 |      |
| Right-turn adjusment factor, $f_{RT}$   |      | 0.993 |      |      | 0.998 |      |     | 0.977 |      |      | 0.976 |      |
| Left-turn ped./bike adjusment factor, $f_{Lpb}$   |      | 1     |      |      | 1     |      |     | 1     |      |      | 1     |      |
| Right-turn ped./bike adjusment factor, $f_{Rpb}$  |      | 1     |      |      | 1     |      |     | 1     |      |      | 1     |      |
| Adjusted saturation flow $s$ (veh./h, )<br>$s = s_0 N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{RT} f_{LT} f_{Rpb} f_{Lpb}$ |      | 2306  |      |      | 1948  |      |     | 1561  |      |      | 1569  |      |

Table 5: Uniform Delay,  $d_1$  ( sec. / veh.)

| Lane Group | $d_1$ |
|------------|-------|
| EB         | 10    |
| WB         | 10    |
| SB         | 26    |
| NB         | 26    |

Table 6: Incremental Delay,  $d_2$  ( sec. / veh.)

| Lane Group | $d_2$ |
|------------|-------|
| EB         | 0.44  |
| WB         | 0.66  |
| SB         | 0.47  |
| NB         | 0.41  |

Table 7: Approach Lane Group Delay,  $d$  ( sec. / veh.)

| Lane Group | $d$ |
|------------|-----|
| EB         | 10  |
| WB         | 11  |
| SB         | 26  |
| NB         | 26  |

Table 8: Level of Service (LOS) by Lane Group

| Lane group | Delay s/veh.) | LOS | Remarks          |
|------------|---------------|-----|------------------|
| EB         | 10            | B   | Slight delay     |
| WB         | 11            | B   | Slight delay     |
| SB         | 26            | C   | Acceptable Delay |
| NB         | 26            | C   | Acceptable Delay |

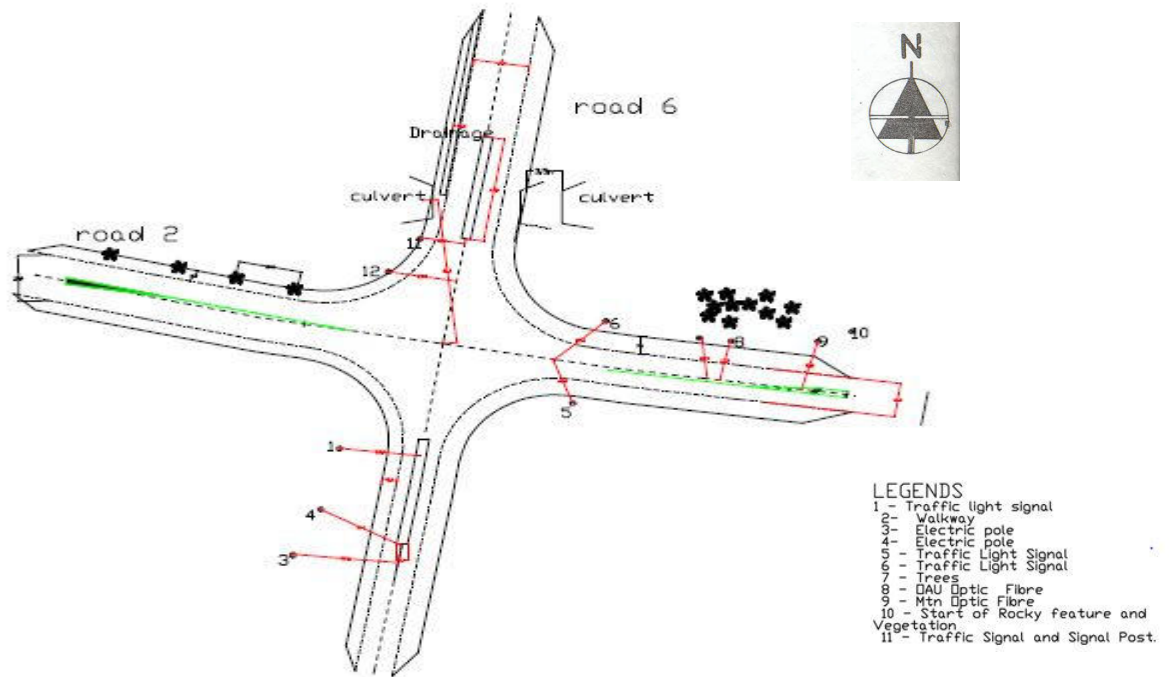


Figure 3: Proposed New Configuration of Intersection.



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