Traffic Performance Analysis and Improvement Strategies for Roundabouts in Samawa City's CBD

Dr. Saad H. Jasim, Ahmed T. Hassan*

Assistant Professor, Civil Engineering Department, University of Baghdad, Baghdad, Iraq
M.Sc. in Transportation Engineering, Civil Engineering Department, University of Baghdad, Baghdad, Iraq

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ABSTRACT

The objective of this paper is the evaluation and improvement of traffic performance at the two selected roundabouts in Samawa city at CBD area. This is followed by suggestions of some improvement proposals, which vary from some of geometric improvements strategies. The video recording techniques is used to collect the traffic data for eight approaches. These data are abstracted from video films using EVENT program.

SIDRA INTERSECTION 5.1 software was used for evaluation and analysis of the two roundabouts and the best proposal was evaluated for the target year 2021.The results of the evaluation process showed that the two roundabouts was within a level of service (LOS) (F and E).By suggestion some of geometric strategies for the both roundabouts, the level of service has improved from (E and F) to (B and B) respectively for the both roundabouts. This results considered a reasonable and economy solutions for the existing problems at theses roundabouts.

INTRODUCTION

The rapid growth of Samawa population, and the increased number of vehicle users, in addition to the flourish of shopping centers, cafes and others activities, cause an increase in number of daily trips on most streets and intersections especially during peak hours, the increasing in number of vehicles and the limited new roads construction will increase the problem in the network. Consequently, affect the traffic flow roadway network and lead to traffic congestion, especially the road network around the city center. The traffic performance is at low level of service and needs evaluation and iprovement.

The purpose of transportation system is to provide a mechanism for the exchange of goods, people, information, and to support economic improvements for society. Transportation provides the means to travel for purposes of employment, exploration, or personal fulfillment and is a necessary condition for human activities, such as commerce, recreation, and defense [**Hoel, et. al., 2011].**

Global cities face rising traffic congestion problems. This situation is getting worse and is becoming a major concern of the public. Traffic congestion is a condition of traffic delay, because the number of vehicles using a road exceeds the operational capacity of the network to handle it **[Boamah, 2010].**

One of the negative effects of Congestions: increase in large amounts from fuel consumption that affects from financial terms on the car's owner and from productivity terms of the state that reflected the economy in those areas. In addition, it contributes to air pollution, which has a harmful effect on the quality of life, and reduces the investment attractiveness in the city by some global investors **[Warid, 2004].**

CAPACITY OF ROUNDABOUT

The full capacity of roundabout is the maximum value of the sums of all entry flows. On the assumption that the traffic operation characteristics are remained unchanged which include critical gap, the minimum headway, the following headway and the turn-orientation proportion of each entry, the sum of all entry flows is the full capacity of roundabout when each entry flow is equal to the entry capacity correspondingly. The entry capacity can be calculated by use of the equation based on the gap acceptance theory. This process can be finished with the help of computer. The theoretical calculation value was verified and the study found that full capacity of roundabouts should be unique solution and unrelated with the initial flows of entries **[Guo, 2009]**.

Capacity is the main determinant of performance measures such as delay, queue length and stop rate. It represents the service rate (queue clearance rate) in the performance (delay, queue length, stop rate) functions, and therefore is relevant to both under-saturated and oversaturated conditions. Conceptually, this is different from the maximum volume that the intersection can handle which is the practical capacity (based on a target degree of saturation) under increased demand volumes, not the capacity under prevailing conditions **[Akcelik, 2005].**

CAPACITY ANALYSIS

Three performance measures are typically used to estimate the performance of a given roundabout design: degree of saturation, delay, and queue length **[Robinson and Rodegerdts, 2001].**

Degree of Saturation

Degree of saturation is the ratio of the demand at the roundabout entry to the capacity of the entry. It provides a direct assessment of the sufficiency of a given design. Although there is not any source to specify an exact amount for the degree of saturation for an entry lane, there are several sources recommending it less than 0.85 in order to have a satisfactory operation. When the degree of saturation exceeds this range, the operation of the roundabout will likely deteriorate rapidly, particularly over short periods of time. Queues may form and delay begins to increase exponentially **[FHWA, 2000]**.

Delay

Roundabout delay is defined separately for each entry approach. The delay for any entry approach is composed of two distinct components: queuing and geometric delay. Queuing delay occurs when drivers are waiting for an appropriate gap in the circulating traffic. Geometric delay results from vehicles slowing down, when traversing the roundabout **[Hummody, 2007].**

Delay is a standard parameter used to measure the performance of an intersection. The Highway Capacity Manual identifies delay as the primary measure of effectiveness for intersections, with level of service determined from the delay estimate **[FHWA, 2000].**

Control delay defined by the HCM2000 at the time that a driver spends decelerating to a queue, queuing, waiting for an acceptable gap in the circulating flow while at the front of the queue, and accelerating out of the queue **[TRB, 2005].**

Control delay can be considered to be the overall time loss that includes all delays experienced in traveling through an intersection with reference to approach and exit cruise speeds (including all acceleration and deceleration delays, delay due to cruise at a lower speed, and stopped delay). Geometric delay is the delay experienced by a vehicle going through (negotiating) the intersection in the absence of any other vehicles **[Akcelik, 2009 b].**

Queue Length

Queue length is an indicator that reflects the proper design of the geometric parameters for a roundabout approaches. Average queue length is equivalent to the vehicle-hours of delay per hour on an approach. It is useful for comparing roundabout performance with other intersection forms, and other planning procedures that use intersection delay as an input **[FHWA, 2000]**.

LEVEL OF SERVICE FOR ROUNDABOUT

Level of service is a qualitative measure describing operational conditions within a traffic stream, and their perception by motorists and/or passengers The level of service criteria facilitates the traffic flow parameters such as delay, speed, travel time, comfort, safety and freedom to maneuver into a simplified A to F scale, where A represents ideal conditions based on the traveler's perspective and F represents the worst conditions **[Taylor, 2012].**

The principal service measure in the Highway Capacity Manual (HCM, 2010) for evaluating the level of service (LOS) is control delay. Level of service can also be related to the degree of saturation. **[Akçelik, 2009]** presented the criteria shown in Table (1) which determines the level of service criterion to both the delay and degree of saturation.

Table (1): Level of Service Definitions for Vehicles based on both Delay and Degree of Saturation (Akçelik, 2009).

Level of service	Roundabout	Degree of saturation (V/C)
A	$D \leq 10$	$0 < X \leq 0.85$
B	$10 < D \leq 20$	$0 < X \leq 0.85$
C	$20 < D \leq 35$	$0 < X \leq 0.85$

D	35< D ≤50	0 < X ≤ 0.85 0.85 < X ≤ 0.95
E	50 < D ≤ 70 0 < D ≤70	0 < X ≤ 0.95 0.95 < X ≤ 1.0
F	70 < D	1.0 < X

The roundabout descriptions

Hussain Kathem Abood Square (Roundabout 1)

Hussain Kathem Abood is a four legs roundabout, and located in the center of commercial, governmental and residential area and links the traffic coming from Al-Gharbi Street from the north, and Al-Ghadeer street from the east . The geometric layout is illustrated in Figure (1).

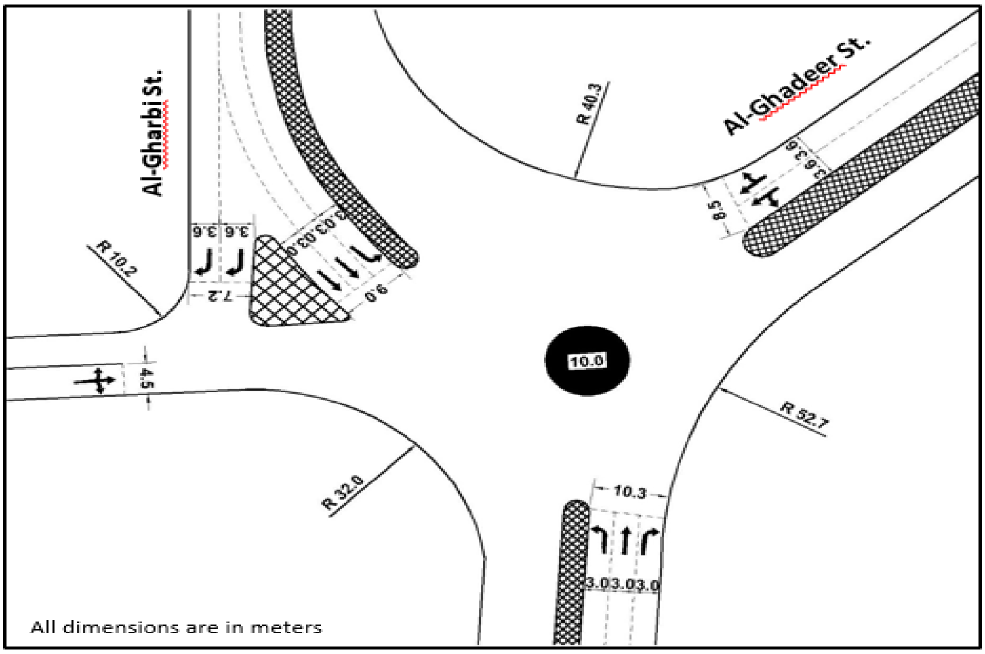

Figure (1) Hussain Kathem Abood Roundabout Layout

Al-Ghadeer Square (Roundabout 2)

Al-Ghadeer square is a four legs roundabout, and considered one of the most roundabouts that suffering from high traffic congestions as a result of the presence of several schools very close to the roundabout, and also, the north approach leads to Al-Hadeed bridge that suffers from high congestion as previously mentioned. All the approaches that linked with the square consist of two lanes. The geometric layout is illustrated in Figure (2).

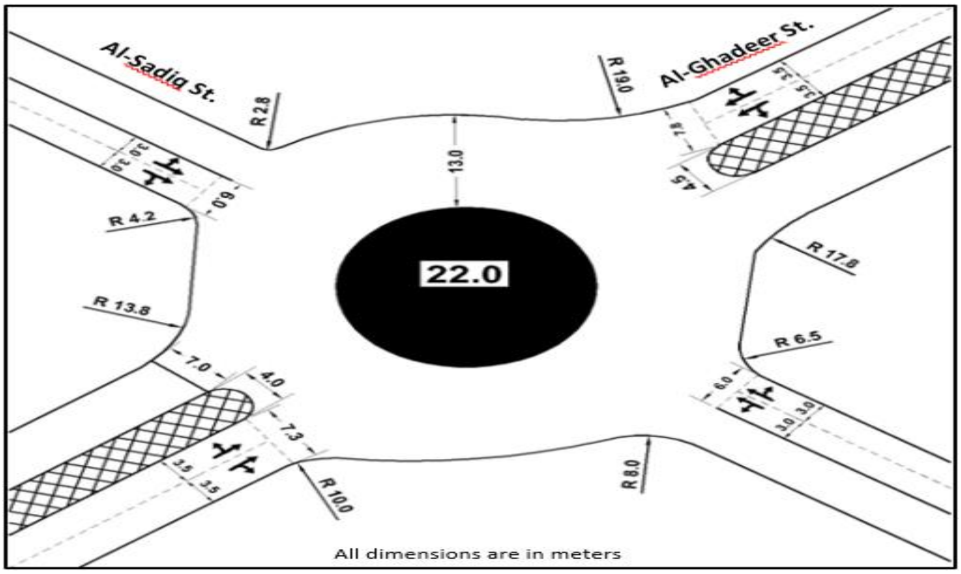

Figure (2) Al-Ghadeer Roundabout Layout

DATA COLLECTION METHODOLOGY

To accomplish the study objectives, it was important to follow a designed procedure to assemble the required data. The procedure is divided into three stages:

1. Determining the peak period for each roundabout.
2. Distinguishing the specific input data for the selected program.
3. Checking, coding, and preparing the data to be used in the chosen software program.

The data collection stage was aimed for gathering all data that would be necessary to show the traffic flow conditions at the two roundabout. After careful consideration, the types of data to be collected were chosen to include:

1. Geometric characteristics (e.g., number of lanes per approach, lane designation, lanes width, entry radius, island diameter, circulating width and so on) .
2. Traffic flow data including traffic volume of vehicles at peak periods, vehicles classification, and turning movements.
3. Land use data and projected changes in land uses.

Geometric Data

Some of geometric data have been collected by using GIS tools in map measurements depending on the available satellite photographs for Samawa city with accuracy of 0.6m, updated to 2013. Field measurements are done by using measuring tape to obtain the lane width, median width, splitter island width and so on.

In addition some of geometric features for roundabouts like entry and exit radius, island diameter, circulating width, and so on are taken from Municipality department of Samawa city, because it's difficult to be measured at the field, and also, drawn to scale with AutoCAD program and measured to make a double check, and other features that cannot be measured in field are also obtained, such as entry angle.

Determination of Peak Hour Periods

Several individual observations and pilot survey have been done in the study area, also personal interviews were made with interested people like traffic policemen, Owners of shops and offices at the study area and different road users in order to predict what is most congested period for traffic volumes data collection. Traffic data was collected for 14 days from (6-12-2015 to 19-12-2015) for each intersection by video recording techniques. The video recording is made in normal conditions, good weather (dry), and good visibility. These dates were chosen in the days where there is no occasions. From all of these considerations, it was concluded that Kathem Hussain Abood square, and Al-Ghadeer square have a morning peak hour of (7:30 – 8:30) A.M. as shown in figure from (3) and (4) .

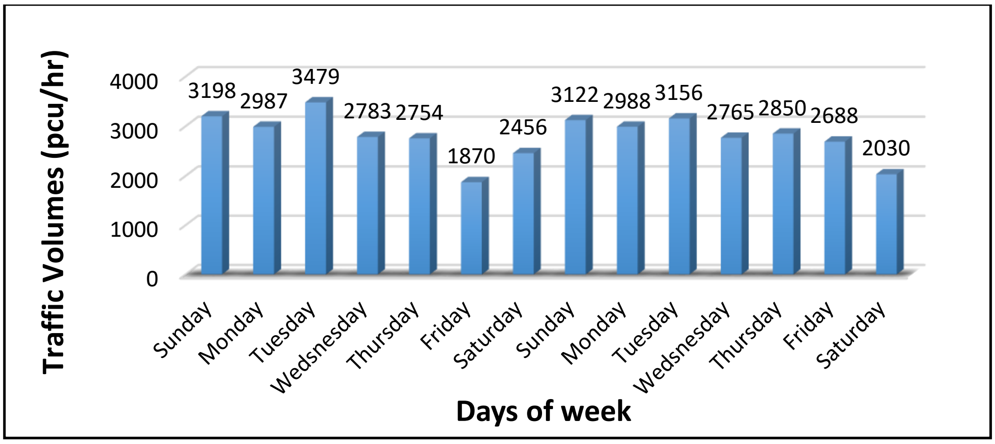

Figure (3) Total Traffic Volumes at Kathem Hussain Abood Roundabout

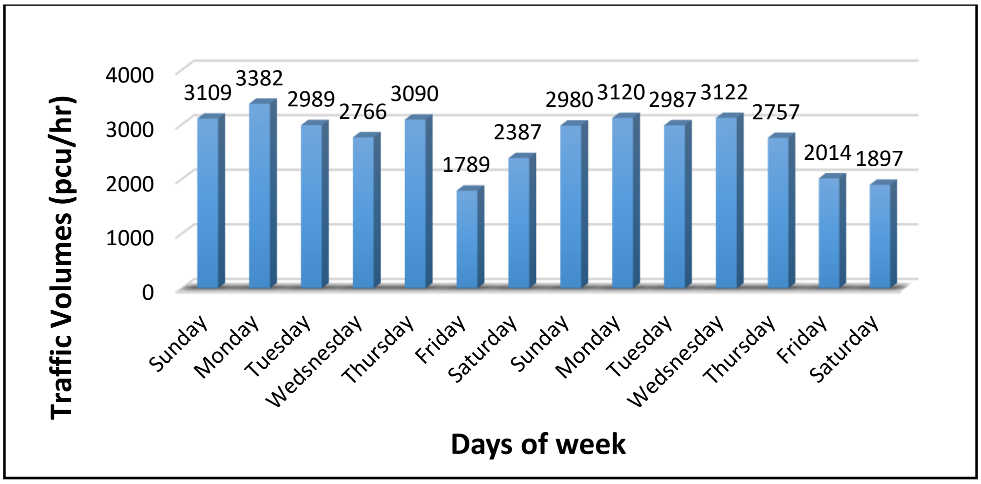

Figure (4) Total Traffic Volumes at Al-Ghadeer Roundabout

Data Collection Method

The traffic flow data was recorded by using a video camera SONY HANDYCAM lens (8mm and 3mm), and later copied onto solid disk. The advantages of this method are as follows:

- Gives a constant and permanent records of all the events occurring within the view of the camera.
- Minimizes the human mistakes that can result in manual data collection method
- Enables the researcher to collect the information with less effort.
- Allows for large number of events to be recorded at the same time.
- Any incident which might influence on the observed data will also be recorded, this incidents can be reviewed and checked at a later stage to determine any obvious abnormalities in the data.
- It is unobtrusive and requires little labor power.

However, video equipment has some disadvantages, as follows:

- A good vantage point is not always easy to find a suitable location.
- The climate conditions could cause delay, postponement and difficulty during the process of recording.
- Extra delay sometimes caused by the routine formalities which is important to permit access for video recording.

Survey was made to choose the suitable vantage point to execute the video recording on an appropriate building within each intersection area. This is to ensure the optimum possible coverage of intersection approaches. Trial shots were recorded from these locations and then played back. Finally, the ideal location at each site was chosen.

In order to get the required traffic data to be as an input for the selected software, the video recording films were played back many times for each intersection. Data abstraction during video playing back was conducted with the aid of data abstraction programs EVENT.

Traffic Volume Data

Turning movement traffic volumes are an important part of the analysis of any roundabout. To measure turning movement traffic volumes, vehicles must be followed through the roundabout from their approach leg to their exit leg.

Collecting turning movement volumes especially for roundabout (2) through field observations presents two specific challenges. First, the camera was installed in a place far away from the intersection and was a difficult to monitor the direction of turning movements of vehicles around the island diameter. Second, even if both legs can be observed at the same time, by the time an observer has followed one vehicle through the roundabout to its exit leg; one or more new vehicles may have entered the intersection unobserved.

Roundabouts turning movement estimates were derived from collected traffic volume data as recommended in the Federal Highway Administration **[FHWA, 2000]**. The FHWA procedure requires the entering, exiting, circulating, and right turns for each leg of the traffic circle, as in Figure (5) Traffic passing ‘through’ the roundabout and ‘left turning’ vehicles were determined from Equations (1), and (2), respectively.

Equation (1) shows the through movement flow rate for the eastbound approach as a function of the entry flow rate for that approach, the exit flow rate for the opposing approach, the right turn flow rate for the subject approach, the right turn flow rate for the approach on the right, and the circulating flow rate for the approach on the right. Other through movement flow rates can be estimated using a similar relationship.

$$V_{EB,\,TH} = V_{EB,\,entry} + V_{WB,\,exit} - V_{EB,\,RT} - V_{NB,\,RT} - V_{NB,\,circ} \quad (1)$$

The left turn flow rate for an approach is a function of the entry flow rate, the through flow rate, and the right turn flow rate for that same approach, as shown in Equation (2). Again, other movements' flows are estimated using similar equations.

$$V_{EB,\,LT} = V_{EB,\,entry} - V_{EB,\,TH} - V_{EB,\,RT} \quad (2)$$

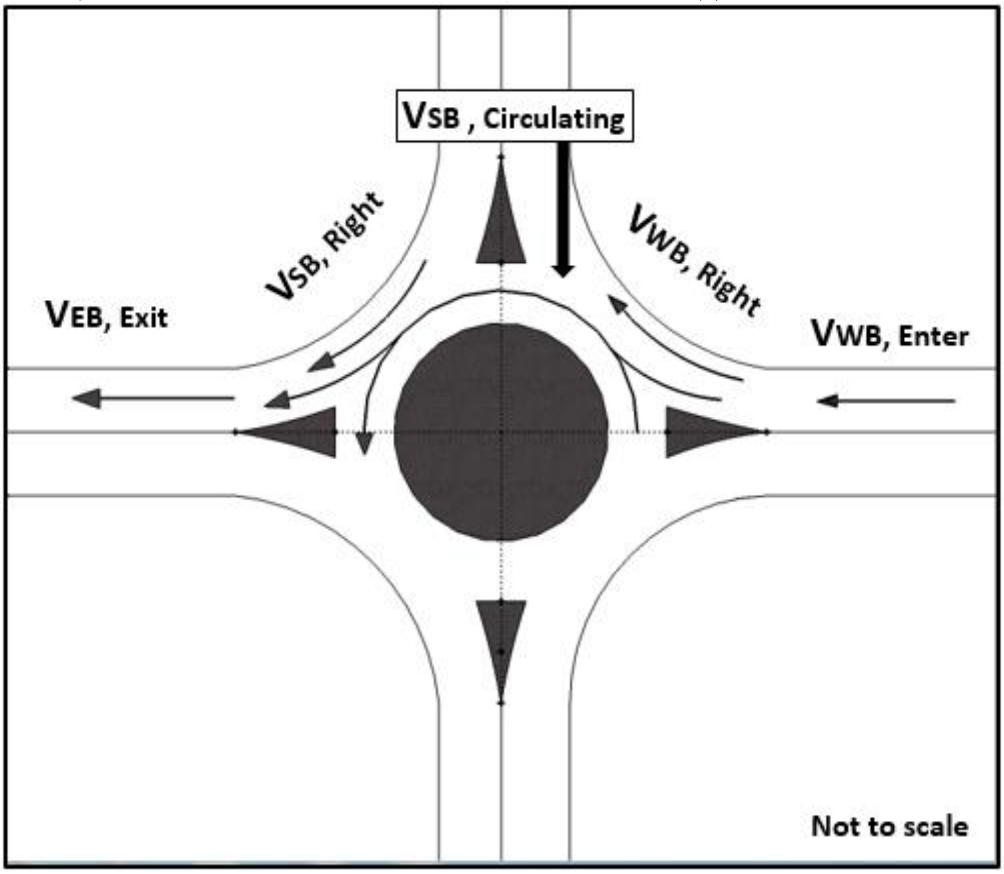

Figure (5) Turning Movements per Approach

The accuracy of the aforementioned procedure was tested and tried by **[Dixon, et. al., 2007]** and found to be satisfactory, acceptable, less complicated and similar calculation as compared with other methods, where they all would require one observer per approach.

Application of SIDRA INTERSECTION 5.1

The abstracted and collected data required for this software were fed to the program for each intersection alone. Many runs were implemented to exclude the bias data. **SIDRA INTERSECTION 5.1** software was used to analyze the existing traffic flow patterns for the both roundabouts as isolated at the study area.

Table (2) and (3) indicates the output results of simulation runs which include the degree of saturation, total delay, and level of service for each roundabout.

Table (1) Performance Analysis for Roundabout (1)

Kathem Hussain Abood Roundabout					
Roundabout code	**Approach**	**Traffic volume**	**V/C**	**LOS**	**Average Delay (sec)**
1	**North**	**578**	**0.32**	**B**	**15.9**
	South	**1557**	**0.65**	**B**	**14.9**
	East	**812**	**1.12**	**F**	**212.4**

	West	540	0.84	C	21.2
Summary					
Average delay : 62.4		LOS : E		V/C ratio : 1.12	

Table (2) Performance Analysis for Roundabout (2)

Al-Ghadeer Roundabout					
Roundabout code	Approach	Traffic volume	V/C	LOS	Average Delay (sec)
2	North	1047	0.87	D	33.4
	South	1169	1.01	F	79.5
	East	689	1.09	F	233.1
	West	942	1.29	F	554.1
Summary					
Average delay : 209.6 sec LOS : F V/C ratio : 1.28					

Improvements of roundabout

The geometric improvement include by applying the simulation method on roundabout (1) and (2), and as can be seen in Table (3).

Table (3) Measure of Effectiveness for the two roundabouts Produced by SIDRA INTERSECTION 5.1

code	Improvement Type	Max V/C	Average Delay (Sec)	LOS	Fuel Consumed (L)
1	Base Condition	1.12	62.4	E	375
	Pavement widening	1.05	40.5	D	334
	Widening Wc	1.06	44.2	D	341
	Widening We	1.11	60.2	E	370
	Island Shifting *	0.73	12.7	B	278
	Percent Saving		79.6 %		25.9 %
2	Base Condition	1.29	209.9	F	674
	Pavement widening	1.17	137.7	F	544
	Widening Wc	1.23	147.8	F	563
	widening We *	0.95	31.9	C	341
	Percent saving		84.8 %		49.4 %

Using the suggestion of pavement widening as a first trail has gave unacceptable results for both roundabout (1) and (2) with level of service (LOS D and LOS F) respectively . Using of these method need to enough space for widening or adding an extra lane, and in those mentioned roundabouts area do not have enough space.

The second improvement is by widening the circulatory width, width of circulating roadway has a great effect on capacity, and then on the delay value. Although the use of that method, but also did not improve the roundabout to the desired level, where 29.2 % and 29.6 delay saving respectively.

Increase the entry radius is followed by increasing the entry width and consequently increase approach capacity, and that changing has a great effect on the delay time. Using of this method was a third trial for the improvement strategies on roundabouts (1) and (2). According to roundabout (1), there is no noticeable changes when using this method because of geometric design and nature of the site.

Increasing the entry radius has given satisfactory results at roundabout (2). Where the average delay decreased to 32.0 seconds with 84.4 % percent saving, and reduced fuel consumption by half, and level of service has changed to be LOS C. The changing in geometric features and the new design for the roundabout (2) has shown in figure (6).

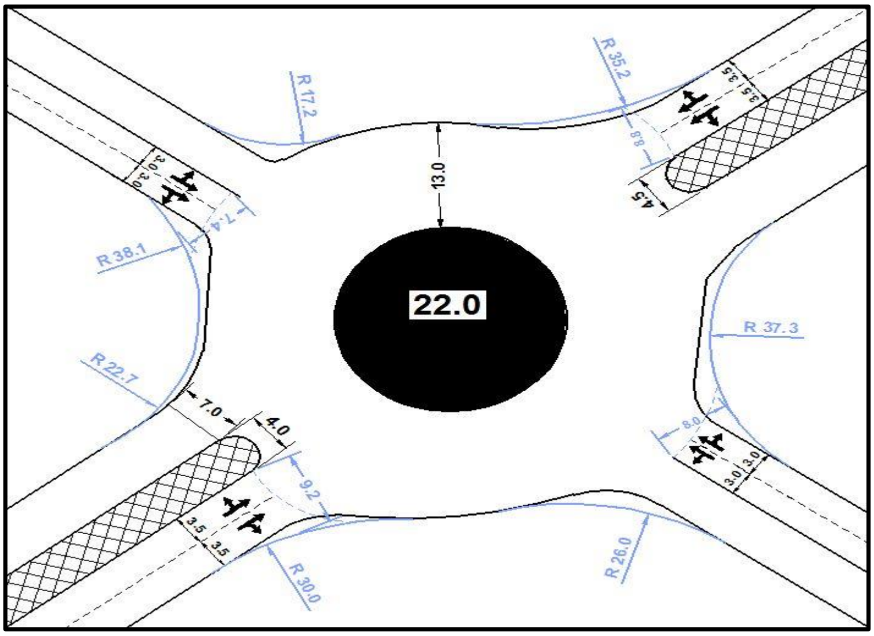

Figure (6) Improvement Proposal for Al-Ghadeer roundabout

The final improvement suggestion was applied on roundabout (1), by shifting the central island into the center of the square and increase the diameter into 20 m, with circulatory width equal to 17m for south ,east and north approach. Also, by adding third lane into east approach to become the overall width of the approach equal to 9m, with one meter extra to the south approach. The results obtained were, the delay value reduced to 12.7 seconds with 79.6 % as a percent saving and the degree of saturation (V/C) reduced to be 0.73, and as shown in figure (7).

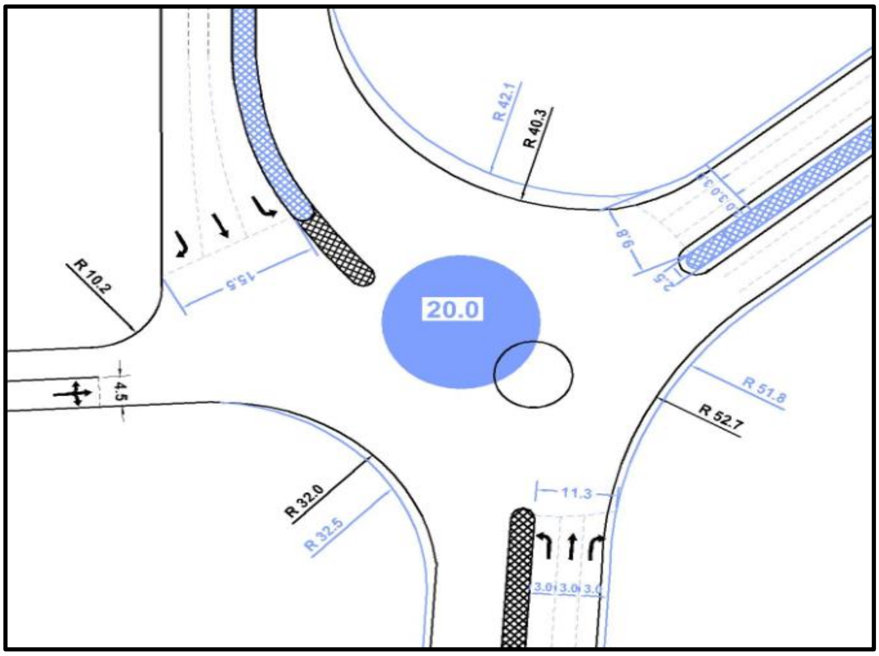

Figure (7) Improvement Proposal for Kathem Hussain Abood roundabout

Summary

After improved the roundabouts that suffer from congestion with different strategies and method and getting good results, it could be give a summary for values of delay and degree of saturation In order to understand the improvements in simple and fast way, and as shown in figure (8) and (9)

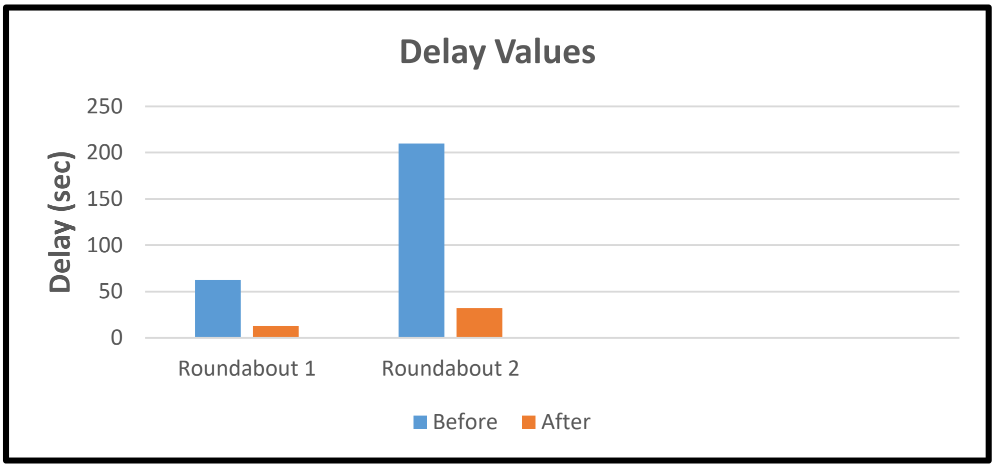

Figure (8) The Delay Value Before and After the Improvements

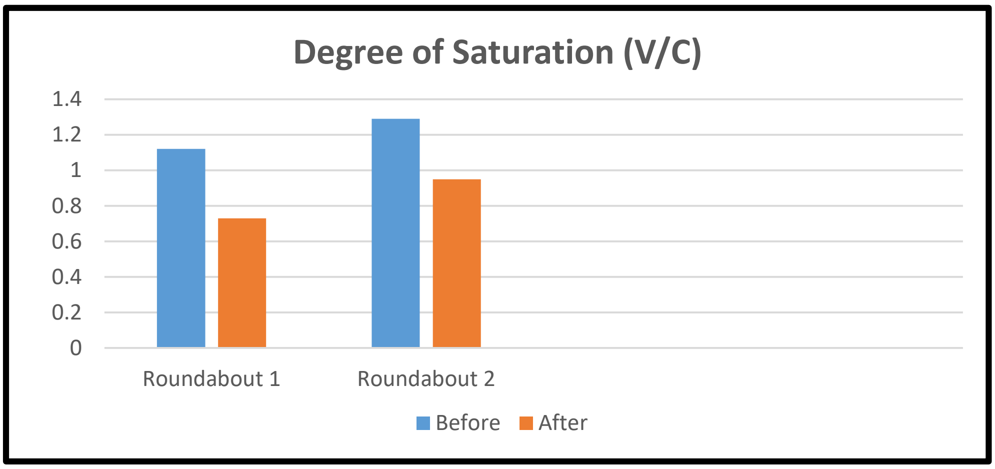

Figure (9) The Degree of Saturation Before and After the Improvements

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