CONVERSION OF A LARGE ROUNDABOUT IN BAGHDAD CITY TO A SIGNALIZED INTERSECTION

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ABSTRACT

This paper reports the conversion of a large unsignalised roundabout (HURIYA SQUARE) relatively close to the University of Baghdad campus to a signalized intersection. The study focused on reduction of vehicle delay and queue length at this intersection area.

During the course of this research project, two software packages for the analysis and design of isolated intersection, SIDRA (Akcelik, R.1986 and 1991) and HCS (Transportation Research Board, National Research Council 1994) were available. A trial site selected and the observed data used in the evaluation of the SIDRA and HCS outputs.

The evaluation process indicated that SIDRA produce vehicle delay, which is reasonably consistent with the observed vehicle delay. Hence, SIDRA software used in the evaluation of alternative designs of the HURIYA SQUARE intersection.

Five proposals of signaling plans and four proposed geometric layouts examined. The first proposal evaluated on site; the other four proposals examined with aid of the SIDRA software. Based on the carried analysis, the intersection geometric layout, signal timing, and phasing plan which result in lower vehicle delay and higher reserved capacity selected.

The Local Authority (AMANAT BAHGDAD) adopted the selected design and the large roundabout converted to a signalized intersection. Observation of traffic behavior following the conversion indicates a considerable improvement in traffic movement performance.

الخلاصة

تقدم هذه الورقة تقريراً عن تغيير تقاطع دائري كبير يعمل وفق مبداء الأسبقية المرورية (ساحة الحرية) قريب من مجمع جامعة بغداد الى تقاطع إشارة ضوئية. ركزت الدراسة على تقليل تأخير المركبة و طول الطابور في منطقة التقاطع.

توفر خلال مدة هذا المشروع البحثي برنامجين حاسبيين هما SIDRA و HCS. تم اختيار موقع تجريبي لجمع بيانات استخدمت في تقييم دقة مخرجات البرنامجين SIDRA و HCS. بينت عملية التقييم أن تأخير المركبات المحسوب من برنامج SIDRA هو منسجم مع التأخير الذي تمت مشاهدته حقليا. في ضوء هذه النتيجة تم اختيار SIDRA لتقييم البدائل التصميمية لتقاطع ساحة الحرية.

خمسة خطط مقترحة للتناوب الزمني للأشارة الضوئية و أربعة تصاميم هندسية للتقاطع تم تقييمها. المقترح الأول تم تقييمه موقعيا أما المقترحات الأربعة الأخرى فقد قيمت بالاعتماد على البرنامج الحاسبي SIDRA. على ضوء نتائج التحليل تم اختيار التصميم الهندسي للتقاطع و توقيت الإشارة و خطة توزيع أطوار الإشارة

التي أدت الى أقل تأخير متوقع للمركبات و أعلى سعة مدخرة مستقبليا للتقاطع. اعتمد التصميم الذي توصلت اليه الدراسة من قبل أمانة بغداد و تم تغيير التقاطع الدائري الكبير الى تقاطع أشارة ضوئية.أن مراقبة انسيابية المرور بعد التغيير دللت على حصول تحسن ملموس في أداء حركة المرور.

KEY WORDS
Traffic behavior, large signalized roundabouts, signal controlled junctions.

INTRODUCTION

The increase in traffic demand at junctions with limited capacities causes congestion. Consequently, travel cost increases. This increase has implications to the National Economy of world countries. To demonstrate that, consider the Road Research Laboratory investigation into the effect of traffic delay on economy in the U.K (Webster, F. V. 1977). They found that, the loss to community in Britain from traffic delay in a city with about 100 intersections was around 4,000,000 pounds per year. Similar study in Paris (Webster, F. V. 1977) concluded that, the time losses caused by congestion every day in Paris were approximately equal to the daily working time of a city with 100,000 inhabitants. Furthermore, recent study in USA (Hewlett-Packard Company 1997) estimated the cost of delay amount to $120 billion per year. In conclusion these costs are extremely high and require attention to ease traffic movement.

In Baghdad, the available statistics indicated that the number of vehicles in 1980 was about (146000) increased into approximately (410,000) vehicle in the year 1992 (Japan International Corporation 1988, Al-Kubaisy, M. T. 2000). This increase corresponds to 12.5% increment in traffic volume per year. Similar percent of increase observed in Mosul and Arbil cities. The percent increase was 12% (Sofia, G. G. 1998) and 12.5 (Mohammed, I. B. 2000) respectively. These percentages of increase suggest that, there is necessity to investigate the performance of the existed transportation system elements.

With the steady increase in traffic flow, many major roundabouts have insufficient capacity during peak periods. This has become a particular problem where the roundabout connects major roads with minor roads.

A common cause for concern has been the queues that form on major roads during peak periods which, result from the continual stream of circulating traffic effectively blocks the entry to the roundabout. The queues formed can extend back onto the major road where they cause a safety hazard. This is in addition to the community loss resulting from the increase in travel cost and air pollution (Chard, B. M. and Lines, J 1987 and Lines C. J. and Crabtree, M. R. 1988).

Signaling roundabout to prevent queues blocking the junction was studied as long ago as 1959 (Webster, F. V. 1960), and the technique has been selectively applied over a range of circumstances, but only recently has interest in signaling roundabout revived. Several authors (Flanagn, T. B. and Salter, R. J. 1983 and Davies, P. and Jamieson, B. 1980) have shown the performance of three arm roundabouts improved by traffic signal. Relatively recently this work has been applied to larger roundabouts (Huddart, K. W. 1983 and Wright, P. T. and Marie, C. S. 1984). Other authors studied signalized roundabouts in London, Sheffield, midland and Baghdad with success. (Bull, P. and Dunne, G. M. 1983, Khalaf, T. M. 1993, Khalaf, T. M. 1998, Hallworth, M. S.1980 Chard, B. M. and Lines, J. 1987 and Lines, C. J. and Crabtree, M. R. 1988).

However, signaling roundabout does not always result in substantial improvement in traffic flow performance. This is particularly the case, at intersections where substantial difference in road width between the intersection roads exist and/or where there is heavy left turn traffic movement. These factors observed at the developed site.

SCOPE OF RESEARCH

This research project made in two stages. The first stage focused on selection of analysis and design package. During this stage, the output of SIDRA and HCS traffic analysis and design packages evaluated based on site observation. The selected package is that, which produce output with no considerable difference with the observed data.

In the second stage, the selected software used to examine different possible layouts and signaling plans for the studied site. The required data collected on site by direct observation. Simple statistical analysis used to examine the difference between the obtained results. Based on the analysis results, conclusions are drawn and recommendation made.

EVALUATION OF ANALYSIS AND DESIGN SOFTWARE

Specifications and selection of the required trial site

To measure the accuracy of the output of the available analysis packages, it was necessary to select an intersection with the listed below requirements to satisfy the specification of the necessary data:

1- No street parking allowed.
2- No nearby bus stop.
3- No flared lanes.
4- The existence of zero gradient.
5- The existence of exclusive lanes for any traffic movement.
6- Minimum percentage of heavy good vehicles.

after careful consideration of the possible intersections, a decision made to select the eastern baghdad station intersection. it is a (t) intersection at al-nahda area situated relatively close to the mohammad al-kasim expressway. the geometric layout, phasing, and timing plan of the selected intersection are presented in **Fig. (1)**.

At this intersection, vehicle delay of the left turn movement coming from the Port Saeed approach observed. This is because this traffic movement is in agreement with the specification of the required data. The observed average vehicle delay found to vary from 19.2 sec/veh to 56.0 sec/veh. The corresponding vehicle flow data are 300 veh/hr to 1320 veh/hr respectively.

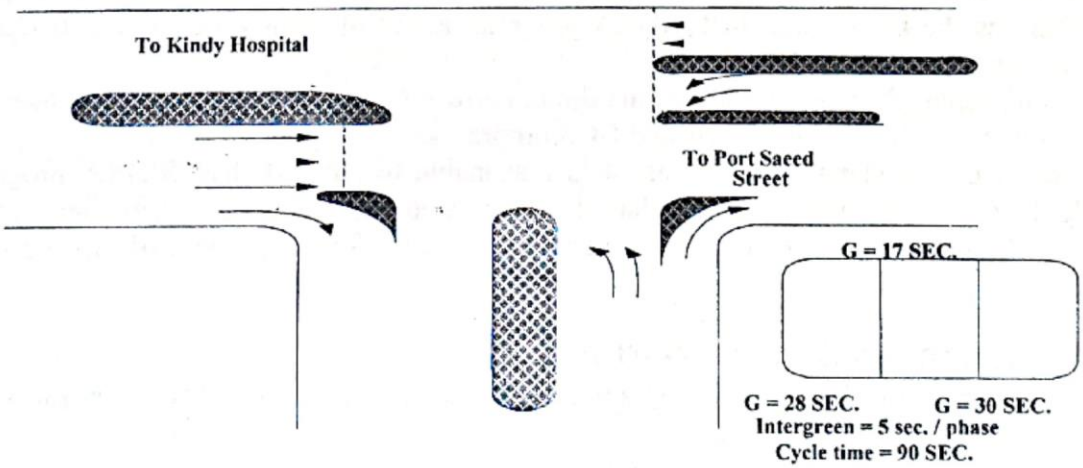

Fig. (1) Geometric layout, phases aspects and signal timing plane of Nahda intersection

Selection of analysis and design software

Following the selection of the required trial site, SIDRA and HCS programs used to provide anticipation for vehicle average delay under conditions similar to that existed at the observed site for the selected left turn traffic movement.

The observed and obtained results of vehicle average delay shown graphically in **Fig. (2)**. Examination of the presented data suggests that HCS output of vehicle delay is higher than the observed at the relatively low and high traffic flows. By contrast, SIDRA output of vehicle delay is relatively closer to the observed data at almost all the observed levels of vehicle flow.

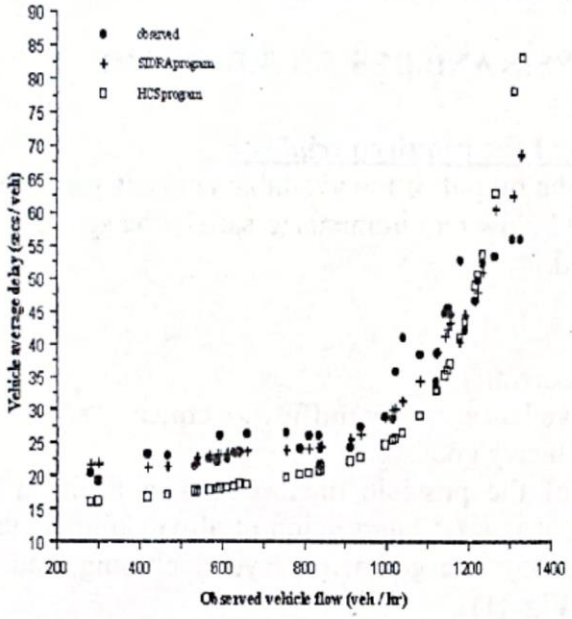

Fig. (2) Comparison between observed vehicle delay with that produced by SIDRA and HCS programs

The difference between observed data and that produced by the two software packages examined statistically using regression analysis. Result of the analysis showed that the calculated R^2 (coefficient of determination) values were 0.905 and 0.821 for SIDRA and HCS outputs respectively. This has the implication that SIDRA program output of vehicle delay is statistically more acceptable than HCS output.

Fig. (3) provides a graphical representation of the direct correspondence between observed average vehicle delay and that anticipated by SIDRA and HCS programs.

Based on the result of the statistical analysis, it is reasonable to suggest that, SIDRA program produce vehicle delay which is more realistic than that calculated by the HCS program. Hence, it is logical to use SIDRA program in the analysis of alternative designs for the purpose of this research project.

DESCRIPTION OF THE OBSERVED INPUT DATA

The data required as input for the SIDRA program observed on site, whenever it was possible. The observed data classified into the following:

Traffic flow data

Vehicle flow observed over a period of two years to monitor the increase in traffic demand over the years. **Table (1)** show the data observed on March 1995 and on March 1997. The presented data provides information about the circulating and entry flows observed during the AM peak for a period of one hour.

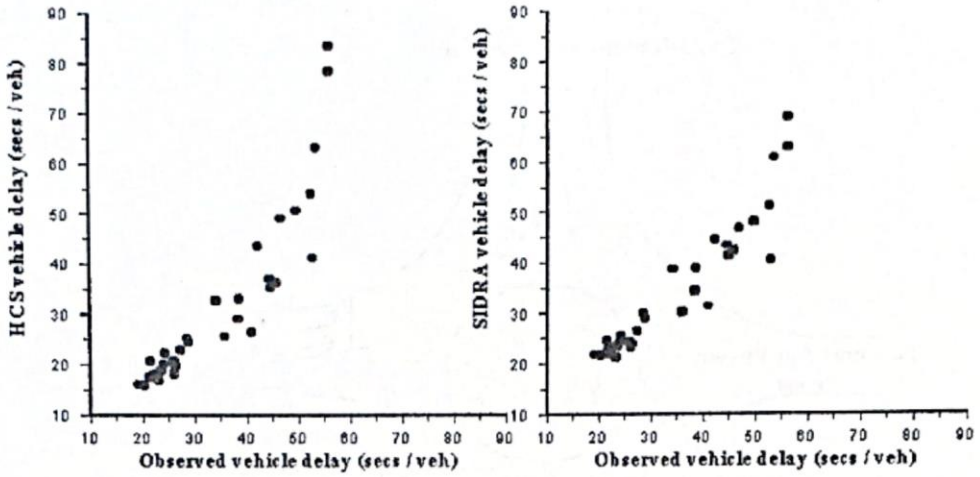

Fig. (3) Comparison between observed vehicle delay with that produced by SIDRA and HCS programs

It is worth mentioning that, when the observed traffic flow was not statistically meaningful, that is very light traffic flow the data is not presented in **Table (1)**. However, for the purpose of analysis a minimum value of 100 veh/hr used as input for the analysis program whenever it is applicable. **Fig. (4)** below shows the assignment flow observed at the roundabout before conversion used as input flow for the analysis computer program.

Table (1) Observed vehicle flow during the period 1995-1997

APPROACH NAME	ENTRY VEHICLE FLOW		CIRCULATING VEHICLE FLOW	
	Year of the survey		Year of the survey	
	1995	1997	1995	1997
From Ahmad Aurabi Square	2160	2400	292	350
To Al - Sada	560	900	2030	2180
To Al-NadmyiAa Intersection	1510	2000	--------	1300
To Amar Bin Yasser Street.	--------	--------	1328	2400

Origin destination data

In SIDRA, it is required that permitted traffic movement data for each approach specified on lane by lane basis. Where the lane allocated more than one type of traffic movement to carry, it considered as non-standard lane. For intersection approaches consist of non-standard lanes, the origin-destination data for each approach specified. This was the case at the studied site

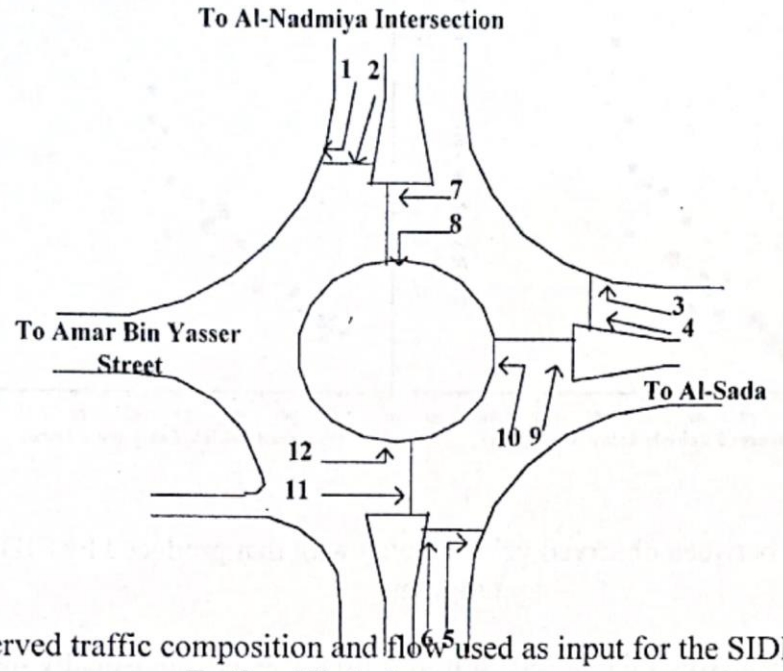

Fig. (4) Observed traffic composition and flow used as input for the SIDRA computer program

N.B. The observed number of vehicles and traffic composition associated with each labeled traffic stream shown in Figure - 4 -, is given in Table below.

Stream No.	1	2	3	4	5	6	7	8	9	10	11	12
PCU	180	1780	96	890	204	2130	670	935	1458	715	302	43
HGV	2	21	2	6	6	32	5	8	25	7	3	0

Therefore, origin-destination survey made to provide the required lane discipline data. The collected data shown in **Table (2)** below presented in the form of an (O-D) matrix.

Saturation flow data

Because of the method of control of traffic movement at the studied site during the period of study, it was not possible to measure the saturation flow directly.

The method of control was flashing amber, and before the flashing amber, the roundabout controlled by priority rule. Therefore, saturation flows observed at (Anter-square) roundabout are used. This square is a large signalized roundabout. The observed values presented in **Table (3)** below.

THE INTERSECTION ANALYSIS METHODS USED IN SIDRA

In contrast to modeling by simulation, SIDRA uses an analytical modeling approach, coupled with an iterative approximation method of computation. The analysis methods based on ARRB report ARR No 123 (Akcelik, R. 1989).

Table (2) Observed origin – destination matrix of traffic flow

TO / FROM	Ahmed Aurabi Square	Al-Sada	Al –Nadmiya Intersection	Amar Bin Yasser Street
Ahmed Aurabi Square	100	220	1680	400
Al-Sada	540	-----	100	260
Al – Nadmyia Intersection	1410	350	-----	240
Amar Bin Yasser Street	-----	-----	-----	-----

Table (3) Observed saturation flow data at Anter-square

Type of vehicle movement	Saturation flow(veh/hr)
Straight through	1700
Left turn	1550
Right turn	1500

The capacity prediction and performance models employ the lane by lane method. Signal timing (cycle time and green split) determined by the program based on the permitted movement from each lane in the intersection approaches. It is applicable to both group based and phase based controllers The vehicle delay, vehicle queue length, and vehicle stop rate estimation based on a time dependent formulation. This method is similar to that used in the development of OSCADY (Burrow, I. J. 1987) computer program. The time dependent approach, provide a simple continuous model which applies to both under and over saturated intersections.

PRESENTATION AND DISCUSSION OF RESULTS

The basic geometric layout of the roundabout and the land use of the surrounding area were as shown in **Fig. (5)**. The approach width and number of lanes of each together with other geometric information were as presented in **Table (4)**.

To improve traffic flow performance, five proposals of signal strategies and four geometric layouts examined. The first proposal was signaling the roundabout using flashing amber. The flashing amber intended to inform the drivers to wait until it is safe to move.

The signals installed at the exit and entry of the roundabout approaches, and in the circulating area of the roundabout. The traffic movement performance monitored, but no record made. Unfortunately, the results of observation were not encouraging. Therefore, it was necessary to consider another feasible solution.

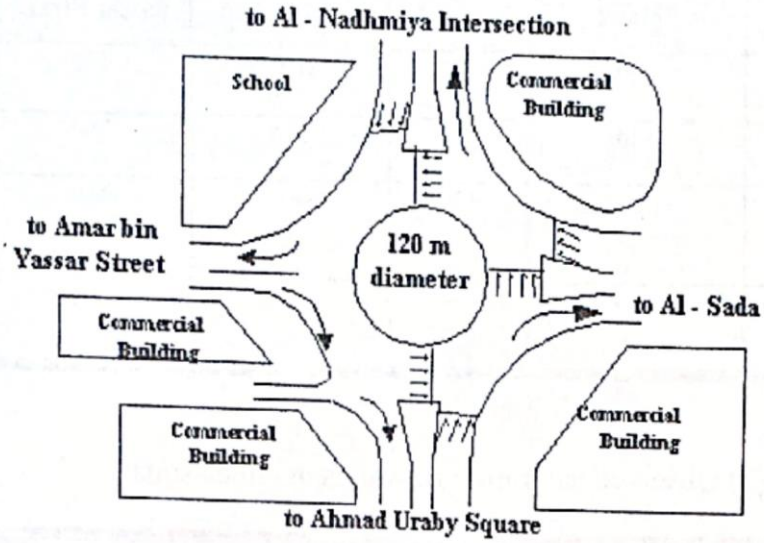

Fig. (5) Details of geometric layout and land use of surrounding area of the studied roundabout

Table (4) Geometric features of the approaches to the studied roundabout

Approach	No. of lanes	Width at stopline (m)
To Ahmad Uraby square	3	10
To Al – Sada	3	10
To Al – Nadhmiya intersection	3	10
To Amar Bin Yassir street	3	11

Fig. (6) shows the geometric layout used in the second proposal. In this proposed layout, the inner circle diameter reduced to increase the space available for the circulating flow.
The new geometric and vehicle flow data together with all necessary information input to the SIDRA program. Results of the analysis presented in **Table (5)**. The resulting reserved capacity as calculated by the analysis program is (2%). This reserved capacity is relatively low. Therefore, it was necessary to consider further improvement to this proposal.
Fig. (7) shows the third proposed geometric layout. In this geometric layout the conflict between traffic coming from AL – SADAA approach with that coming from the circulating flow reduced. The reduction made by the channelization of the circulating traffic as presented in **Fig. (7)**.
Following the analysis of the third geometric layout, the calculated reserved capacity was (18%) as anticipated by the SIDRA program. In addition, the degrees of saturation and average vehicle delay were much lower than that of the second proposed layout. Results of the analysis presented in **Table (6)**.

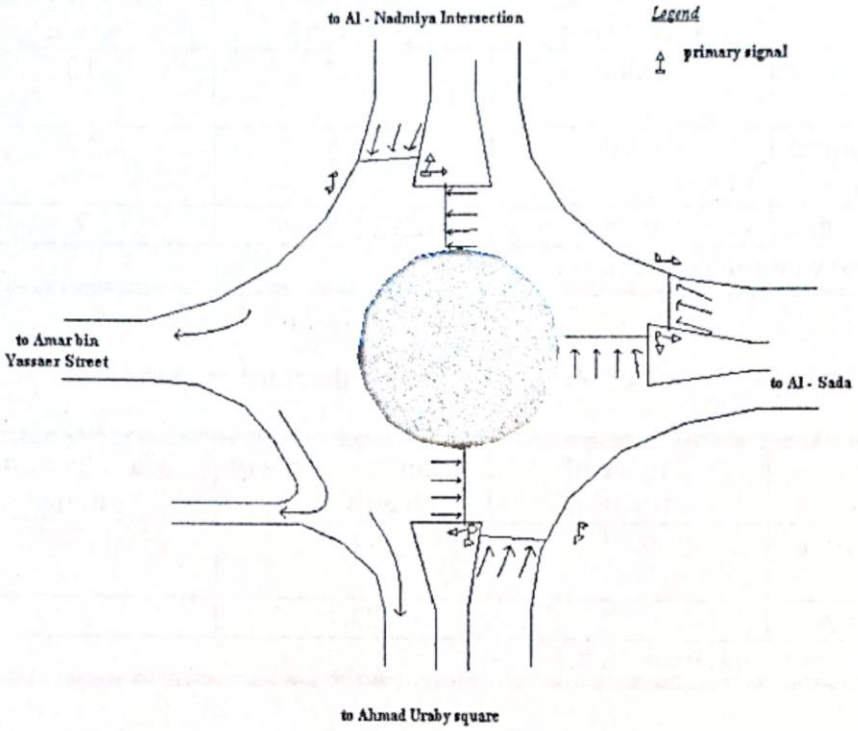

Figure (6) Second examined geometric layout of reduction of central island diameter and installation of traffic signals

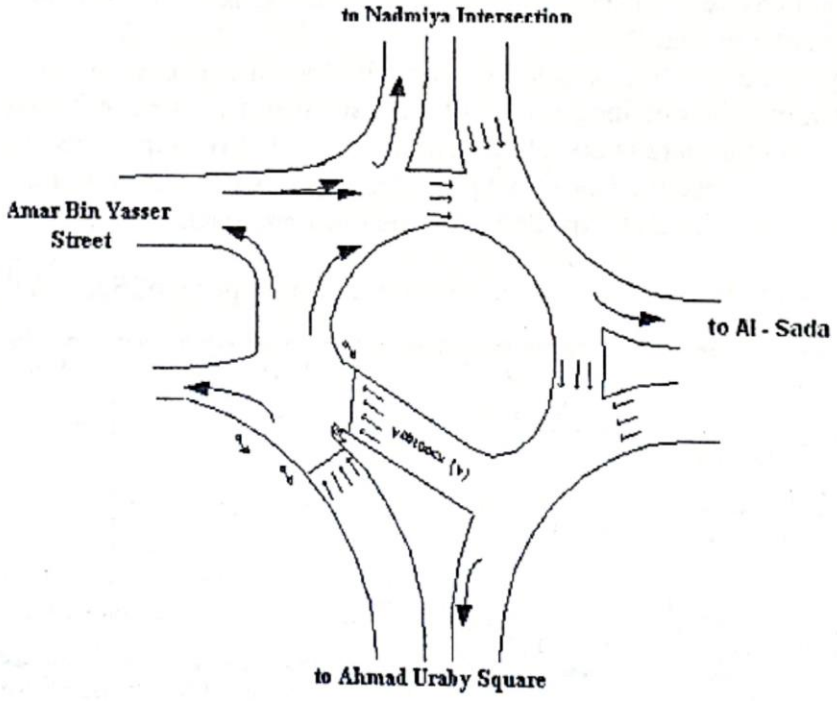

Fig. (7) Third examined geometric layout and the obtained results

Table (5) Details of obtained results of the second proposal

Direction	Degree of saturation	Mean delay (sec/veh)	Max. back of queue
From Nadmiya Int.	0.82	11.2	10
From Ahmad Uraby Square	0.90	20.5	17
From Al – Sada	0.75	26.8	7
Practical spare capacity = 2%			

Table (6) Details of obtained results of the third proposal

Direction	Degree of saturation	Mean delay (sec/veh)	Max. back of queue
From Nadmiya Int.	0.75	14.8	13
Approach A	0.77	23.1	8
Practical Spare Capacity = 18%			

At this stage of the analysis process, it was realized that, no further improvement could be made to the roundabout to achieve the objectives of low vehicle delay and relatively high reserved capacity. Therefore, it was necessary to consider another feasible geometric layout and method of control of traffic movements. The possible alternative is the conversion of the roundabout into a signalized intersection.

The considered alternative is that proposed by Scott Wilson company during the course of BCTS (Baghdad Comprehensive Transportation Study) (Scott W. K. and Partners 1980). Details of the fourth proposal shown in **Fig. (8)**.

The geometric, phasing and timing data together with the other necessary information were input to the analysis software. The obtained results of analysis also presented in **Table (7)**. Examination of these results suggest that there is no substantial difference between the outcome of this modification in comparison with the described as above proposals. This is in addition to the reduction in reserved capacity in comparison with that expected from the third proposal.

Table (7) Details of obtained results of the fourth proposal of Scott Wilson (BCTS)

Direction	Degree of saturation	Mean delay (sec/veh)	Max. back of queue
From Nadmiya Int.	0.73	21.9	8
From Ahmad Uraby Sq.	0.82	25.3	11
From Al - Sada	0.80	39.2	5
Practical spare capacity = 11%			

Based on the above analysis and obtained results, it was decided to modify Scott W. K. and Partners (1980) proposed intersection geometric layout, phasing and timing plans.

The modified geometric layout, phasing and timing plans, and the obtained results of analysis shown in **Fig. (9)**. The presented data indicates substantial reduction in degree of saturation, vehicle

mean delay and vehicle queue length. In addition to that, the reserved capacity increased to 38%. This increase is tangible in comparison with discussed as above results.

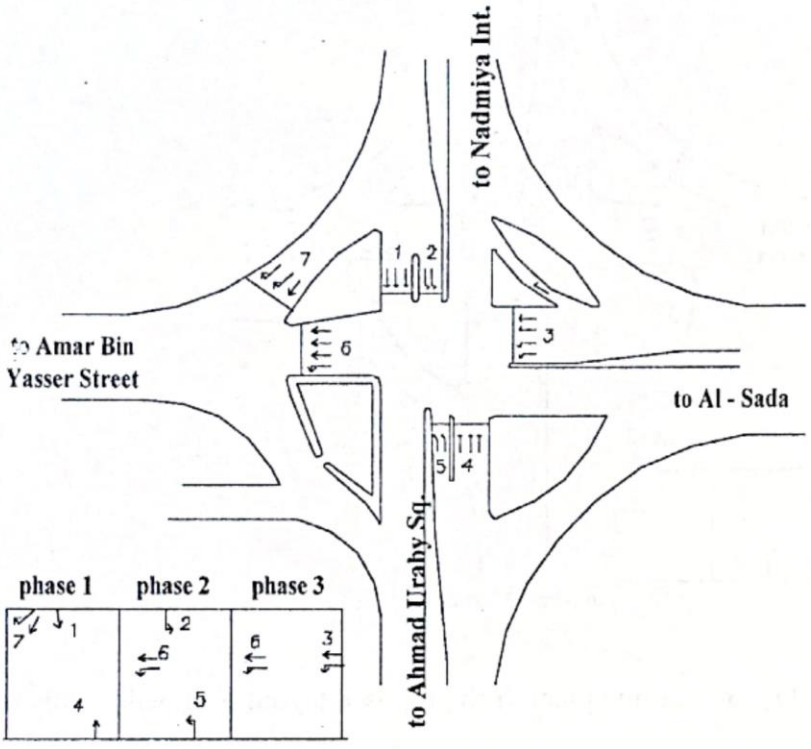

Fig. (8) Fourth geometric layout and the phasing plane proposed by Scott Wilson (BCTS Study)

CONCLUSIONS

To assist concluding the carried out analysis, the obtained results of the different examined proposals summarized in **Table (8)**. Comparison between the presented data indicates that the fifth proposal is possibly one of the best feasible solutions to the traffic movement problems at the studied site.

The Local Authorities (AMANAT BAHGDAD) sponsor the conclusion of this research project and the large roundabout converted to a signalized intersection. The geometric layout, phasing and timing plans of the fifth proposal applied on site. Observation of traffic behavior following the conversion indicates a considerable improvement in traffic movement performance.

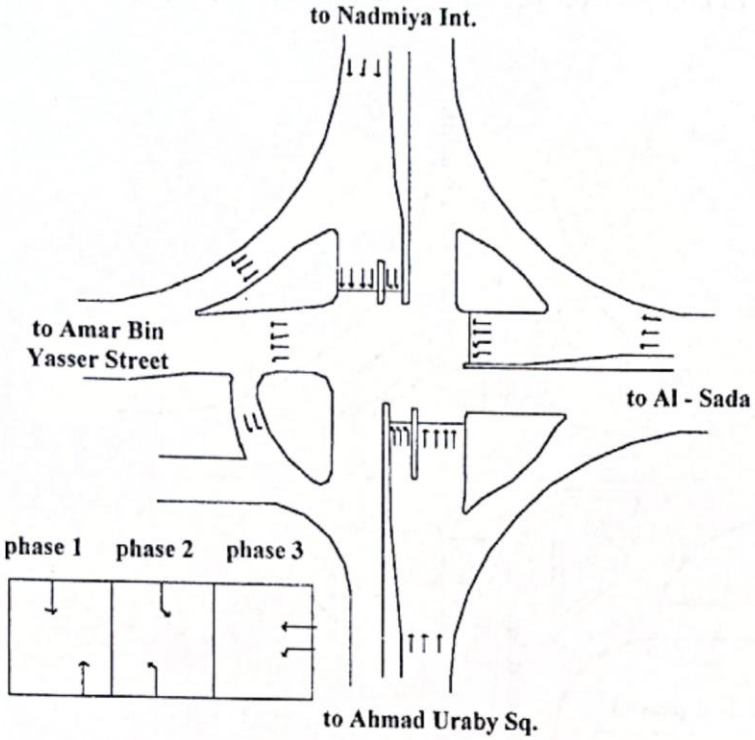

Fig. (9) Geometric layout, phasing plane fifth proposed layout obtained by this study

Table (8) Comparison between results of analysis of the different examined proposals

Proposal No.	Vehicle mean delay (sec/veh)	Vehicle queue length per lane	Degree of saturation	Reserved capacity
2	18.1	17	0.90	2%
3	18.5	13	0.77	18%
4	27.5	11	0.81	11%
5	21.3	7	0.65	38%

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