KUFA JOURNAL OF ENGINEERING
ISSN 2071-5528
PRINTED IN IRAQ

Volume 4, Number 1 pp.39-51, 2012

The Median U-Turn Intersection Treatment (MUTIT) as an Alternative for Congestion at Intersections

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(Received: 31/1/2012; Accepted: June/2012)

Abstract:

Throughout urban and suburban areas, congestion at intersections going continuously to worsen, especially, in such high religious tourism cities like Najaf city. One potential treatment to combat congestion and safety problems at intersections is the Median U-Turn Intersection Treatment (MUTIT), which has been used worldwide extensively for many years and has been implemented successfully in recent years.

This paper summarizes the advantages and disadvantages of the MUTIT as alternative to conventional, un-signalized and signal-controlled intersections with left turns permitted. Furthermore, presents the design guidelines including the location and design of the median crossovers on the major roads. Many of the guidelines presented here are from the Michigan Department of Transportation (MDOT), and the 2004 AASHTO Green Book (AASHTO2004) The paper also takes three intersections in Najaf city in traffic volume counting, evaluation as intersection controls by roundabout once and by traffic signal in another, and discusses application criteria for the MUTIT, and presents how the performance of intersections, can be improved.

Keywords: ***HCS2000, multilane highways, MUTIT, roundabout, signalized intersection, Traffic operation, Un-signalized intersection.***

معالجة التقاطعات باستخدام جزرات الاستدارة الى الوراء (MUTIT) كبديل لمعالجة اختناقات تلك التقاطعات

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الخلاصة:

ازدحام التقاطعات المرورية يزداد شدة وسوءا بشكل متواصل في المناطق الحضرية والريفية على حدِ سواء. خصوصا في المدن ذات الطابع التجاري او الخدمي او السياحي العالي مثل مدينة النجف الاشرف حيث يزداد معدل السياحة الدينية فيها بشكل متسارع. من الطرق قليلة الكلفة والمعتمدة في تحسين مستويات الخدمة في التقاطعات ولتقليل الازدحام المروري هي معالجةُ تقاطعِ الاستدارة الوراء المتوسطةِ (MUTIT)، التي استعملت عالمياعلى نطاق واسع لعدّة سَنَوات وطُبّقتْ بنجاح في العديد من المدن.

يلخّصُ هذه البحث ايجابيات وسلبيات الMUTIT كبديل في التقاطعاتِ المسيطر عليها بدون أشاره مرورية ضوئية وبالإشارة المرورية الضوئية ولحركات اليسار المحمية في تلك التقاطعات. علاوة على ذلك، يُقدّمُ هذا البحث تعليماتَ التصميمَ الهندسي للموقعِ وتصميم حركات الاستدارة على الطرق الرئيسيةِ اعتمادا على عدد من المواصفات القياسية العالمية مثل مواصفة قسمِ ميشيغان للنقل (MDOT)، و كتاب آشتو الأخضر الـ ٢٠٠٤ (AASHTO2004) . كذلك يأخذ البحث ثلاثة تقاطعاتِ في مدينةِ النجف كحالة دراسة وتقييم من خلال حِساب الحجم المروري، التقييم الهندسي وتقييم مستوى الخدمة الحالي لها كتقاطعات مسيطر عليها باستدارة مرة وبإشارات مرورية مرة اخرى وتُناقشُ معاييرَ تطبيق ال MUTIT ويبين كيف يمكن إن يحسن أداء التقاطعاتِ ويرفع مستوى الخدمة فيها.

الكلمات المفتاحية: برنامج استيعابية الطرق ٢٠٠٠، طرق متعددة المسارات، جزرات الاستدارة الى الوراء (MUTIT)، الدوار، تقاطعات بإشارة ضوئية، تشغيل المرور، تقاطعات بدون اشارات ضوئية.

Symbols:

EB	East bound
HCM2000:	Highway Capacity Manual 2000
HCS2000:	Highway Capacity Software 2000
L	Left turn
LOS	Level of service
MODT:	Michigan Department of Transportation
MUTIT:	Median U-Turn Intersection Treatment
NB	North bound
pcphpl	Passenger car/ hour/ lane
PHF	Peak hour factor
R	Right turn
RTOR	Right turn on red
SB	South bound
Th	Through movement
v/c:	Volume/capacity ratio
WB	West bound

Introduction:

The Median U-turn Intersection Treatment (MUTIT) involves the elimination of direct left turns at signal-controlled or at-grad intersections from major and/or minor approaches. Drivers desiring to turn left from the major road onto an intersecting cross street must first travel through the at-grade, signal-controlled intersection and then execute a U-turn at the median opening downstream of the intersection. These drivers then can turn right at the cross street. For drivers on the side street desiring to turn left onto the major road, they must first turn right at the signal-controlled intersection and then execute a U-turn at the downstream median opening and proceed back through the signalized intersection. The (MUTIT) can be implemented with and without signal control at the median openings on the major road. Figure 1 shows the schematic for a typical MUTIT. Levinson et al. (Levinson et al., 2000) recommended that the application of MUTIT along the corridor should not be mixed with other indirect left-turn treatments or conventional left-turn treatments, thereby meeting driver expectancy. Figure 2 shows the MUTIT movements corresponding to left turns at conventional at-grade intersections.

The MUTIT has been used in several highways in Michigan, particularly in the Detroit Metropolitan area, were constructed with wide medians on wide rights of way. Many of these medians are 18.3 to 30.5 (m) (60 to 100 (ft)) wide in semi-rural areas to separate opposing directions of traffic and to provide an adequate median width for landscaping and beautification. By the early 1960s, many of these highways had capacity problems, generally because of interlocking left turns at the conventional intersections. Partial implementations or designs with similar concepts have appeared in Florida, Maryland, New Mexico, and New Orleans (Taylor, et al, 2007). Hummer and Reid (Hummer, et al, 1999) and Levinson et al. (Levinson et al. 2000) compared the MUTITs to conventional intersections. Hummer and Reid (Hummer, et al, 1999) recommended that agencies consider the median U-turn alternative for junctions on high design arterials where relatively high through volumes conflict with moderate or low left-turn volumes, regardless of the cross-street through volumes.

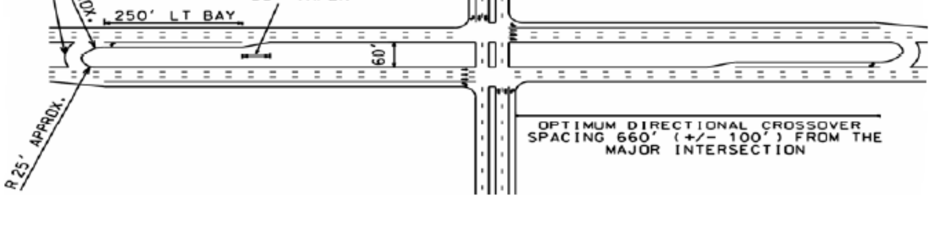


Fig.1 typical schematic of MUTTT (Taylor, et al, 2007)

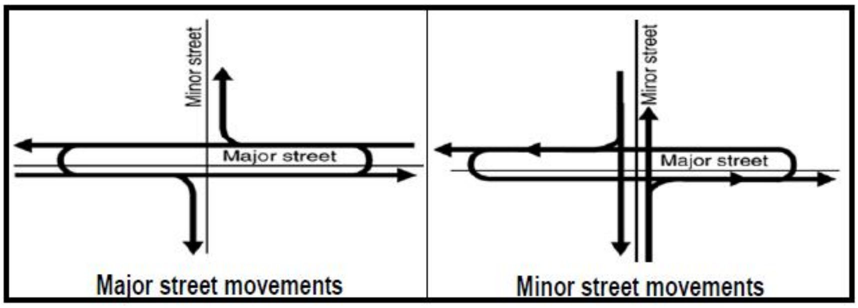


Fig.2 vehicular movements at MUTTT (Taylor, et al, 2007)

Some of the (MUTIT) s advantages cited include:

- Reduced delay and better progression for through traffic on the major arterial.
- Increased capacity at the main intersection.
- Fewer stops for through traffic, especially where there are STOP-controlled directional crossovers.
- Reduced risk to crossing pedestrians.
- Fewer and more separated conflict points.

Some disadvantages include:

- Possible driver confusion and disregard of left-turn prohibition at the main intersection.
- Possible increased delay, travel distances, and stops for left-turning traffic.
- Larger rights of way required for the arterial, although this potentially could be exceeded by the provision of loons on roads with narrow medians.
- Higher operation and maintenance costs attributable to additional traffic signal control equipment if the directional crossovers are signalized.

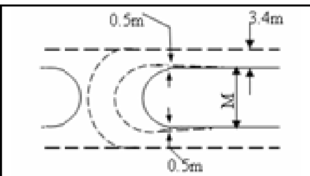
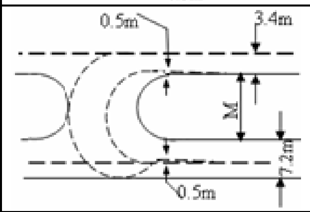
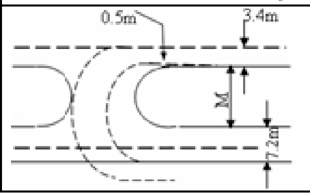
MUTIT Design Guidelines:

The 2004 AASHTO Green Book (AASHTO, 2004) recommends a distance of 122 to 183m (400 to 600 ft) for the min. spacing between the median crossover and the MUTIT intersection. The longer distance facilitates the completion of the U-turn maneuver at the median crossover and subsequent right turn maneuver at the intersection of the major road and cross street for a 72 km/h (45 mi/h) posted speed limit on the major road. The Access Management Manual recommends an access spacing of 201m (660 ft) on minor arterials and 402.3m (1320 ft) on principal arterials between consecutive directional median openings on divided highways. Table 1 gives the minimum median widths required for U-turns from the major road as suggested by The 2004 AASHTO Green Book.

Location and Design of Median Crossovers:

Figure 3 shows the two types of median crossovers, the “bidirectional” and the “directional.” A bidirectional crossover is simply an opening in the median for vehicles to make U-turns from either direction. Bidirectional crossovers are sometimes installed without any deceleration or storage lanes. With high turning volumes, an interlocking effect is sometimes created. A directional crossover is a one-way crossover with a deceleration/storage lane. As a result, motorists at a properly designed directional crossover should never experience the interlocking effect found at medians with a bidirectional crossover.

Table 1 the minimum median widths required for U-turns from the major road (AASHTO,2004).

TYPE OF MANUVER		M- Min Width of Medians (M) For Design Vehicle						
		P	WB-12	SU	BUS	WB-15	WB-18	TDT
		LENGTH OF DESIGN VEHICLE (m)						
		5.7	15.0	9.0	12.0	16.5	19.6	35.4
Inner lane To inner lane		9	18	19	19	21	21	30
Inner lane To outer lane		5	15	15	15	18	18	27
Inner lane to shoulder		2	12	12	12	15	15	24

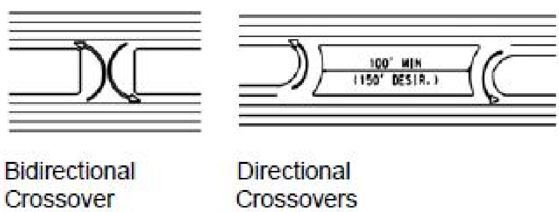


Fig.3 bidirectional and directional crossovers (AASHTO,2004)

Taylor et al. (Taylor et al, 2001) studied the effects of replacing existing bidirectional crossovers with directional crossovers on eight roadway sections in Michigan between 1991 and 1997. The important findings of this study were:

- The average reduction in total crash frequencies was 31%.
- The average reduction in injury crash frequencies was 32%.
- The crash types that experienced the largest decreases in crash frequency were rear-ended and angle crashes. This effect was attributed to the lack of storage space and restricted visibility associated with bidirectional crossovers. There was an average 37% reduction in rear-end crashes when the bidirectional median crossovers were converted to directional median crossovers.
- Replacing bidirectional median crossovers at four-legged intersections and three-legged intersections produced reductions in total crash frequencies of 58 % and 34 %, respectively.

Capacity of Un-signalized U-Turn Lanes:

The Highway Capacity Manual 2000 (HCM2000) treats U-turns as left turns for estimating saturation flow rate. However, the operational effects of U-turns and left turns are different. U-turning vehicles have slower turning speeds than left-turning vehicles. Al-Masaeid (Al-Masaeid, 1999) studied the capacity of U-turns at un-signalized intersections as a function of the conflicting traffic flow on two opposing through lanes for median-divided roadways in Jordan. He developed regression equations to predict the U-turn capacity based on the conflicting flows on two opposing through lanes.

Case study:

AL-Salam, AL-Garage alshamali, and AL-Maqbara (AL-Hizam alakhder) intersections in Najaf center city, were selected for case study that are suffering from traffic congestion especially in last a few year where many thousands of vehicles have been imported to Iraq without any evaluation or studies for roads and intersections capacities and operations. These intersections are the main features of the transport networks in the city. The traffic condition and geometric characteristics of the intersection affect the motion of the vehicle. Traffic flow interference may be caused by weather conditions, cross traffic, an accident, or other marginal conditions.

Interference to traffic flow by one or more of these conditions cause reduction in speed, closer vehicle spacing, and greater density (Pignatro, 1973).

The studied area is located within the urban area, which is characterized by a large number of commercial shops, and private and governmental offices. In addition to that, these intersections connect the city with other rounded cities.

Geometric and Volume Data Survey:

Data observations and recordings were made during February (2011). Measurements and classifications traffic volumes entering the intersections were made manually at site. The traffic volume is classified into two classes, passenger car and heavy vehicles in order to obtain accurate volume variations by vehicle type. Heavy vehicle is defined as “any vehicle having more than four tires touching the pavement” (HCM, 2000). Table 2 represents the traffic data collection and the details of geometric design for the three intersections in addition to the names of four directions streets. The traffic volume ranges between (97-1536) veh/h, percentage of heavy vehicles ranged between (0-34.0) percent.

The Data Analysis Results:

Although, that the methodology presented by HCS2000 for un-signalized intersection from Roundabout types, is for one line rounding, this methodology was depend in evaluation the performance of the selected three intersections. The traffic analysis results for these three intersections, which analyze as un-signalized intersection from type (Roundabout), shown in table 3 below in terms of approach capacity and volume/capacity (v/c) ratios depending on the traffic volumes collected and estimated values of variables required according to HCS2000. It is obvious from result data in table 3, that all approaches for all approaches in these intersections have a problem in operation due to the capacity less than the flow rate and traffic volume causes high values of v/c ratios. Where, it well knowing that in order to keep any intersection in acceptable level of services it should be have a value of v/c ratio less than 1(HCM2000).

There is another attempt to analyze these three intersections as signalized intersections according to HCS2000 methodology for signalized intersection representing in figure 4 that explain the methodology of analysis, and after a lot of trials in changing the No. of lanes in each movement, phasing and timing it could be saying there is no typical solution for arising their levels of services by adding traffic signal due to high traffic volumes and the geometric design limitation. Therefore, because of the delay time is in high level and cycle length is full, a lower level of service (LOS) accrue in all approaches and as a result, the three intersection present a LOSF. Best trial of them are shown in table 4 for each intersection, in terms of cycle length, lane group capacity, v/c ratio, control delay, lane group LOS, approach delay, approach LOS, intersection delay, and intersection LOS. While figure 5 illustrated the configuration of intersection, lane group, phasing, traffic volumes, and No. of lanes used as input data in the analyzing the intersections as signalized intersections.

Table 2 the data of geometric design and traffic volume for the three selected intersections

Variables	Intersection name: Al-Salam intersection											
Type	Unsignalized intersection (Roundabout)											
Direction	SB			WB			NB			EB		
Street name	Al-Salam- Al-Gharry			Al-Hizam			Al-Ghadeer			Al-Najaf		
No. of lane	3			4			4			4		
Movement	L	TH	R	L	TH	R	L	TH	R	L	TH	R
Lane width	4.6	4.8	3.9	4.6	4.8	4.5	4.4	4.8	3.9	4.6	4.8	4.5
Volume(veh./h)	1013	1220	678	975	1536	253	489	522	371	415	628	297
PHF	0.83	0.92	0.95	0.88	0.83	0.84	0.73	0.89	0.61	0.83	0.92	0.95
flow rate	500	682	312	1107	1850	301	669	586	608	500	682	312
% heavy veh	6	14	13	6	11	10	24	14	0	2	10	7
Variables	Intersection name: Al-Garage intersection											
Type	Unsignalized intersection (Roundabout)											
Direction	SB			WB			NB			EB		
Street name	Karbala- Najaf			Al-Gammea			Najaf - Karbala			Al-Mohandeseen		
No. of lane	4			4			4			4		
Movement	L	TH	R	L	TH	R	L	TH	R	L	TH	R
Lane width	3.2	4.8	3.3	3.7	4.8	3.8	4.6	4.8	4.1	3.6	4.8	3.9
Volume(veh./h)	524	2494	156	133	369	440	223	1153	222	97	325	411
PHF	0.79	0.90	0.83	0.83	0.95	0.95	0.78	0.97	0.74	0.78	0.85	0.81
flow rate	663	2771	187	160	388	463	285	1188	299	124	382	507
% heavy veh.	23	1	19	24	21	31	12	11	34	15	14	14
variables	Intersection name: Al-Maqbara intersection											
Type	Unsignalized intersection (Roundabout)											
direction	SB			WB			NB			EB		
Street name	Karbala- Najaf			Al-Maqbara			Najaf - Karbala			Al-Mohandeseen		
No. of lane	4			4			4			3		
Movement	L	TH	R	L	TH	R	L	TH	R	L	TH	R
Lane width	3.6	4.8	3.6	3.7	3.7	3.6	3.6	4.8	3.6	3.7	3.7	3.6
Volume(veh./h)	246	2325	136	259	287	316	113	1079	113	123	265	68
PHF	0.73	0.95	0.71	0.82	0.92	0.88	0.76	0.71	0.72	0.94	0.87	0.74
flow rate	336	2447	191	315	311	359	148	1519	156	140	304	91
% heavy veh.	4	2	11	2	1	0	5	3	3	7	9	9

Table 3 the results of analyzing intersections as un-signalized intersection.

Variables		Intersection name: Al-Salam			
		EB	WB	NB	SB
Capacity	Upper bound	96	189	180	35
	Lower bound	188	369	355	59
v/c ratio	Upper bound	15.56	17.24	10.35	42.69
	Lower bound	7.95	8.83	5.25	25.32
Variables		Intersection name: Al-Garag			
		EB	WB	NB	SB
Capacity	Upper bound	23	227	387	363
	Lower bound	49	208	331	347
v/c ratio	Upper bound	44.04	4.45	6.17	9.98
	Lower bound	20.67	4.86	5.35	10.44
Variables		Intersection name: Al-Maqbara			
		EB	WB	NB	SB
Capacity	Upper bound	57	157	421	449
	Lower bound	19	116	360	475
v/c ratio	Upper bound	9.21	6.27	4.33	6.62
	Lower bound	27.63	8.49	5.06	6.26

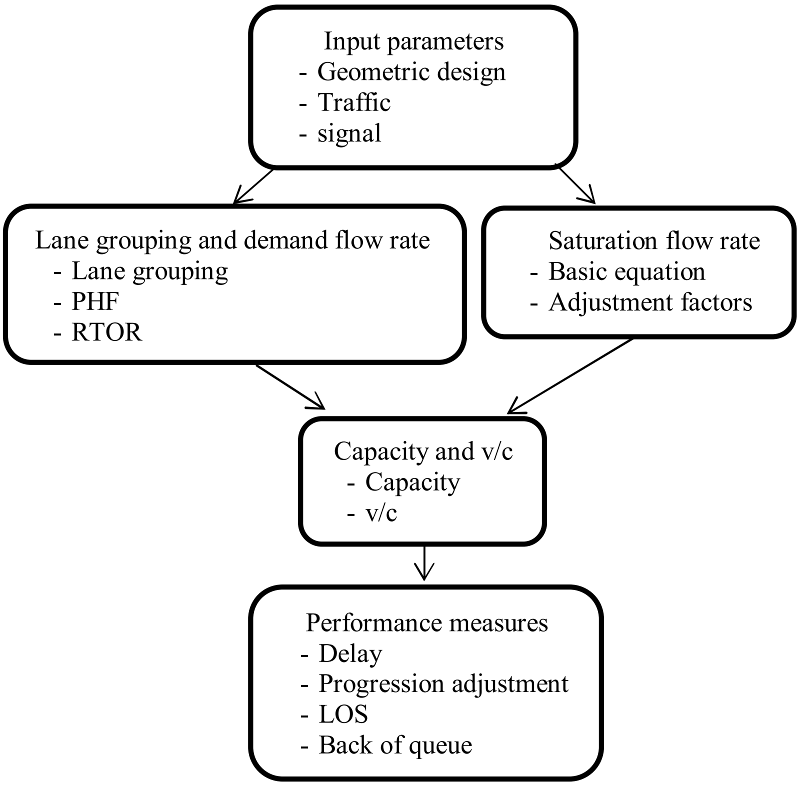


Figure 4 Signalized intersection methodology flow chart (HCM2000)

Highway Capacity Manual (HCM2000) used travel speed and v/c ratio to distinguish between various levels of service. The value of v/c ratio can vary between 0 and 1. Depending upon the travel speed and v/c ratio, HCM has defined six levels of service, level A to level F. The ideal condition representing by LOSA, the design condition representing by LOSD, while the worse operation condition cause LOSF. In other words, level of service F represents the region of forced flow that having low speed and required a real changes and improvements.

Table 4 the results of analyzing intersections as signalized intersections.

Variables	Intersection name: Al-Salam trial No.1											
	EB			WB			NB			SB		
	L	Th	R	L	Th	R	L	Th	R	L	Th	R
Cycle length (sec)	120											
Lane group capacity	264	496	747	524	1009	727	329	859	0	253	253	598
v/c ratio	1.89	1.38	0.28	2.11	1.83	0.41	2.04	0.68	0	4.82	2.72	0.43
Control delay (sec)	466	232	18	549	421	20.7	521	43.9	0	999	833	24.8
Lane group LOS	F	F	B	F	F	C	F	D		F	F	C
Approach delay	284.5(sec)			427.8(sec)			298.5(sec)			523(sec)		
Approach LOS	F			F			F			F		
Intersection delay	608.8(sec)						Intersection LOS			F		
Variables	Intersection name: Al-Garage trial No.1											
	EB			WB			NB			SB		
	L	Th	R	L	Th	R	L	Th	R	L	Th	R
Cycle length (sec)	120											
Lane group capacity	293	665	637	330	748	548	373	768	534	272	763	551
v/c ratio	0.42	0.57	0.73	0.48	0.51	0.84	0.76	1.55	0.56	2.60	3.63	0.34
Control delay (sec)	45.7	46.5	31.7	43.5	41.6	41.8	56.3	299	27.4	779	833	22.0
Lane group LOS	D	D	C	D	D	D	E	F	C	F	F	C
Approach delay	39.3(sec)			42.0(sec)			214.5(sec)			623.7(sec)		
Approach LOS	D			D			F			F		
Intersection delay	598.7(sec)						Intersection LOS			F		
Variables	Intersection name: Al-Maqbara trial No.1											
	EB			WB			NB			SB		
	L	Th	R	L	Th	R	L	Th	R	L	Th	R
Cycle length (sec)	120											
Lane group capacity	264	496	747	524	1009	727	329	859	0	253	253	598
v/c ratio	1.89	1.38	0.28	2.11	1.83	0.41	2.04	0.68	0	4.82	2.72	0.43
Control delay (sec)	466	232	18.3	549	421	20.7	521	43.9	0		833	24.8
Lane group LOS	F	F	B	F	F	C	F	D		F	F	C
Approach delay	284.5(sec)			427.8(sec)			298.5(sec)			765.8(sec)		
Approach LOS	E			E			F			F		
Intersection delay	482.3(sec)						Intersection LOS			F		

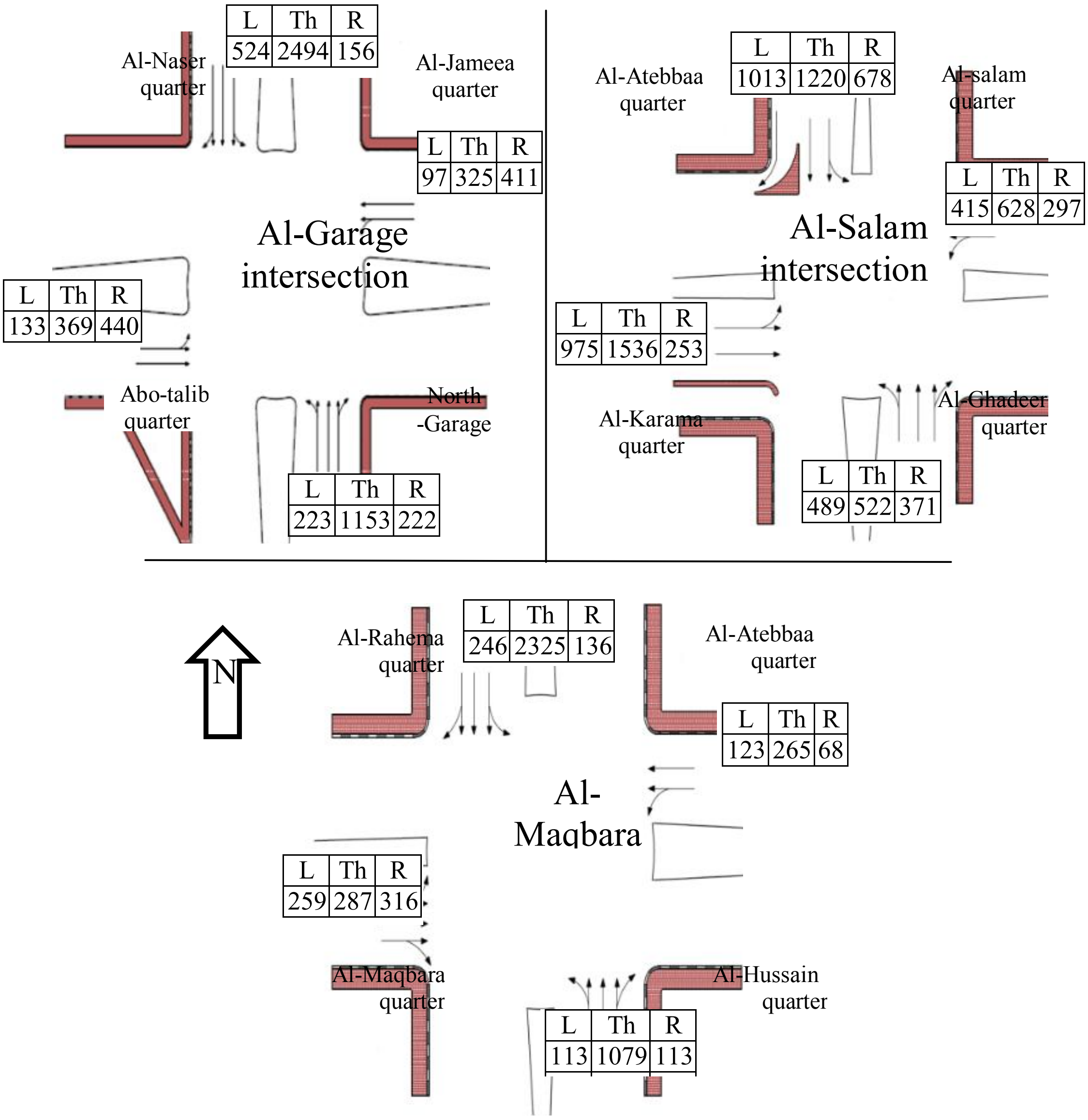


Figure 5 The configuration, phasing, and volumes of signalized intersections

The performance improvement of intersections:

In order to improve the performance of the selected area, it should be change them to at-grade intersections. Furthermore, in order to reduce the cost of construction, it should be depended typical MUTIT intersection in major and minor direction for all left turn movements. The position of U-turns will be in about 500m from the center of intersection in both directions. The right turn will be exclusive for all approaches. In this case the major and minor direction will be classify as multilane highway and easily can be analyze using the methodology presented by HCS2000. Table 5 shows the analysis results of the three intersections in terms of flow rate, LOS, and density, for analyzing as multilane highway. The selected design speed is 100km/h for all approaches. The analysis result gave a free flow speed equal to 98km/h for all approaches of intersections due to the union of assumed input data depending in the improvements, such as lane width, No. of access point, type of median (divided), and lateral clearance. It is obvious from data in table 5 that there a huge improve in performance of the selected intersections, as clear from the low values of density, high level of LOS, although for high values of flow rate for all approaches.

Table 5 the results of analyzing intersection as at-grade intersections and multilane highways.

variables	Intersection name: Al-Salam			
	Major highway		Minor highway	
	Al-Ghadeer- Al-Gharry		Al-Najaf- Al-Hizam	
	Going	coming	Going	coming
flow rate, pcphpl	446	876	683	1076
LOS	A	B	A	B
Density, pc/km/ln	4.5	8.9	7	10.9
No. of lanes	3	3	2	2
variables	Intersection name: Al-Garage			
	Major highway		Minor highway	
	Najaf - Karbala		Al-Mohandeseen - Al-Gammea	
	Going	coming	Going	coming
flow rate, pcphpl	555	870	345	379
LOS	A	B	A	A
Density, pc/km/ln	5.6	8.8	3.5	3.8
No. of lanes	3	3	2	2
variables	Intersection name: Al-Maqbara			
	Major highway		Minor highway	
	Najaf - Karbala		Al-Mohandeseen - Al-Maqbara	
	Going	coming	Going	coming
flow rate, pcphpl	567	1063	270	331
LOS	A	B	A	A
Density, pc/km/ln	5.7	10.8	2.7	3.4
No. of lanes	3	3	2	2

Conclusions:

Three intersections in Najaf city was taking in counting for traffic volumes and geometric design and evaluated for performance. The results obtained from analyzing these intersections by HCS2000, as un-signalized and signalized intersections worse than been accepted. Typical MUTIT intersection treatments were depending in improving performance in addition to convert these intersections to at-grade intersection. The following points can be concluded from this work:

1- Analyzing the intersection as un-signalized intersections from type roundabout by HCS2000 program gave over capacity (v/c) for all approaches;

2- Converting these intersections to signalize intersections not possible due to the results obtained by HCS2000 program, present the level of service for all approaches from type F;

3- By comparison between the results of evaluate for un-signalized and signalize intersections, there was no real improvement;

4- Convert the intersection to at-grade intersections will change the approaches to multilane highways; that represents the huge need to redesign all intersections and enhance the present service.

5- Depending typical treatments of MUTIT intersection enhance the level of service in incomparable values (LOS was (A, B)).

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