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EVALUATION AND IMPROVEMENT OF TRAFFIC FLOW PATTERNS IN URBAN CENTERS

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ABSTRACT

Presented in this paper is process of evaluation and improvement of traffic flow pattern in urban centers. The process is carried out by applying TRANSYT-7F program. The data was collected from a selected network within the study area, which is presented by Kirkuk City. The observations consisted of geometric and traffic data. The existing condition was first evaluated, then different improvement strategies were designed and examined. The results of the analysis suggested some important conclusions to be taken into account by traffic authority in the city to improve the existing flow pattern.

I. GENERAL

The obvious indication of progress and development of the urban societies may be presented by the high standards of traffic regulations and efficient operation of their transportation system. Therefore, road traffic congestion has a major issue and imposes a considerable burden on the local economy, it contributes to accidents, noise and atmospheric pollution. Moreover it creates anxiety, frustration and stress among all classes of road users.

Congestion has many different causes, but the ones that come most readily to mind are traffic growth and bottlenecks within the road network [1]. One of the visible improvements of vehicular traffic control, which provides quick and safe travel from place to another, is the traffic signal. Most of the recent studies have shown that the traffic signal, when not operating efficiently, the consequences would be high percentage of air pollution due to vehicle emissions. This may be caused by the high percentage of the total waste fuel consumed from excessive delay and stops [2]. Therefore, a decision on the installation of traffic signal at an intersection should be based on the expected improvements that may be achieved by optimization or re-timing the traffic signals and interconnecting the individual isolated signalized intersections into a coordinate signal network system.

An improvement of the effectiveness of the traffic control parameters would also contribute to reduce the congestion and interruption of the traffic flow along the network. In order to obtain an effective and efficient traffic network operation an improvement in the elements of traffic operation should be considered such as selecting the best phase sequences, designing alternatives of traffic pattern along network system, and improving the network geometric conditions [3].

Recently, several signal timing optimization computer programs became available for traffic engineers to develop and improve signal-timing plans along arterial or network systems. Some of these programs deal with intersection optimization such as SOAP/M and TEXAS [4], where as others deal with arterial optimization such as PASSER and MAXBAND, or network simulation programs such as TRANSYT, SIGOP, NETSIM, SATURN and TRAFFICQ [5]. These programs have a sophisticated traffic flow model, which allows for realistic modeling of turning movements, queuing and platoon of vehicle [5]. Some programs also have the ability of re-routing (i.e., assignment) travel paths through the network such as SATRUN and TRAFFICQ programs [7].

II. OBJECTIVE OF THE STUDY

The objective of the present study is directed towards evaluating and improving the traffic flow movements for both the existing and forecasted conditions along the intersections of an urban center. Also, the study considers an improvement of public transportation bus routes within the same urban center.

III. SITE SELECTION AND DATA COLLECTION

Following subsection explains some problems of traffic flow, as well as the collection of required data for the proposed study area.

1. Site Selection

The selected site in the present study is Kirkuk City, the provincial center of Ta,amim province. The city is about (255) km north of Baghdad, the capital. From the basic layout of the city, shown in figure (1), it can be noticed that the city is horizontally growing and expanding longitudinally at both west and east sides of Al-Chasa river, which divides the city into two parts. The east side (largest part), is named Al-Saoeb al-kiber, while the west part which situated at the other side of the river is named Al-Saoeb al-Sagher. Within the west part , the major Central Business District (CBD) area of the city is located, which encompasses large centers and employment retail activity, as well as, the government complexes. In addition, two major public transportation parks (PTP) with three secondary parks are also located in the west part. A dense residential area is situated at east part, as well as, the historical castle of the city, as illustrated in Figure (1).

Due to the nature and other restriction effects in north side of Kirkuk City, the growth of the city extended towards the south side, whereas, the CBD remained within the heart in the north side. However, no development occurred on the road and intersections, as well as, traffic system management in the CBD sector of Kirkuk City [3].

The north side of the city, with its two parts (specially the CBD area) represents the major retail and other pedestrian activities. Therefore, large numbers of daily trips are attracted to the CBD area, whereas the accessibility between these two adjacent parts is possible by four bridges. These bridges are distributed along the city's river, only the two smallest are situated in the north side (Al-Tabiqchaley and Al-Shohada), whereas the two other are situated in the south side of the city.

2. The Actual Problems

The most important factor that causes traffic congestion problems along the roads and intersections in the CBD area of Kirkuk City is the public transport vehicles, which have higher number of conflicts. Mainly, it is attributed to the existence of the PTP, in the CBD area of the city. In 1988, a decision was made to construct these parks. The reasons for constructing these parks are to collect and arrange the bus terminals into unified public transportation parks. Moreover, reduction of traffic congestion in the city center may be achieved. Recently, more development has been carried out in the retail and agricultural activities in Kirkuk City. This development is accompanied by an increase in the number of daily traffic volumes along the city network. Therefore, the CBD and arterial road leading to it have become the most congested area in the city.

This new situation of the limited lane width at the CBD roads and the high restriction of turning movements, accompanied by many other reasons, such as on-street parking of private vehicles, and buses in the vicinity of the PTPs makes the problem more complicated.

The above mentioned situation leads to increases in delays of both vehicles and personal trips, this increase is accompanied by an increase in the rate of accidents due to the high number of conflicts between buses and other vehicle movements.

For above reasons, the present study is conducted to reduce accidents, delays, exhaust emissions, vehicle noise and driver irritation, as well as, to increase the level of service of the overall CBD area.

3. Data collection

In order to satisfy the objectives set in section 2 above, data was collected regarding geometric and traffic aspects of the selected site. The details of data collection process are outlined in the following articles.

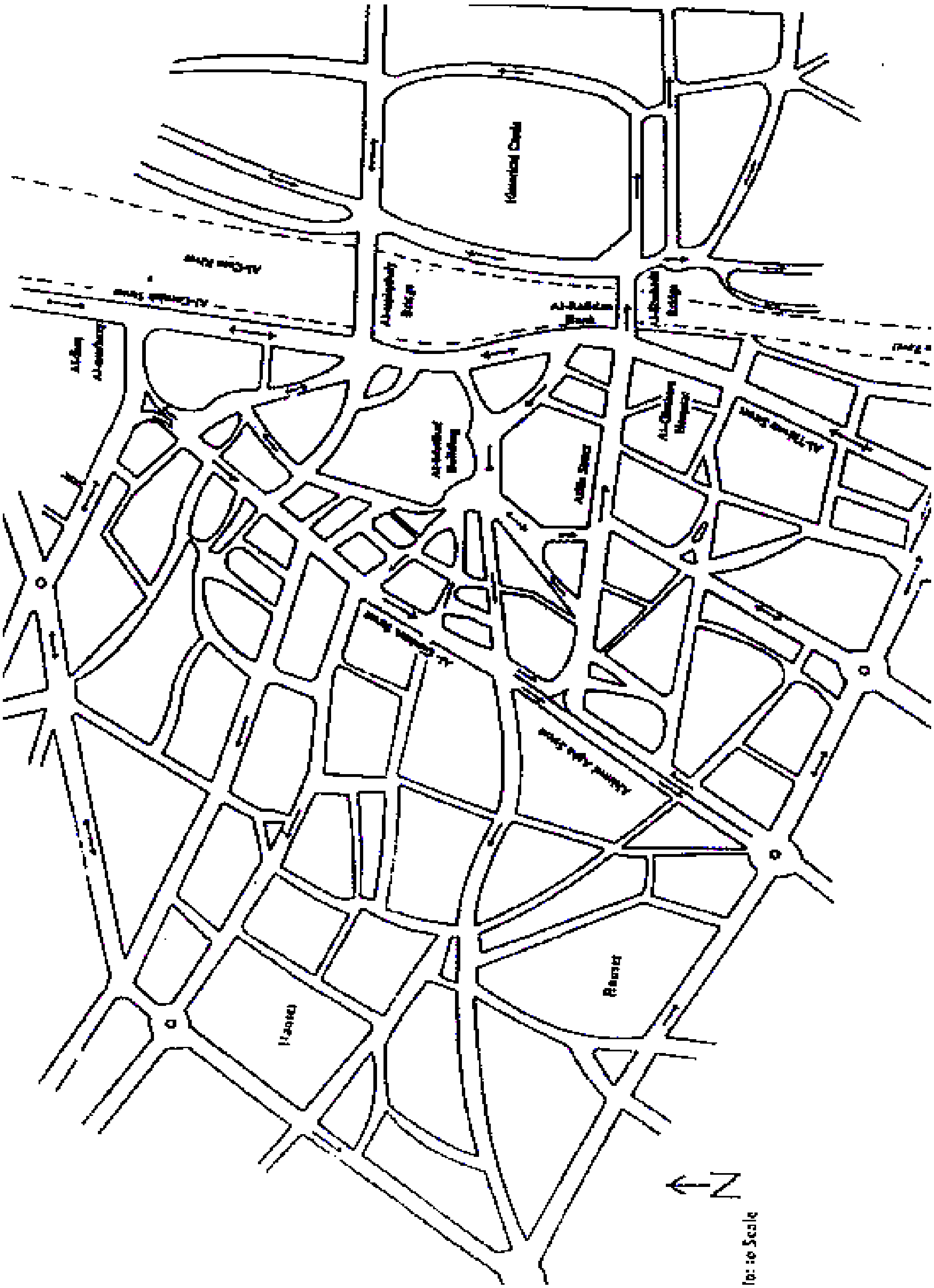

Fig. (1) Basic Layout of the Kirkuk City Center

3.1 Geometrical data

Figure (1) represents a plan of the study area, which consist of (28) intersections. Most of these intersections were unsignalized during the period of the survey. Details of geometrical data regarding these intersections, such as approach width and link length, were collected manually from the site using hand wheel.

3.2 Traffic Volume Data

The existing movement volumes have been collected manually during A.M. and P.M. peak hours for typical weekdays in a clear weather condition. Table (1) shows the existing total link volumes used in the present study.

3.3 Speed Data

Data regarding speed on the different links along the study area were collected, using spot speed concept, during the same selected peak periods.

3.4 Timing data

The timing data required in the present study were as follows:

- The network-wide start-up lost time at the beginning of green intervals.
- The network-wide extension of the effective green into the clearance intervals (Yellow + All Red)
- The Green, Yellow and All Red intervals for each intersection.

IV. METHODOLOGY

1. The procedure and methodology for analyzing traffic flow consists of:
2. Preparing geometric layout for the network and the nodes.
3. Assessment of peak periods for traffic network.
4. Data collection for the programs.
5. Warrants for traffic signals, and
6. Data preparation and coding of input data for TRANSYT-7F computer program.

1. Benefits of Coordinating Traffic Signals

The main concept of coordination is that the adjacent signals are coordinated on a common fixed cycle time, and vehicles travel between the signals in one compact ‘platoon’ per cycle. It may be possible to arrange the relative green time (offsets) so that more vehicles arrive at the downstream signal during its green time [7]. If this can be achieved, then approach queues will be reduced and traffic will suffer less delay, saving fuel consumption, reducing travel time and reducing the stops frequency. As a result, there will also be reduction in the number of exhaust emissions, accidents, vehicle noise, and driver irritation [8].

Many researchers (Robertson and Hunt [7], Castle and Takaski [9], and Willumsen and Coeymans [10]) stated that the benefits of coordinating traffic signals, in general, are affected by several factors, which reduce the coordination process efficiency. The first factor is the platoon of traffic that discharge during the green time of one signal and tends to spread out or disperse as the platoon travels towards the downstream signal. This effect becomes more marked as the time to travel between junctions increases. On long sections of the road, most of the benefits of coordination are likely to be lost because the platoons spread out with little difference between the minimum and maximum rates of flow in the cycle. The second factor is the secondary traffic flows that enter progressions from side-roads and hence make it more difficult to achieve ideal progressions. The third is the constraint, which the choice of the optimum coordination for one traffic stream imposes on other traffic streams [7]. The fourth is traffic flows that exceed the junction capacity so that long queues obstruct the movement of platoon [9]. The fifth, the excessive dispersion caused by double parking, bus stops and uncontrolled pedestrians crossing [10].

In order to reduce the effect of the above factors, Luck [11] explained that, several tools and concepts were provided on the coordination methods can be classified into two major types:

a. Fixed-time control.
b. Traffic-responsive control.

Table (1): Existing Total Link Volumes Used in TRANSYT-7F Program

Node No.	Link N0.	TrafficVolume (Veh/h)		Node No.	Link No.	TrafficVolume (veh/h)		Node No.	Link No.	TrafficVolume (veh/h)	
		A.M.	P.M			A.M.	P.M			A.M.	P.M.
1	101	422	506	6	609	150	240	15	1505	50	44
	102	1098	1120		610	130	134		1506	10	88
	103	482	502		611	134	130		1509	32	60
	106	228	362		612	46	208		1512	162	330
	110	44	62	7	701	558	592	16	1610	330	512
	111	636	684		703	408	510		1605	46	70
2	201	360	486		704	214	150		1606	20	30
	202	166	370		705	186	218		1609	60	170
	203	844	922		706	236	296	18	1801	64	64
	204	304	312		708	118	130		1802	104	108
	209	200	92		709	200	220		1807	418	574
	210	562	554		711	246	196		1810	82	112
	211	122	122		712	220	208	19	1910	210	274
	212	1420	1420	9	903	590	638		1902	172	172
3	301	1320	1550		904	638	604		1903	30	54
	303	534	654		909	690	1152		1907	598	564
	304	256	224	10	1003	658	618		1908	596	552
	305	468	144		1007	192	52		1910	52	40
	306	276	236		1008	618	598		1912	604	378
	309	778	570		1010	86	40	20	2003	188	182
	311	698	604	11	1103	418	918		2004	152	538
4	401	2124	1928		1107	166	182		2005	854	1044
	403	1560	1514		1108	276	476		2009	456	372
	409	324	528		1110	240	74		2011	438	390
	412	380	472	12	1203	460	1304	21	2102	1082	1358
5	501	2446	1972		1204	15	19		2107	736	658
	503	1176	1172		1205	66	40	22	2201	1044	846
	510	176	162		1211	45	42		2203	1230	1350
	511	710	656	13	1303	446	730		2210	736	658
6	601	174	134		1308	30	676	23	2301	1044	846
	602	100	118		1312	256	600		2302	660	944
	603	252	236	14	1405	620	704		2303	808	936
	604	246	202		1407	486	568		2310	424	414
	605	270	264		1408	96	256	24	2405	1220	1506
	606	174	152		1409	294	294		2406	410	324
	607	88	80		1411	358	484	26	2603	840	720
	608	42	38	15	1510	298	482		2609	328	446

V. EVALUATION AND IMPROVEMENT OF TRAFFIC FLOW

The improvement process consists of several strategies and sub-strategies, which can be applied to the network operation. These strategies represent the coordinated network operations at the existing traffic circulation pattern, and the coordinated alternatives of the traffic circulation pattern along the study area. The improvement method presents the most applicable improvement concepts that can be achieved. Most of the link movements, in the intersections at the study area are found as shared links and this due to the narrow approach width in most of the intersections. These shared links will, of course, interrupt the phase sequences schemes with means of leading, lagging and filtration of Right Turn on Red concepts. Therefore, the phase sequence schemes are applicable, particularly along some of the intersections before the suggestions of the geometric conditions improvements i.e., increase of the approach lanes number. The geometric improvements, then, will be adapted in the running of the program to check the sub-strategies, which have been already utilized before carrying out the improvement of the geometric design. These sub-strategies will be explained as follows:

- **Sub-Strategy Improvement No. One**

This improvement includes (if possible) the separate phase sequence of movements, (i.e. signal timing designed as separate phases, and work sequentially), the improvement also depends on the existing geometric conditions of the intersections.

- **Sub-Strategy Improvement No. Two**

This improvement includes (if possible) the leading phase sequence of movements, the improvement also depends on the existing geometric conditions of the intersections. The leading phase sequence means that left-turn movements are permitted after the first phase of protected same left-turn movements.

- **Sub-Strategy Improvement No. Three**

This improvement includes (if possible) the lagging phase sequence of movements, the improvement also depends on the existing geometric conditions of the intersections. The lagging phase sequence means that left-turn movements are protected after the first phase of permitted same left-turn movements.

- **Sub-Strategy Improvement No. Four**

This improvement includes the prevention of the on-street parking along some congested streets. In this case the number of lanes for the approaches will be increased.

- **Sub-Strategy Improvement No. Five**

Improvement of sub-strategy No. five includes the improvement of the geometric conditions of the intersections. Increasing the number of lanes will carry this out, so that the saturation flow rates increase. This is implemented by taking some spaces from the island width of approaches (if it is possible) as well as preventing the on-street parking (as discussed in the sub-strategy number four). The implementation of the sub-strategy stages is described as follows:

Stage Five A; includes the application of separate phase sequence schemes.
Stage Five B; includes the application of leading phase sequences schemes.
Stage Five C; includes the application of lagging phase sequences schemes.
Stage Five D; includes the best phase sequences schemes through the three stages above, moreover the applications of Right Turning Movement on Red (RTOR) can also be found in this stage.

In the CBD area of Kirkuk traffic network, the coordination system is not enough for the improvement process, because even after the implementation of the coordination system there will still be several streets where queue lengths exceed the street lengths. Consequently traffic jumps occur (i.e., spillover points) in the traffic movements at the up stream intersection of these queued links. Therefore, and according to the above issues, the decision of re-routing the network traffic pattern will be of great importance. This importance may increase the level of service of nodes and relieve the congestion in the vicinity of bus terminals by providing several alternatives of traffic circulation pattern along the network. This re-routing, of course, is done manually depending on specific assumptions suitable to the study area.

V. DISCUSSION OF RESULT

In the present article a discussion of the result achieved under the considered improvement strategies will be found. The comparative concepts and the tools used in the comparative analysis as well as the growth scenarios for the best alternative of the traffic circulation pattern are also included, in addition to the L.O.S. evaluation.

VI. COMPARISON CONCEPTS

The benefits prediction among the improvement strategies may include the following MOEs:

1. Maximum (v/c) ratio.
2. Number of saturated links.
3. Number of queued length that exceeds link length (spillover point).
4. Average delay (sec./veh.).
5. Average speed (km/hr).
6. Number of stopped vehicle (veh./h)or percent of stopped vehicle.
7. Total fuel consumption (LT/h)
8. Operating cost ($/h).
9. The major objective, performance Index.

Generally, the effects of the above concepts can be clearly demonstrated by the three final factors, which represent the M.O.E of the network. In the present study, two comparison concepts are carried out regarding the analysis result. These comparison concepts are as follows:

The best sub-strategy, in each strategy, can be selected directly according to the maximum reduction in M.O.Es, which are presented in tables of analysis process.

The selection of the best traffic flow pattern is achieved by comparing the M.O.Es. of the best sub-strategy along each coordinated alternative with the M.O.Es of the base case (i.e., Non-coordinated strategy).

6.1 The Coordinated Network Results at the Existing Traffic Flow

Several optimization runs are conducted for the area using TRANSYT-7F version-4 to coordinate the network operation. Tables (2) and (3) summarize the result of the comparison obtained for both the base and target years, respectively. An examination to the above-mentioned tables shows significant reductions in fuel consumption and operating cost, in addition to the great improvement of the network performance index, as a result of applying improvement sub-strategy 5 to the network. It is worthwhile mentioning that sub-strategy 5 includes all the other sub-strategies.

Table (2): Comparison of the MOE Between the Existing and Improved Coordinated Network, Under Base Year (1998)

Time Of Day	Fuel consumption (Lt/h)			Operating Cost ($/h)			Performance Index (P.I)		
	Exist.	Impro	Saving (%)	Exist.	Impro	Saving (%)	Exist.	Impro	Saving (%)
A.M.	4360	1789	+59	1234	758	+39	1162.0	239.2	+79
P.M.	5181	280	+60	1403	858	+39	1410.3	286.1	+80

Table (3): Comparison of the M.O.E Between the Existing and Improved Coordinated Network, Under Target Year (2008)

Time Of Day	Fuel consumption (Lt/h)			Operating Cost ($/h)			Performance Index (P.I)		
	Exist.	**Impro.**	**Saving (%)**	**Exist.**	**Impro.**	**Saving (%)**	**Exist.**	**Impro.**	**Saving (%)**
A.M.	36339	10174	+72	6861	2561	+61	12233	2898	+76
P.M.	44318	16453	+63	8232	3749	+54	14987	5008	+66

According to the above results, the decision for other improvement concepts must be implemented. The suggested improvements are presented by five coordinated alternatives for the traffic circulation pattern.

6.2 The Best Alternative for the Coordinated Traffic Network

Five coordinated alternatives of the traffic circulation pattern in Kirkuk City were designed. These alternatives represent most of the possibilities of the traffic flow along the CBD area of the city.

In order to achieve the best cycle length and total M.O.E, numerous optimization runs were applied to each sub-strategy improvement for all the alternatives.

With regard to the base year, it is found that spillover was relieved among all the alternatives. This means, that the M.O.E produced by the utilized program are realistically estimated. Some spillover link was found under the target year. According to the above issues, it can be concluded that the alternative results under the base year will give the realistic comparison, if considered to select the best traffic circulation pattern. Therefore, M.O.E that were estimated under the base year were considered to select the best traffic circulation pattern. For this purpose the second comparison concept was utilized to estimate the percent of savings in M.O.E that achieved by each alternative. The comparison considers the result of base case (i.e. non-coordinated network) as the base (existing) condition.

Finally, it is concluded that alternative of the coordinated traffic network is acceptable for both the base and target year. Therefore, the traffic circulation pattern generated from the mentioned alternative can be implemented with different growth scenarios.

6.3 Level of Service of the Intersections

Table (4) presents the L.O.S. of all intersections along the network, as well as, the average delay. HCM program (12) is considered to evaluate the L.O.S. for intersections using the same collected data, in addition to some geometric condition data.

It is apparent that the L.O.S for intersections at the selected alternative are operated at high level of service. Thus, for Growth Factor (G) =7% per year and along the next six years, the L.O.S. are between (A-B) level while, some drops of the L.O.S occur at the last four years. (i.e. 2004-2008).

VII. CONCLUSIONS

The following conclusions may be drawn from the present study:

1. The installation of traffic signals for the unsignalized intersections in the study area are warranted according to warrants given in the“ MUTCD”.
2. Higher delays, stops and fuel consumption were observed in the study area during the P.M. peak hour (4:30-5:30) than A.M. peak hour (9:45-10:45).
3. Maximum reduction of the measure of effectiveness of the existing coordinated network, as well as, the coordinated alternatives, which consists of geometric improvements and filtration of both left-turn and Right-

Turn On Red, were found in addition to the prevention of on-street parking along some Congested streets.

4. According to the maximum reductions in the measure of effectiveness, alternative No.5 was selected as the best traffic circulation pattern for the base and target years .Alternative No.4 was the second best alternative.

Table (4): The Level of Service for Intersections Using Alternative No. Five, Operated Under Base and Different Target Years

Intersection No.	Base year (1998) G=0%		Target year (2001),G=7%		Target year (2004),G=7%		Target year (2008),G=7%	
	Average Delay (sec/veh.)	L.O.S.	Average Delay (sec/veh.)	L.O.S	Average Delay (sec/veh)	L.O.S	Average Delay (sec/veh)	L.O.S
1	4.7	A	5.3	B	6.5	B	8.3	B
2	8.7	B	10.3	B	14.6	B	17.9	C
3	7.0	B	7.3	B	12.6	B	19.2	C
4	5.5	B	4.5	A	4.1	A	5.7	B
5	4.5	A	5.0	A	5.8	B	9.9	B
6	10.1	B	12.6	B	12.4	B	17.3	C
7	14.1	B	14.7	B	27.8	D	24.3	D
9	0.8	A	0.9	A	1.2	A	2.9	A
10	1.5	A	1.6	A	1.9	A	2.5	A
11	2.8	A	2.8	A	3.2	A	4.5	A
12	2.6	A	1.8	A	1.6	A	3.2	A
13	1.9	A	2.3	A	2.5	A	4.4	A
14	2.5	A	2.6	A	3.8	A	5.6	B
15	1.2	A	1.1	A	2.2	A	1.4	A
16	2.5	A	1.9	A	1.5	A	2.0	A
18	3.4	A	4.3	A	5.9	B	5.6	B
19	8.5	B	12.2	B	11.2	B	15.6	C
20	2.8	A	5.2	B	3.9	A	15.4	C
21	1.1	A	1.1	A	1.3	A	1.8	A
22	1.9	A	2.6	A	2.6	A	4.5	A
23	4.3	A	4.5	A	4.9	A	6.3	B
24	2.4	A	2.6	A	2.8	A	5.2	B
27	1.8	A	1.2	A	0.8	A	1.4	A
28	2.6	A	1.9	A	1.4	A	1.8	A

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