THE EFFECT OF THE PROPOSED WIDENING OF DHAHRAN ARTERIAL IN AL-KHOBAR ON THE TRAFFIC FLOW

Khalaf A. Al-Ofi[1], Nedal T. Ratrout[2], Hasan M. Al-Ahmadi[2], and Mohammed A. Al-Sughayier[2]

1: Assistant Professor, Civil Engineering Department, KFUPM and Manager, Urban Area Engineering Section, Center for Engineering Research, Research Institute, KFUPM
2: Assistant Professor, Civil Engineering Department, KFUPM

Corresponding Address: KFUPM Box 945, Dhahran 31261, Saudi Arabia
E-mail: kaluwfi@kfupm.edu.sa

ABSTRACT

Al-Khobar City is located in the Eastern Province of Saudi Arabia on the Arabian Gulf. It is a medium size city that has experienced rapid development in the last few decades. Dhahran Street is a major arterial that connects Al-Khobar to Dhahran and Dammam cities. The arterial is a Six-lane street with 40-meter median and four major signalized intersections. The traffic flow along the arterial is very heavy especially during weekend peak hour. The level of service at the signalized intersections is over capacity. The municipality of Al-Khobar is currently implementing a project of widening the arterial by two lanes in each direction. The extra lanes will be added by reducing the median width to 8 meters. In this paper the traffic condition along the arterial was simulated to assess the current condition with the current signal-timing plan using a traffic simulation and optimization computer package. The optimum signal-timing plan was found for the current situation without widening the street. The traffic flow after widening the street was simulated using the current signal-timing plan and the level of service was assessed. The optimum signal-timing plan for the arterial after the widening was found and the level of service was assessed. The effect of using the optimum signal timing plan without widening the street was compared to the effect of widening the street without using the optimum signal timing plan. The importance of using low cost measures before implementing high cost projects was emphasized.

Keywords: *Signalized intersection, Traffic Signal Optimization, Arterial street design, TRANSYT-7F*

الملخص

تقع مدينة الخبر على ساحل الخليج العربي في المنطقة الشرقية بالمملكة العربية السعودية وهي مدينة متوسطة الحجم شهدت تطوراً سريعاً خلال العقود القليلة الماضية .

ويربط شارع الظهران الشرياني في مدينة الخبر بمدينة الظهران والدمام . وهو مكون من ست مسارات بواقع ثلاث مسارات في كل اتجاه مفصوله بجزيرةعرضها ٤٠ متراً ويقع عليه أربع تقاطعات محكومة بإشارات ضوئية . وكمية الحركة على الشارع كبيرة خصوصاً خلال ساعات الذروة في أيام الأسبوع ونهاية الأسبوع . وتصل كمية الحركة على الشارع الى أكثر من الطاقة الاستيعابية مما حتم البدء في توسعة الشارع عن طريق اضافة مسارين في كل اتجاه وتضييق الجزيرة الوسطية الى ٨ أمتار فقط .وفي هذه الورقة تم محاكاة الحركة المرورية في الوضع الحالي من حيث التصميم الهندسي والخطط الزمنية للاشارات المرورية بواسطة نموذج المحاكاة TRANSYT-7F وبعد ذلك تم ايجاد الخطط الزمنية المثلى للوضع الحالي وتم تقييم مستوى الخدمة على التقاطعات وفي المرحلة الأخيرة تم محاكاة الوضع المستقبلي بعد توسعة الشارع واستخدام الخطط الزمنية المثلى وتم تقييم مستويات الخدمة على التقاطعات وقد تم عمل مقارنة بين مستويات الخدمة للسيناريوهات المذكورة وتم التأكيد على ضرورة التدرج في تنفيذ الحلول بدءاً بالحلول ذات التكلفة المنخفضة مثل تنسيق الاشارات المرورية وصولاً الىالحلول ذات التكلفة العالية كاعادة التصميم والتوسعة .

1. INTRODUCTION

Congestion of arterial streets in Saudi cities is one of the problems that traffic engineers have to solve. As the population and number of vehicles increase the existing transportation facilities become insufficient to handle traffic volumes. Dhahran Street in Al-Khobar city in the Eastern Province of Saudi Arabia is one of the arterial that has been experiencing traffic congestions in recent years especially during peak periods. The Municipality of Al-Khobar decided to widen the arterial by adding new lanes in the wide median, which will upgrade the arterial from 6-lanes divided arterial to 12-lanes arterial. The arterial currently has a signal-timing plan that is not optimum, especially during the peak hours.

In this study, a simulation optimization computer package (TRANSYT-7F) will be used to investigate the potential benefits of using the optimal signal timing plan compared to the benefit of widening the arterial while using the current signal timing plan. The study will emphasize the importance of exhausting all low case measure that allow efficient use of existing facilities before committing large funds for major construction projects.

2. GOALS AND OBJECTIVES

The goal of study is to determine the effects of the widening of Dhahran arterial in Al-Khobar on the traffic flow of the signalized intersections and to determine the effectiveness of using the optimal signal timing plans on the arterial intersections before and after the widening project.

Top

The specific objectives of the study are as follows:

1. Collect information about the arterial before the project and the plans to widen the arterial. This information includes the geometric design and the land use.
2. Collect traffic data of the arterial links and intersection. These data include daily traffic volumes to determine peak volumes, turning movement traffic volumes on intersections, signal timing plans operating on the intersections and traffic speeds on the links.
3. Simulate the traffic flow on the intersection with the current signal timing plans and current geometric (before widening) to assess the measures of effectiveness.
4. Optimize the current signal timing plan using TRANSYT-7F simulation and optimization model and compare the measures of effectiveness of the optimum signal timing plan with the current situation.
5. Optimize the signal-timing plan of the arterial after the widening project and compare its measures of effectiveness with the previous situation.
6. Assess the impact of using optimum signal timing plan with the impact of widening the arterial.

3. DESCRIPTION OF THE ARTERIAL

The arterial is main entrance of Al-Khobar City from the West. It serves most of the traffic coming from Dhahran, Riyadh, Azizia, Bahrain, Dammam and Jubail. It is a six-lane street divided by a wide median (40 m) that is cultivated with grass and trees. There are four main intersections on the arterial: Makkah Street, Riyadh Street, King Abdulaziz Street and corniche Street. There is a minor intersection at Prince Bin Jelewy Park between Riyadh Street and King Abdulaziz Street at the main streets, there are two left lane bay on Dhahran Street approaches while there are one left lane bays at the crossing streets approaches. The area is mixed commercial, residential in nature with some vacant land.

This study, due to budget constraints was limited to the area that includes Makkah Street intersection and Riyadh Street intersection.

4. DATA COLLECTION

The data that was collected for this study fall into three categories. The geometric data of the arterial before and after the project, the volumes on the arterial links and intersections during the peak hour and the current signal timing plan of the signalized intersections.

Top

4.1 Geometric Data

The current geometric data was collected through site visits to the arterial. It includes, link lengths, number of lanes, presence of left turn lanes and number of lanes at the intersection approaches. Figure (1) shows the geometry of the arterial with current geometry.

The future geometry of the arterial was extracted from the project plans obtained from the municipality. The arterial will be widened to be 10 lanes divided arterial. The increase in the number of lanes will be accomplished by constructing extra lanes in the wide median. There will be 4 main lanes in each direction as well as one lane in each direction that will be used as service roads. Figure (2) shows the geometry of the proposed arterial after the execution of the project.

4.2 Traffic Data

The traffic data that was collected for this study include: the determination of the peak hour, the turning volumes on the intersections during the peak hours, the determination of average speeds through various links and the current signal timing plans for the signalized intersections.

The determination of peak hour was accomplished through collecting volumes on a Monday representing typical weekday and a Thursday representing a weekend day. This was done using Hi-Star electronic counter that collects traffic volumes in 15-minutes intervals for 24 hours. It was fixed in the middle through lane of Dhahran Street. This was done on Monday 16/07/2001 and Thursday 08/07/2001 from 06:00 am to 06:00 am of the next day. The data revealed that there were two peak period, morning and afternoon, where afternoon peak is higher than morning peak for both Monday and Thursday. The peak hour for Monday was between 04:15-05:15 pm and for Thursday between 07:15-08:15 pm. The weekend peak hour has higher volume than for the weekday peak hour. It was decided to further collect turning volumes on the weekend peak hours.

Trained students using manual tally boards at Makkah Street intersection and Riyadh Street intersection collected the turning volumes. Table (1) shows the turning volumes during the peak hour.

Table-1 Turning movement volumes at Dhahran arterial intersections.

Direction	Eastbound			Northbound			Westbound			Southbound		
Intersection	Right	Thru	Left	Right	Thru	Left	Right	Thru	Left	Right	Thru	Left
Makkah St. Intersection	156	1788	856	226	270	302	130	1702	272	258	278	368
Riyadh St. Intersection	118	1840	234	163	160	218	182	1548	260	308	281	292

It was noticed that there were large left turning volumes on the eastbound approach of Dhahran Street-Makkah Street intersection. That was due to the fact that there was a large Shopping Mall (Al-Rashed) that attracts large traffic during weekend evenings. It was noticed that the two-lane left turning bay was not enough to serve these volumes which cause a spill over of the queue to the through lanes. The average speed on the links was assumed to be similar to the speed limit posted on the links, which was 80 km/hr.

The signal timing plans data for the two signalized intersection collected using stopwatch. It includes the green, yellow and all red for each approach as well as the offset between the two intersections, which was 55 sec between the start of green on the east bound approaches of Makkah Street intersection and Riyadh Street intersection. The cycle length areas found to be the same for both intersections, which was 140 sec. Table (2) shows the split of green, yellow and all red for each approach on both intersections.

Table-2 The current signal timing plans for the intersections.

Direction	Eastbound			Northbound			Westbound			Southbound		
Intersection	Green	All Red	Yellow	Green	All Red	Yellow	Green	All Red	Yellow	Green	All Red	Yellow
Makkah St. Intersection	19	5	4	35	3	4	18	5	4	36	3	4
Riyadh St. Intersection	40	3	4	18	3	4	19	3	4	35	3	4

5. TRANSYT-7F PACKAGE

TRANSYT-7F is a computer program that is widely used around the world to simulate traffic flow of networks. It has the capability of optimizing signal timing plans for traffic networks by trying different signal timing plans, simulating the traffic flow and comparing measures of effectiveness (MOE's). This done by the hill climbing technique, where the cycle length, splits and offsets are varied using large and small steps to find optimum solution that matches minimum performance index, which is a combination of delay and stops. The hill climbing technique insures finding optimum solution by using large and small steps to a void local minimum. The program simulates the platoon dispersion along links taking into account the type of activities along the links by assigning the appropriate platoon dispersion factor. The above-mentioned collected data are needed as input to the program. The program has been calibrated for the study area by Ratrout (1989) and Al-Ofi (1994) and the proper calibration parameters for the study area were used such as start up lost time, saturation flow rate for through and left turn lanes and vehicle pacing.

Top

6. ANALYSIS

TRANSYT-7F package was used to perform the following tasks:

1. Simulate the existing condition and calculate the MOE's.
2. Optimize the existing signal-timing plan and calculate the MOE.
3. Simulate the arterial with future geometric improvements but using the current signal timing pan and calculate MOE's.
4. Optimize the signal timing for the arterial with future geometric improvement and calculate MOEs.

The objective is to compare the effect of optimizing the signal-timing plan to the effect of geometric improvement.

Table (3) shows the level of service for each movement on both intersection for the current situation and the average delay/vehicle at each intersection during the peak hour. The level of service is a measure of delay per vehicle with A being excellent and F being failed. The table shows that the level of service at both intersections is F with average delay of 214.0 sec and 110.0 sec at Makkah Street intersection and Riyadh Street intersection respectively. The table shows that almost all the through movements along Dhahran arterial have level of service F.

Table-3. Level of service and average delay for current geometry and signal timing plan.

Direction	East	North	West	South	Average delay
Movement	LTR	LTR	LTR	LTR	L. O. S.
Makkah St. Intersection	FFC	FFC	AFA	FFC	214.00 F
Riyadh St. Intersection	AFA	EEC	DFB	FFC	110.00 F

Table (4) shows the level of service of the intersections and different movements and the average delay per intersection if the optimum signal timing plan is used without changing the geometry of the intersection. The level of service of Riyadh Street intersection has improved from F to D with a reduction in the average delay from 110.0 sec/veh to 51.06 sec/veh, which a 53.6% reduction. The level of service of Makkah Street intersection is still F but the average delays have reduced from 214.0 sec/veh to 95.0 sec/veh, which is a 55.6% reduction. There has been a major improvement in the level of service of different movements with considerable reduction in average delay of most movements.

Table-4. Level of service and average delay for current geometry with optimum signal timing plan.

Direction	East	North	West	South	Average delay
Movement	LTR	LTR	LTR	LTR	L. O. S.
Makkah St. Intersection	EFC	FFD	EFE	FFC	95.00 F
Riyadh St. Intersection	ABA	FFD	DEC	FFC	51.06 D

Table (5) shows the level of service of both intersections and different movements and the average delay per intersection if the current signal timing plan is used after the arterial has been widen. The level of service of Makkah Street is improved from F to E, while at Riyadh Street intersection from F to D. The average delays for the two intersections were reduced to 79.1 sec/veh and 42.4 sec/veh respectively. Compared to the current situation, these reductions are 63% and 61.5% respectively.

Table-5. Level of service and average delay for improved geometry with current signal timing plan.

Direction	East	North	West	South	Average delay
Movement	LTR	LTR	LTR	LTR	L. O. S.
Makkah St. Intersection	FDC	FFC	BCB	FFC	79.1 E
Riyadh St. Intersection	ACA	EEC	DDB	FFC	42.4 D

Table (6) shows the level of service of intersections and different movements and the average delay per intersection if the optimum signal timing plan was used after the widening of the arterial. Makkah Street intersection has a level of service E with average delay of 59.9 sec/veh, while Riyadh Street intersection has a level of service C with average delay 34.4 sec/veh, which is a 72% and 68.7% reduction in average delay respectively. The movements level of service has improved significantly for all the movements on Dhahran arterial (Eastbound and Westbound movement) due to the increase in the number of lanes but the Eastbound left turn movement at Makkah Street intersection is still at level of service F because of the high volume of vehicles making left and U-turn going to Al-Rashid Mall. The widening of the street didn't help much and alternation access of the Mall should be considered that traffic.

Top

Table-6. Level of service and average delay for improved geometry with optimum signal timing plan.

Direction	East	North	West	South	Average delay L. O. S.
Movement	LTR	LTR	LTR	LTR	
Makkah St. Intersection	FDC	FFC	CDC	FFC	59.90 E
Riyadh St. Intersection	BBA	EEC	DDB	EEC	34.40 C

It is interesting to compare the percent improvement in average delay due to geometric change with the improvement achieved by using the optimum signal-timing plan alone. Table (7) shows the comparison. It is noticed the average delay has improved by 63% for Makkah Street intersection and 61.5% at Riyadh Street intersection due to geometric change only, while the improvement due to optimum signal timing plan only was 55.6% and 53.6% respectively.

Table-7. Comparison between the effect of geometry improvement and optimizing signal timing plan on average delay.

Intersection	Average delay for current site	Average delay for optimum signal timing plan	% Improvement	Average delay for improved geometry	% Improvement
Makkah St. Intersection	214	95.0	55.6	79.1	63
Riyadh St. Intersection	110	51.06	53.6	42.4	61.5

The implementation and maintenance of optimum signal timing plan will cost a small fraction of the cost of widening the arterial; therefore, it has a very high rate of return. It should be emphasized that the low cost measures of traffic management should be exhausted before going to the high cost measures.

Top

7. CONCLUSIONS

The major results that can be concluded from this study are as follows:

1. Dhahran arterial peak hour is on Thursday 07:15-08:15 pm.
2. The current signal-timing plan is failing at the peak hour.
3. Using the optimum signal-timing plan with the current geometry will reduce the average delay at intersections by as much as (55.6 %).
4. Using the current signal-timing plan with the improved geometry will reduce the average delay at intersections by as much as (63 %).
5. Using the optimum signal-timing plan with the improved geometry will reduce the average delay at intersections by as much as (72 %).
6. It is important to exhaust all low cost solution before committing large funds to major construction.
7. The left turn movement of the Eastbound of Makkah Street intersection will still be problem even after the geometric improvement and alternative access to Al-Rashid Mall should be considered.

ACKNOWLEDGMENT

The authors wish to acknowledge King Fahd University of Petroleum and Minerals for supporting this research.

REFERENCES

1. Al-Ofi, K. A. 1994, “The effect of signal coordination on intersection safety.” Unpublished Ph.D. Dissertation, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.
2. Ratrout, N. T., 1989, "Assessment of the Applicability of "TRANSYT 7F" Optimization Model to the Traffic Condition in the Cities of Al-Khobar and Dammam, Saudi Arabia," Unpublished Ph.D. Dissertation, Michigan State University, USA.
3. Wallace, C. E., 2000, “TRANSYT 7F User Manual” Release 8 FHWA Washington, D.C.

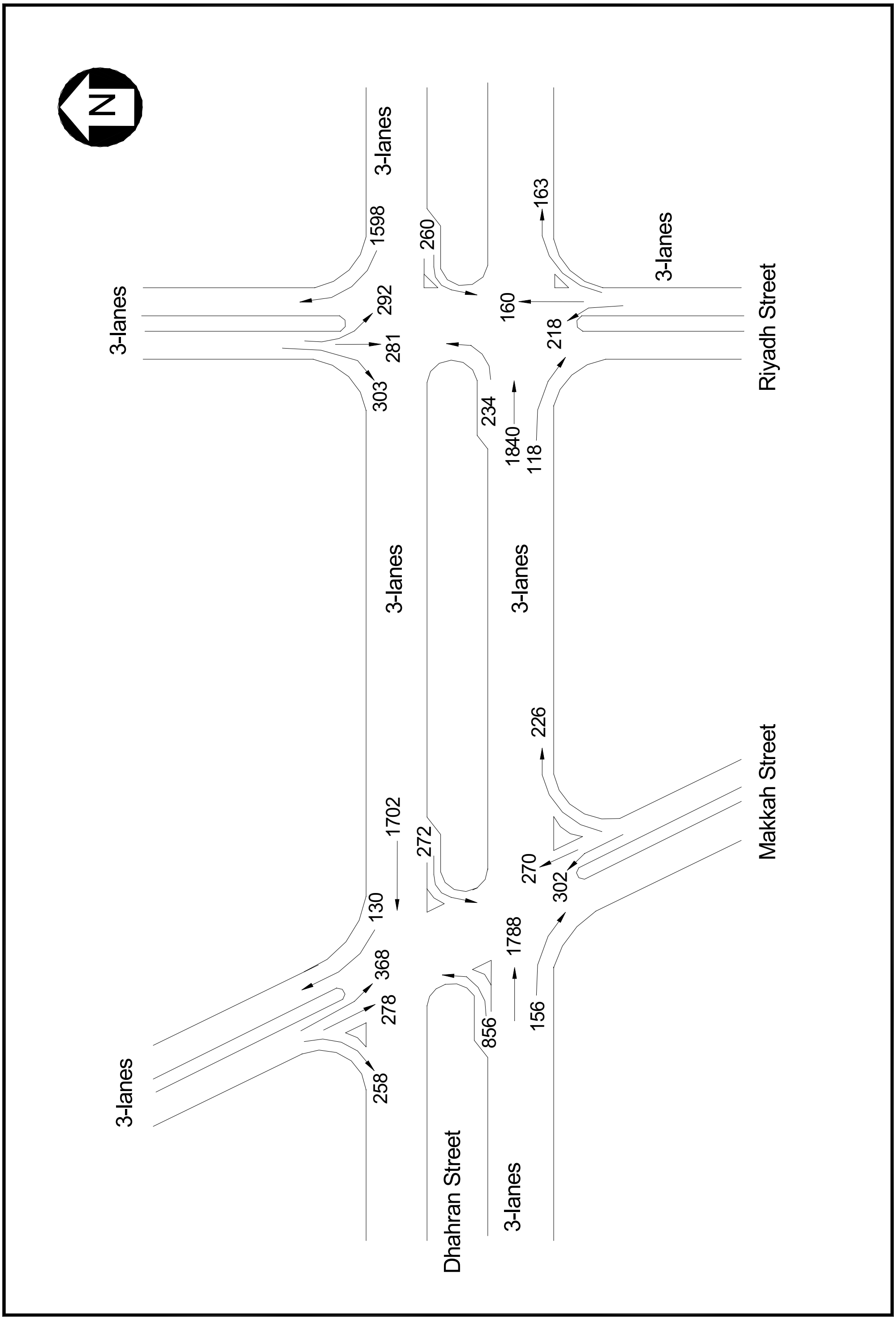

Figure 1. Existing geometry and volume of Dhahran Street.

Top

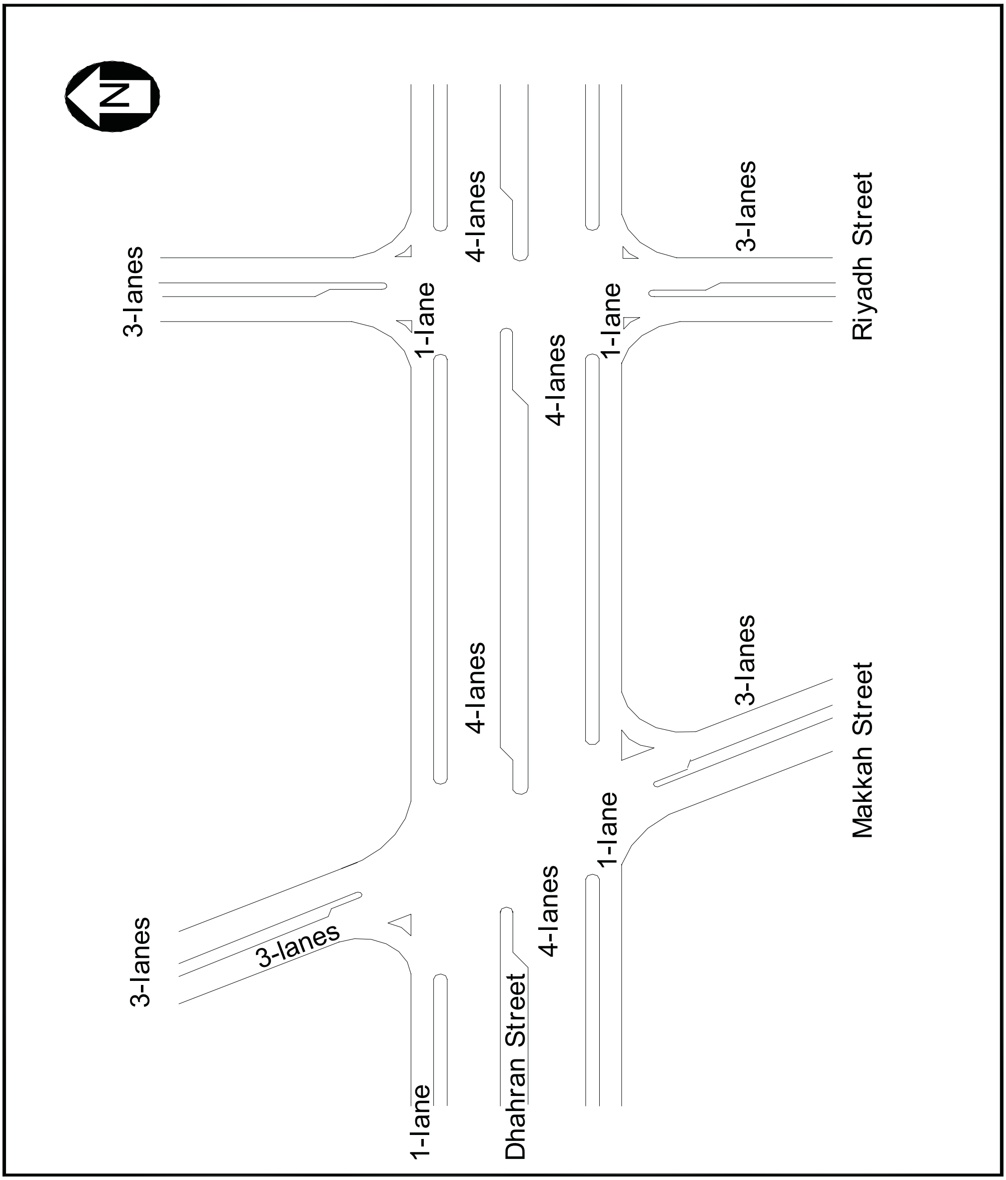

Figure 2. Dhahran Street after widening.