

Comparison of Actuated and Fixed Traffic Signals in Controlling Air Pollution and Delay at Intersections

MANSOUR HADJI HOSSEINLOU¹

SOMAYE SADAT AZIMI²

Transportation Dept., Faculty of Civil Eng.

K.N.Toosi University of Technology

Vali_Asr St., Mirdamad Cr., Tehran, Iran

IRAN

Abstract: Using of actuated traffic control signals is a practical and useful method for controlling traffic at intersections. In spite of wide use of actuated signals all over the world, unfortunately, many intersections in Tehran are still controlled by fixed traffic signals. The first purpose of this research is to compare the operation of actuated and fixed-timing traffic signals at intersections in Tehran. Synchro software was used to analyze fixed and actuated signal timings at nine intersections and after analyzing, delays were compared. The second purpose of this paper is comparison of air pollutants produced by vehicles under fixed and actuated signal timings at intersections. Results showed that after using actuated-timing instead of fixed-timing in Tehran, delays would be reduced by 13,183,800 hours in one year. Also, the amount of pollutants such as CO, HC and NOX, would be annually reduced by 619, 104, and 59 tons, respectively. As the Synchro software is designed for countries which are different from Iran in culture and facility circumstances, the results of its analysis were not good representatives for Tehran. In this research some actions were taken to calibrate the software for the existing conditions.

Key-words: Fixed-timing, Actuated-timing, Traffic signal, Intersections, Delay, Air pollutant

1 Introduction

Effective way of controlling intersections is one of the important subjects in traffic engineering. The intersections that are not controlled effectively may severely damage the country economy, traffic safety and cause environmental pollution and travel delays. Delay is an important parameter that is used in the optimization of traffic signal timings and the estimation of the level of service at signalized intersection approaches. However, delay is also a parameter that is difficult to estimate. While many methods are currently available to estimate the delays incurred at intersection approaches, very

little research has been conducted to assess the consistency of these estimates [1]. The environmental costs linked to an isolated signalized intersection have been quantified in terms of CO emission, fuel consumption and standard pollutant emission[2]. Intersections are one of the most important parts in transportation system in which both vehicles and pedestrians are involved. Inappropriate timing in traffic signals can produce delays and pollutants which can not be ignored. Although with progress of technology and science, the new traffic controlling systems are intended to

make things better, their accuracy should be considered according to traffic conditions, driving habits, geometrical conditions of roads, checking and controlling over traffic signals and vehicles in use. In advanced countries, the modern methods of traffic control and related soft wares are produced according to their country's conditions, in order to use these methods and soft wares in Tehran, they must be adjusted accordingly. In this research, by comparing the actuated traffic signals and fixed signals and their related delays and pollutants in some intersections in Tehran as one of the most polluted cities in the world, it has been tried to show the necessity and efficiency of using the actuated-timing in this country. The first step is to simulate Tehran's intersections by Synchro software in two conditions: First by pre-timed and actuated traffic signals in order to achieve their delays and pollution parameters and secondly by comparing the delays and pollution of pre-timed and fixed signals; in the end, generalizing the results to Tehran. In this research, an effort is made to select intersections that are close to each other and also have different traffic and geometrical conditions so that the results could be generalized for similar conditions. Meanwhile, for consistency between the results and the real condition of Tehran, the pollution information published by Tehran Air Quality Control Company (AQCC) was used [6].

2 Review of the past works

After installing the actuated traffic signals at intersections, traveling time decreased by 4 to 37 percent. Moreover, during the morning peak hours, delay for each vehicle decreased by 38 percent and the following diminution for rest of the hours was 11-38 percent. There is a direct relation between the travel time and the pollution [8]. By comparing the traveling time in actuated condition with fixed condition, this research shows that by installing actuated traffic signals, the amount of pollutant like CO₂ and CH₄ decrease by 751/786 kg [7, 3]. Moreover, researches in the city of Sydney in Australia show that 90% of carbon monoxide in atmosphere is produced by vehicles. By installing SCATS system in Sydney, the average traveling time decreased by 25% in comparison with fixed signals method and this deduction was equal to 18% decrease in CO gas. Moreover there is a 12% decrease in hydro carbon gas and the amount of Nitrogen reduced by 30% [4].

3 Manner of research

The hypotheses and the software which is used in this research are introduced in the following.

A. Intersections were analyzed individually and the effect of coordination was not studied.

B. For calculating delays, Webster's model of delay from HCM regulation was used.

C. In the software, the amount of pollutant which is made by trucks assumed to be 3 times more than normal vehicles. But in Tehran's used data base, the pollutant for each vehicle is calculated separately.

D. The duration of peak hours assumed to be 2 hours according to the experts at Tehran Traffic Controlling Organization which includes 20% of the total daily traffic in Tehran.

E. Synchro is software for simulating and optimizing traffic signals timing. Synchro has some pre-processors for 'Corsim' and 'Transyt' Programs. All versions of Synchro include 'HCS2' and 'Simtraffic' programs.

This software uses chapter 9 of Highway Capacity Manual (HCM). It can be installed on windows operation system and can analyze an intersection and adjust its timing. Moreover Synchro can calculate and optimize the cycle length and time period without the need for multiple time patterns for searching the optimum condition, Synchro is a set of interactive software for simulating actuated signals. This software can simulate skipping and gapping manners and combine this information with delay simulation.

4 Field study

In this section the intersections and information centers which are used in this software will be introduced.

4.1 Intersections

There are 566 Intersections in Tehran. Most of them are operating under heavy volumes with different level of services. The intersections were selected from main intersections of Tehren in varous circumstances. The analyzed intersections are introduced in the table 1. The levels of service and peak hour volume of the intersections are shown in the table 1.

Table 1. Intersection's specifications in Tehran.

Intersection's name	Level of service	peak hour volume
Esfandiar – Africa	E	4921
Haghani – Africa	F	6874
Mina – Shariaty	D	4668
Oday – Resalat	F	4954
Janbazan – Sanmangan	C	4330
Niayesh – Seoul	F	9372
Dastgerdi –Vali asr	B	5312
Niayesh –Vali asr	F	6896

4.2 Introducing the amount of pollutants produced by vehicles in Tehran

In order to calculate the amount of produced pollutants in Tehran, Tehran Air Quality Control Company's data was used [5], [6]. These tables include the percentages of all vehicles in Tehran and also the amount of pollutants produced by each one. The percentage of each vehicle's type in Tehran is listed in table 2. At first, the manner of distribution is found for each kind of vehicle in Tehran from table 2. Afterwards, according to tables 3 to 5, which the amounts of produced pollutants at the speeds of 18.7, 40, 60, 80 km/hr are mentioned in, the average weight of each kind of pollutant is shown based on the vehicle's distribution. Note that the production of each kind of pollutant is shown in mgr/km. The amount of CO, HC and NOX is shown in tables 3 to 5.

Table 2. Percentage of vehicles in Tehran [6].

Intracity bus	taxi	bus	Mini bus	Motorcycle	van	car
14.7	0.8	8.8	6.4	1	15.9	52.4

Table 3. Average weight of CO produced by vehicles in Tehran in mgr/km [5].

Average weight	Intracity bus	taxi	bus	Mini-bus	Motorcycle	van	car	speed km/hr
37669.105	13349	39678	12691	6148	25935	106546	38078	18.7
26520.573	8583	12499	7909	3661	37770	99126	23217	40
16868.117	4566	8989	4047	1873	23174	49550	16447	60
13077.229	2049	9235	1656	1277	9254	44134	13889	80

Table 4. Average weight of HC produced pollution by vehicles in Tehran in mgr/km [5].

Average weight	Intracity bus	taxi	bus	Mini bus	Motorcycle	van	car	speed km/hr
4486.516	8482	2133	5959	2835	8555	6934	3939	18.7
2642.375	7682	1548	4200	1811	4761	3975	2237	40
2012.785	5515	1117	3575	1086	4200	2864	1632	60
1764.998	4925	1148	2979	965	3888	2454	1328	80

Table 5. Average weight of NOX produced pollution by vehicles in Tehran in mgr/km [5].

Average weight	Intracity bus	taxi	bus	Mini bus	Motorcycle	van	car	Speed km/hr
2271.604	19951	2438	22508	8344	64	2102	1195	18.7
1836.266	10035	1792	9297	4421	64	1979	1625	40
1943.485	14244	1688	9786	3052	75	1776	2025	60
2262.722	15293	1751	10765	2909	97	2259	2539	80

After finding average weights from tables 3 to 5, figures number 1 to 3 shows the amount of produced pollutants according to the vehicle's

speed. The numbers obtained from these graphs can be used in the software.

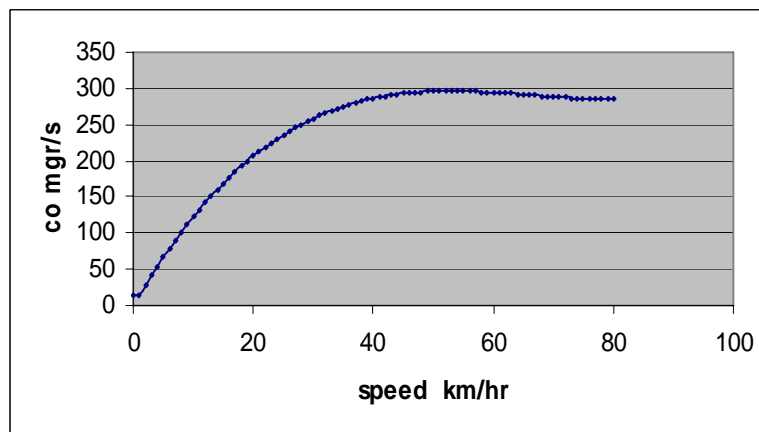


Fig.1. Amount of CO pollution which produced in different speeds in mgr/s.

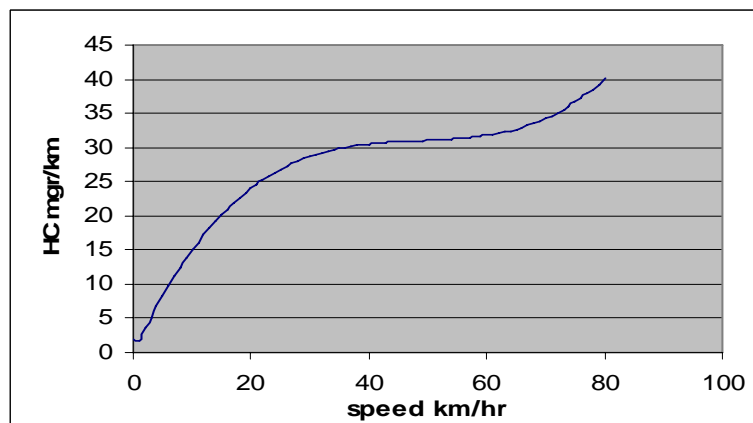


Fig.2. Amount of HC pollution which produced in different speeds in mgr/s.

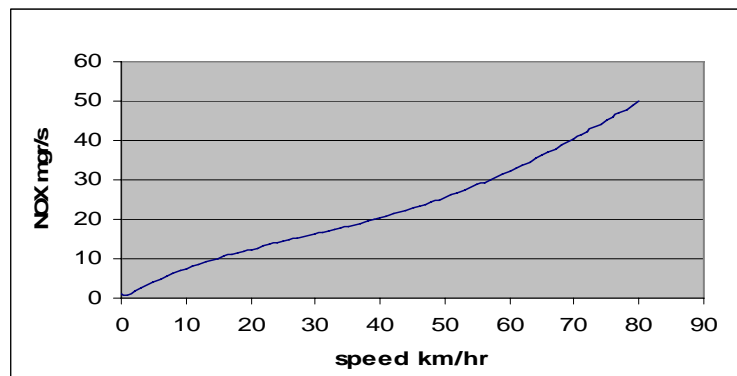


Fig.3. Amount of NOX pollution which produced in different speeds in mgr/s.

As it can be seen from graphs, if the speed increases, the amount of pollutants which is produced by vehicles will increase. The process of producing NOX pollution is in the ascendant but for CO and HC the grade of the graph will reduce at high speeds.

4.3 Peak hour analysis results

After entering the data to the soft ware's data base and analyzing, the results of the comparison between actuated-timing and fixed timing method were achieved. These results are shown in table 6.

Table 6. Results of the comparison between actuated and fixed timing in peak hour

NOX(mgr)	CO(mgr)	HC (mgr)	Intersection's name
2000	84800	4000	Africa – Esfandiar
2222	72667	2667	Africa – Haghani
40233	447400	41600	Shariaty – Mina
15600	273000	64200	Resalat – Oday
8400	117000	12000	Sanmangan– Janbazan
29400	246800	46200	Seoul – Niayesh
18600	467400	62600	Vali asr –Dastgerdi
8400	157800	180000	Vali asr –Niayesh

If there is a good service in the intersection, actuated-timing has more effect on reducing delays and pollutants. It seems that actuated-timing has more effect in light traffic and there is little difference between delays and pollutants in actuated and fixed timings near level of services near F. At high level of services there is an increase in volume of traffic and there is bigger difference in total delays and pollutants between actuated-timing and fixed timing. While in higher level of

service the delays and pollutants produced by each vehicle decreases, because of the heavy congestion in traffic, delays and pollutants multiply the amount of traffic volume, so there will be bigger difference between actuated-timing and fixed timing. In other words, volume of traffic will neutralize the effect of level of service. As it is shown in table 6, usually delays and Pollutants would decrease more in higher level of service.

4.4 Normal hour's analysis results

Delays and pollutants in normal hours and normal traffic were studied carefully. The results are shown in table 7. As it is shown in table 7, there may be an increase or decrease in amount of pollutants due to delays. In the case of accelerating, fuel consumption and pollutants are increased.

Sometimes, pollutant increases when delays and stops decrease [9]. This phenomenon seems illogical. While a vehicle stops, it consumes less fuel so it produces less pollutant. But, when there is light traffic and all vehicles are moving, more fuel is consumed by them so there is more pollution.

Table 7. Results of comparison between actuated-timing and fixed timing in normal hours.

NOX(mgr)	CO(mgr)	HC(mgr)	Delay(hr)	LOS	Intersection's name
1800	70800	4200	0.36	E	Africa – Esfandiar
12000	97200	7200	4.6	F	Africa – Haghani
55200	625800	93600	1.08	D	Shariaty – Mina
2400	34800	22800	6.42	F	Resalat – Oday
3600	64200	8400	0.42	C	Sanmangan-jan bazan
22800	39600	3000	0.18	F	Seoul – Niayesh
1200	60000	19200	1.38	B	Vali asr –Dastgerdi
7800	201000	12000	5.94	F	Vali asr –Niayesh

5 Conclusions

The following results were taken from this research:

1. According to the statistics from traffic controlling organization, there are 566 intersections in Tehran. If all of the intersections were equipped with actuated signals, the annual decrease in delays and pollutants would be:

- 13,183,800 hours decrease in delays.
- 619 tons decrease in CO pollutant.
- 104 tons decrease in HC pollutant.
- 59 tons decrease in NOX pollutant.

2. There would be better reduction of delays in lower level of service in comparison to higher level of service. Although there is a reduction of delays in lower level of services, because of the traffic congestion in high level of services, delays increase the amount of traffic so total reduction of delays would not be significant.

3. As the pollutant values taken into account by Synchro software are different from actual values, the results of its analysis are not representatives of Tehran.

References

[1] Francois Dion, Comparison of delay estimates at under-saturated and over-saturated pre-timed

signalized intersections, science direct journal Volume 38, Issue 2, February 2004

[2] Sophie Midenet, Signalized intersection with real-time adaptive control on-field assessment of pollutant emission reduction, science direct journal 2004

[3] Abbas azizian, Effect of using actuated traffic systems on delay and pollution reduction, www.irandoc.ir, 2003.

[4] Tehran's control traffic company, actuated control traffic system feasibility, research report number 25, research and develop department, 1997.

[5] Tehran's weather quality control, pollution emission report, 1998.

[6] Tehran's weather quality control, emission produced by difference kind of vehicles report, 1998

[7] Mansour Haji Hosein Lou, Effect of actuated and fixed signals at intersections on traffic and environment, science and technology magazine, 2006

[8] Oil ministry, energy international research institute report, 2006

[9] Synchro software manual, 2007

[10] Xiugang Li, Signal timing of intersections using integrated optimization of traffic quality, emissions and fuel consumption, .science direct journal, 2004