(Re)Construction or Optimization of Tirana Transportation System? Which comes first? A case study of an Isolated Intersection in Tirana.

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ABSTRACT

Transportation system of Tirana Municipality has significantly evolved over the last two decades. Besides the huge number of constructions, Tirana Municipality has invested a lot in construction and reconstruction of new roads resulting in a large transportation system. This system has been expanded in order to meet the continuously increasing traffic demand. However, this situation has led to higher traffic congestion level since the other parts of the Transportation System such as intersection signalization, parking capacities and mass-transportation facilities, are neglected and not adapted to these changes. This research analyses an isolated signalized intersection by giving quantitative results of economical and environmental impacts. Analysis and simulation of an isolated intersection for the existing conditions is evaluated via SIGNAL2000 and Synchro6 software (microscopic simulation) under Highway Capacity Manual (HCM 2000). The same intersection is redesigned and optimized to increase the capacity and decrease the delays. The optimization of the traffic signal system is an important step towards successful traffic control, since delays in urban networks largely depend on the performance of the signal system. Comparison of existing and optimized conditions emphasizes the importance of optimization of the transportation system as the first and cheapest step to improve efficiency of the transportation system.

Keywords: *Isolated Signalized Intersection, microscopic simulation, traffic control***.**

INTRODUCTION

The traffic congestion is defined as the level at which the performance of the transportation system becomes unacceptable (New York Transportation Council, 2005). It was found out that the traffic congestion does not only stand to depress people but also brings about some substantial cost to the economy.

To begin with, it was found out that 9.7% of urban arterials in Manhattan, New York, have demand volume rations over 1.0. According to the Annual Mobility Report of Texas Transportation institute, a recent research regarding 85 major urban areas in USA, the congestion has been increased everywhere of all sizes and thus longer portion of the day as well as more travellers and goods were affected by congestion. According to this study, in 1982, 32% of the peak period was congested and this value was increased to 67% in 2002. Therefore, the total time spent stuck has increased from 0.7 billion hours to 3.5 billion hours. At the same time, the fuel consumption has increased from 1.2 billion to 5.7 billion gallon.

Furthermore, the total annual cost of traffic congestion, was estimated in 1982 to be \$14.2billion while increasing to \$63.3 billion in 2002 (Schrank and Lomax, 2003).

Average weekday peak period trip takes 37 per cent longer than the same trip during the off-peak period whereas it used to be 12 per cent longer in 1982 (Cambridge, Systematics, 2004). According to the same study 5% of the congestion in USA resulted due to signal improper usage. Differently from USA where the real time adaptive signals are widely used, the per cent of traffic congestion caused by improper traffic signal timings is expected to be higher in Tirana, since Tirana does still use the traditional traffic signals which are time-of-day adapted or time-fixed signals. Hence, proper signal timing, which enables more efficient utilization of existing facilities, would be an effective method of handling the traffic operation in a better way and reducing congestion in Tirana.

PROBLEM DEFINITION

Optimization of existing traffic signal system usually lead to the highest benefit-cost ratios in terms of reducing congestion on Surface Street if there are no other deficiencies along arteries and intersections. The improvement of existing signalized systems includes the following (Meyer, 1997)

- Update the equipment (more sophisticated)
- Maintenance the existing equipment
- Improvement of signal phasing and timing corresponding to current traffic flow
- Coordination of current traffic signal
- Removal of traffic signals that are no more longer justified

For Tirana the accomplishment of the above measures are within the responsibility of Transportation Directorate of Tirana Municipality. There are approximately 220 intersections in Tirana signalized (112 units) and not signalized but shall (warranted) be signalized (108 units). About 28% of signalized intersections in Tirana are not operational. Another problem with these signalized intersection is the maintenance and electricity cut offs. On the other hand, intersections which are warranted but not signalized (from observations) impose a significant safety and operational concerns. Tirana Municipality has invested 2.3 billion ALL (16.4 million Euro) out of its total budged of 7.6 billion ALL (54.3 million euro) in Transportation Maintenance and Management in 2009 (www.tirana.gov.al). Furthermore, it gained more than 31.2 million Euro credit and 400 thousand Euro grants.

Adaptive control strategies, which make use of mathematical algorithms to achieve real-time optimization of traffic signal with respect to varying traffic conditions, demand, and system capacity, are advantageous over traditional fixed-time/time-of-day in three functional area; delay reduction, safety and operational maintenance (Hicks and Carter, 2000). SCATS (Sydney Coordinated Adaptive Traffic System, gave rise to a delay reduction of 42% and travel time reduction of 20% (TransCore, 2000) by Florida Department of Transportation, enhanced the traffic delay from 7 to 32% over optimized fixed-time traffic control.

THE PURPOSE AND METHODOLOGY

The purpose of this study was to update intersection signal timings in order to maximize intersection capacity, reduce driver delays, reduce vehicle emissions, and improve the overall efficiency of traffic operations for the motoring public.

In order to accomplish this task, traffic count data, signal timing parameters, and intersection geometry was provided to evaluate the current performance of the intersections. Adjustments in signal timings, off-sets, detection, and other parameters were considered in three different scenarios shown in the Table 1. Once adjustments were identified, changes to the field equipment could be made to implement improvements.

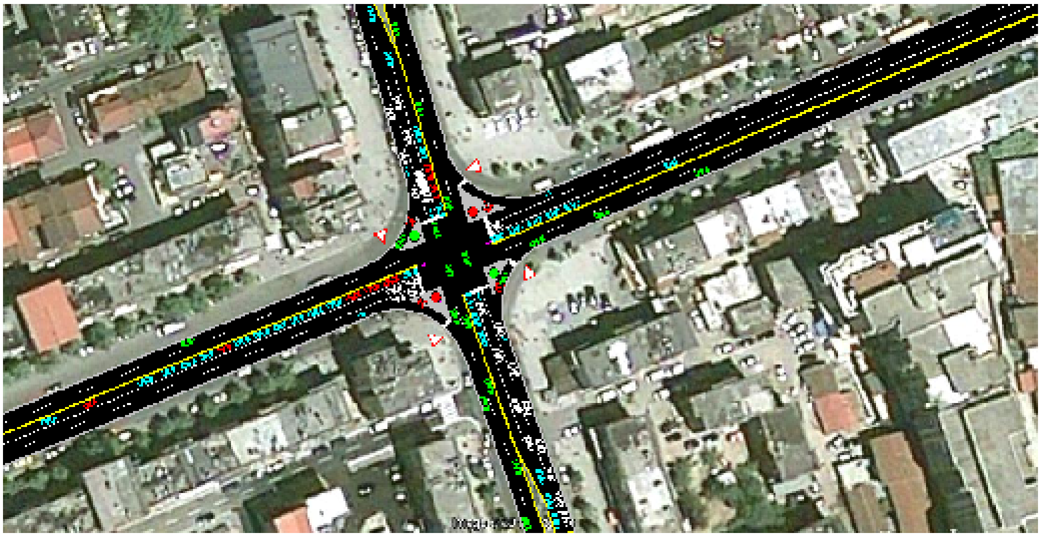

Figure 1. Typical Aerial Photo Simulated on CORSIM

These three scenarios are employed in the signal optimization in *21 Dhjetori Intersection* with *Synchro 6* and *Signal 2000*. The aim of the first scenario was to present the existing signal split assuming it is a Fixed-Time signal (one configuration) and signal splits not optimized. Thereby, the current measure of effectiveness (MOE) like traffic delay, carbon monoxide emission, and fuel consumption were obtained.

In the second scenario a Fixed-Time signal is considered, however the signal split is optimized. The intersection is first modelled in Signal 2000 to find the most suitable signal phasing combination. Then this phase plan is transferred and modelled in Synchro 6 to evaluate MOEs.

In the third scenario Time-of-Day signal type is considered. Then a new phase plan is obtained from Signal2000 for three different time intervals; morning peak, off-peak, and evening peak. This signal phases are modelled in Synchro 6 separately and optimized signal splits are obtained. Again the MEOs for this scenario has been obtained. The changes in the signal timing parameters and the resulting performance changes were then documented to identify the net benefits for the actions.

Table 1. Summary of the scenarios employed in the signal optimization of 21 Dhjetori

Scenario No	Type of Signal	Signal Optimization	Software
1	Fixed-Time	NO	SYNCHRO
2	Fixed-Time	YES	SIGNAL2000/SYNCHRO
3	Time-of-Day*	YES	SIGNAL200/0SYNCHRO

*Fixed for three times of the day; morning peak, off-peak, and evening peak

Hence, being the first intersection signal optimization study in Tirana that involves the employment of professional computer software, this project may be used and constituted to optimize the other signals in Tirana.

Daily Fluctuation in 21 Dhjetori Intersection

Control counts are basically aimed to reveal the seasonal, daily, hourly volume variations. In this study, a 12hr control count was performed to find the hourly fluctuation of the traffic during a weekday. This control count was conducted on October 28th 2011. This study revealed that the morning peak (the highest traffic volume) was observed to be between 7:30am to 8:30am, whereas the evening peak was observed between 3:30pm and 4:30pm. According to Figure 2, the traffic flow in this intersection is pretty high during the whole day reaching its maximum of 3,751veh/h at morning peak. The maximum flow rate during evening hour was found out to be 3,550veh/h. On the other hand, the minimum flow rate between morning and evening peaks was observed to be 3,255veh/hr. South approach has revealed the maximum flow rate of 1,089veh/h in the morning peak.

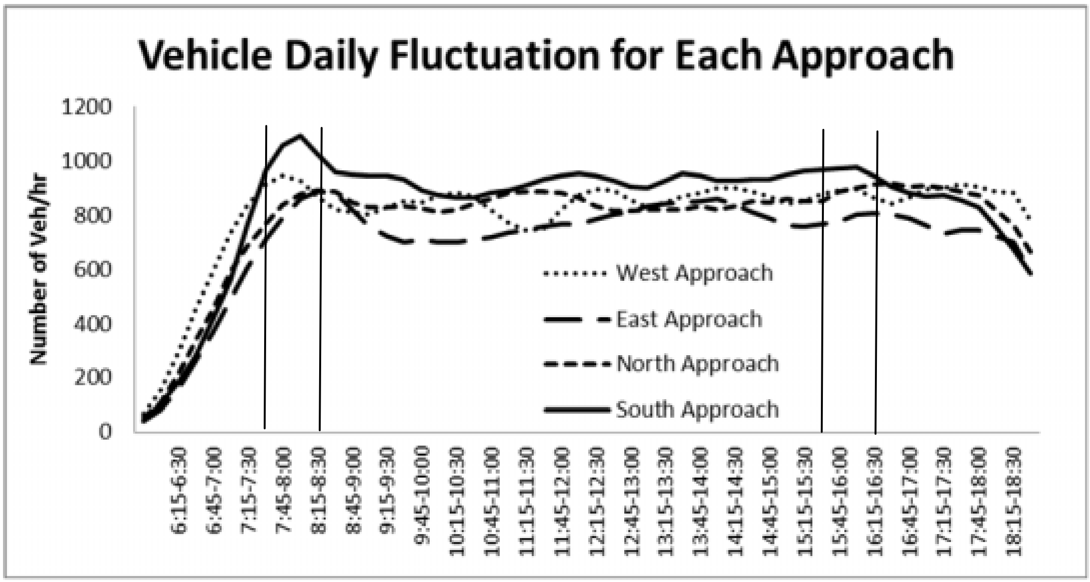

Figure 2. Vehicle Daily Fluctuation for Each Approach.

The Actual and Optimum Signal Timing

The actual and optimum signal timings for Morning Peak, Off Peak, and Evening Peak for each scenario are tabulated in the Table 2. For the first scenario, where the actual condition is considered, green (G), yellow (Y), and all-red (AR) times are fixed during all the day. These data is measured form the actual configuration of these intervals on site.

Second scenario considered the same signal type (fixed-time; only one configuration) and the peak hour during the whole study duration, in this case the morning peak, was analysed. This information was optimized by Signal 2000 and Synchro 6. On the other hand, the third scenario took into account three different peak hours (morning peak, off-peak, and evening peak) and optimized them for each peak hour.

Table 2. Signal Timing Splits for each Scenario

MORNING PEAK (7:30-8:30 on 31-October-2011)									
Phase No	CURREN TIMING			SCENARIO 2			SCENARIO 3		
	G	Y	AR	G	Y	AR	G	Y	AR
φ1	26	3,5		27,5	3,5		27,5	3,5	
φ2	18	3,5	1,5	29	3,5	1,5	29	3,5	1,5
φ3	26	3,5		31,5	3,5		31,5	3,5	
φ4	18	3,5	1,5	12	3,5	1,5	12	3,5	1,5
φ5	26	3,5		25,5	3,5		25,5	3,5	
φ6	18	3,5	1,5	27	3,5	1,5	27	3,5	1,5
φ7	26	3,5		32,5	3,5		32,5	3,5	
φ8	18	3,5	1,5	11	3,5	1,5	11	3,5	1,5
C	105			115			115		
OFF PEAK (9:30-10:30 on 31-October-2011)									
Phase No	CURREN TIMING			SCENARIO 2			SCENARIO 3		
	G	Y	AR	G	Y	AR	G	Y	AR
φ1	26	3,5		27,5	3,5		30,5	3,5	
φ2	18	3,5	1,5	29	3,5	1,5	31	3,5	1,5
φ3	26	3,5		31,5	3,5		29,5	3,5	
φ4	18	3,5	1,5	12	3,5	1,5	14	3,5	1,5
φ5	26	3,5		25,5	3,5		19,5	3,5	
φ6	18	3,5	1,5	27	3,5	1,5	20	3,5	1,5
φ7	26	3,5		32,5	3,5		28,5	3,5	
φ8	18	3,5	1,5	11	3,5	1,5	13	3,5	1,5
C	105			115			110		
EVENING PEAK (15:30-16:30 on 31-October-2011)									
Phase No	CURREN TIMING			SCENARIO 2			SCENARIO 3		
	G	Y	AR	G	Y	AR	G	Y	AR
φ1	26	3,5		27,5	3,5		30,5	3,5	
φ2	18	3,5	1,5	29	3,5	1,5	30	3,5	1,5
φ3	26	3,5		31,5	3,5		33,5	3,5	
φ4	18	3,5	1,5	12	3,5	1,5	15	3,5	1,5
φ5	26	3,5		25,5	3,5		25,5	3,5	
φ6	18	3,5	1,5	27	3,5	1,5	25	3,5	1,5
φ7	26	3,5		32,5	3,5		32,5	3,5	
φ8	18	3,5	1,5	11	3,5	1,5	14	3,5	1,5
C	105			115			120		

MEASURE OF EFFECTIVENESS (MOE) OF EACH SCENARIO

The measure of effectiveness of each scenario is summarized in this section. Table 3. presents measure of effectiveness (MOE) such as delay, number of stops, fuel consumption, and environmental pollutants. Scenario 1 shows deteriorated MOE parameters especially during the morning peak. However, the same signal split shows pretty much better MOEs during the off-peak and evening peak. The second scenario has better MOEs than the first scenario. Optimizing the intersection based on morning peak volumes, has significantly decrease delays and thus fuel consumption and hazardous chemicals emission. On the other hand, the last scenario provided the best MOEs. Adapting the signal splits for three different types of volumes provided the lowest delays, fuel consumption and emission of this intersection.

Table 3. Measure of Effectiveness of each Scenario

	Scenario No 1			Scenario No 2			Scenario No 3		
MOE	MorPeak	Off-Peak	EvenPeak	MorPeak	Off-Peak	EvenPeak	MorPeak	Off-Peak	EvenPeak
Cycle Lenght (s)	105	105	105	115	115	115	115	110	120
Control Delay / Veh (s/v)	199	117	131	159	95	111	159	87	104
Queue Delay / Veh (s/v)	0	0	0	0	0	0	0	0	0
Total Delay / Veh (s/v)	199	117	131	159	95	111	159	87	104

Total Delay (hr)	207	106	127	166	86	108	166	79	101
Stops / Veh	0.79	0.82	0.81	0.80	0.81	0.81	0.80	0.81	0.82
Stops (#)	2975	2685	2841	2995	2638	2828	2995	2649	2850
Average Speed (km/hr)	13	19	17	15	21	19	15	22	20
Total Travel Time (hr)	284	173	199	243	152	179	243	146	172
Distance Traveled (Km)	3679	3199	3423	3679	3199	3423	3679	3199	3423
Fuel Consumption (l)	992	659	743	878	602	689	878	584	670
Fuel Economy (km/l)	3.7	4.9	4.6	4.2	5.3	5.0	4.2	5.5	5.1
CO Emissions (kg)	18.46	12.26	13.82	16.34	11.19	12.82	16.34	10.86	12.45
NO Emissions (kg)	3.56	2.37	2.67	3.15	2.16	2.47	3.15	2.10	2.40
VOC Emissions (kg)	4.26	2.83	3.19	3.77	2.58	2.96	3.77	2.51	2.87
Unserved Vehicles (#)	755	262	404	634	186	342	634	145	268
Duration during the day (hr)	2	8	3	2	8	3	2	8	3

The Benefits of Signal Optimization

Figure 3. shows reduction of delay, fuel and hazardous emissions for each scenario. Total delay is reduced 19% from the first scenario to the second one. On the other hand, scenario 3 showed 5% lower value than scenario 2. Fuel consumption and emissions are decreased by 9% when 21 Dhjetori intersection is optimized. Employing the third scenario these values are reduced further by 2.2%. This results show once more that, optimization of the traffic signals and using more sophisticated traffic signal devises is a crucial step toward improving transportation system of Tiran.

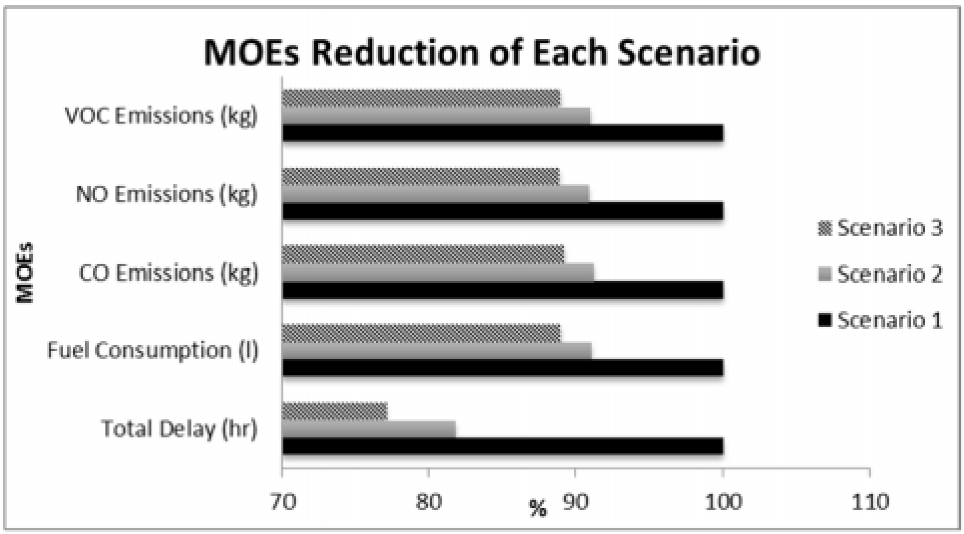

Figure 3. MOEs reduction for each scenario

It is assumed that the morning peak takes two hours, the off-peak period takes 8 hours and the evening peak takes 3 hour each weekday. As shown below the signal optimization of 21 Dhjetori gives rise to annual fuel savings of 463,000USD and annual time saving equivalent to 188,000USD, since the annual average income equals to 4,000USD (Instat, Albanian Institute of Statistics, 2009). As far as environmental consequences of the intersection optimization are considered this signal optimization has led to an annual reduction of 4,940kg carbon dioxide emission, 985kg of nitrogen oxide emission and 1,170kg volatile organic compound emission.

Table 4. Summary of savings and reduction in the emission of pollutants owning to the signal optimization of the 3rd scenario

	Daily Sum	Annual Sum (weekday only)	Annual Savings (USD) (weekdays only)
Total Delay Reduction (hr)	376	97.760	188.000
Reduction of Fuel Consumption (l)	1047	272.220	462.774
Reduction of CO2 Emission (kg)	19	4.940	
Reduction of NOx Emission (kg)	3,79	985	
Reduction of VOC Emission (kg)	4,5	1.170	

Conventional vs LED Traffic Signals

Conventional and LED traffic signal characteristics are compared and evaluated in Table 5. LED traffic devices have lower power consumption. Furthermore, LED signals are brighter compared to incandescent traffic signals, which enhance intersection safety. In addition, elimination of catastrophic failures is another advantage of these devices. Unlike an incandescent bulb which has only one filament, an LED signal is made out of a matrix of several dozen LEDs. The signal continues to function even if several of these miniature diodes stop working. On the other hand, when the filament of an incandescent bulb fails, the display goes dark requiring immediate replacement. Last but not least, elimination of phantom effect makes LED a safer device. Incandescent traffic signals use reflectors behind the bulbs. For signals on east-west approaches during morning and evening hours, all colours seem to light up when the sunrays fall directly on these signals. This problem is eliminated when LED signals are used because there are no reflectors in LED signals.

Table 5. Conventional and LED Traffic Signal characteristics

Description	Conventional	LED
Material Cost	1.408	8.880
Installetion Cost	440	440
Power Consumption (kWh/Year) Power Consumption (USD/kwh) Power Consumption (USD/Year)	14.436 0,085 1.227	1.332 0,085 113
Study/Optimization Cost (USD/Year)	250	250
Maintenance Cost (USD/Year)	200	200
Total Value for one intersection (USD/Year)	**3.525**	**9.883**

CONCLUSIONS AND RECOMMENDATIONS

5% of the traffic congestion in USA is found to be due to improper signal timing. However this study showed that this value is pretty high for Tirana (22%). Tirana involves neither real-time adaptive control strategies (monitoring room) nor an optimization tool that is capable of the traffic delay or particular vehicle stops. The traditional fixed-time or time-of-day signal optimization can bring about at most 80 per cent of the benefits of a real-time coordination (MacShane at al, 2004). However, a fixed-time or time-of-day devices in the existing intersections in Tirana are significant tool for providing the fool utilization of existing facilities till the development and implementation of adaptive control strategies.

Moreover, the signal timing and phasing improvement in 21 Dhjetori intersection brought about substantial savings in term of time and fuel consumption. Values of time and fuel consumption reductions resulted from signal optimization summarised to 653,000USD annual savings for this intersection. Taking into account that total cost of traffic device (material, installation and operation) is evaluated to be 9900USD the cost benefit ratio for the

21 Dhjetori Intersection is approximately 1:67. Typically, the benefit to cost ratio for signal retiming is 40:1 (Sunkari 2004)

Furthermore, Environment improvements are obviously recognised by a less polluted environment. Recently increasing public awareness of environment condition improvement has put this subject to the top most crucial field for research. CO_2, NO_x, and VOCs amounts emitted from vehicles are decreased by, 4,940kg, 985kg, and 1,170kg, respectively.

The optimization of the traffic signal system is an important step towards successful traffic control, since delays in urban networks largely depend on the performance of the signal system. Software packages like Signal 2000 and Synchro 6 are very useful tools which help engineers to model the traffic flow and evaluate the benefits of signal optimization. This study emphasizes the importance of optimization of the transportation system as the first and cheapest step to improve efficiency of Tirana transportation system.

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