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Signal Coordination of Oversaturated High Volume Arteries: A Case Study of Outer Ring in Tirana

Edison Barhani[1]
[1]*Department of Civil Engineering/ Epoka University, Albania*

ABSTRACT: *Movement of people and goods has become more difficult last decades, especially within urban areas. Traffic congestion level has continuously increased as dependence on passenger cars has gone up. This has led to significant travel delays, increase of travel costs and pollution. Signalized intersections are an important part of urban transportation system which mainly are considered bottlenecks of the system. Hence, their operation condition gains top importance for a better and smother movement of vehicles. One of the least expensive improvements of intersections which in turn brings about high improvements is signal split optimization and coordination. This study focused on analyzing the cost-benefit ratio of improvement of signal coordination for high volume arteries. Measures of Effectiveness (MOEs) like delay time, number of stops, fuel consumption, pollutant emission and performance index was analyzed by SYNCHRO, a widely used software for signal optimization and coordination. A case study in Tirana (Albania) has revealed to provide a cost-benefit ratio at least 1:29 annually. Environment improvements are obviously recognized by emitting less pollutant. CO2, NOx, and VOCs amounts emitted from vehicles are estimated to decrease annually by, 2,795kg, 540kg, and 540kg, respectively.*

Keywords: *signal coordination, intersection optimization, simulation*

I. INTRODUCTION

Urban mobility is confronted by many challenges, foremost among them traffic congestion as urbanization and a high dependence on cars have led to congestion in cities. This, in turn, has negative implications in terms of delays, pollution and costs which are likely to further increase over the next decades with increasing traffic levels (1). New York Metropolitan Transportation Council (2005) defined traffic congestion is defined as the level at which the performance of the transportation system becomes unacceptable (2).

According to Urban Mobility Scorecard report (3), a recent research regarding the 471 major urban areas in the USA, yearly delay per auto commute has been increased by 13.5% last 14 years (2014 figures). The same (Table 1) report revealed that congestion cost per auto commuter was increased by 18.5% reaching about \$960 for the same interval period. The overall congestion cost has been increased by 40% (from B\$114 to B\$160) last fourteen years.

Table 1. Major Findings of the 2015 Urban Mobility Scorecard (471 U.S. Urban Areas) (3)

Measures of…	1982	2000	2010	2013	2014
… Individual Congestion					
Yearly delay per auto commuter (hours)	18	37	40	42	42
Travel Time Index	1.09	1.19	1.20	1.21	1.22
Planning Time Index (Freeway only)	--	--	--	--	2.41
"Wasted" fuel per auto commuter (gallons)	4	15	15	19	19
Congestion cost per auto commuter (2014 $)	$400	$810	$930	$950	$960
… The Nation's Congestion Problem					
Travel delay (billion hours)	1.8	5.2	6.4	6.8	6.9
"Wasted" fuel (billion gallons)	0.5	2.1	2.5	3.1	3.1
Truck congestion cost (billions of 2014 dollars)	--	-	--	--	$28
Congestion cost (billions of 2014 dollars)	$42	$114	$149	$156	$160

Another significant effect of the remarkable increase in traffic congestion is that the average weekday peak period trip takes 37 per cent longer than the same trip during the off-peak period whereas it used to be only 12 per cent longer in 1982 compared to 2004 figures (4). The same research found out that 45 per cent of the traffic congestion is led by recurring problems including insufficient capacity, improper signal timing and inadequate utilization of intelligent transportation systems. Figure 1 summarizes the causes of the traffic congestion in the US according to the mobility report. Table 1 clearly depicts that improper signal timing is a one of the major causes of traffic congestion in the US.

While five per cent of the traffic congestion in the US was found to be caused by improper signal timing, it would be reasonable to assume that this rate could be higher for Tirana since Tirana does not have real-time adaptive control strategies (5). Nevertheless, fixed-time or time-of-day optimization of the existing transportation systems in Tirana is a significant tool for providing the full utilization of existing facilities till the development and implementation of adaptive control strategies.

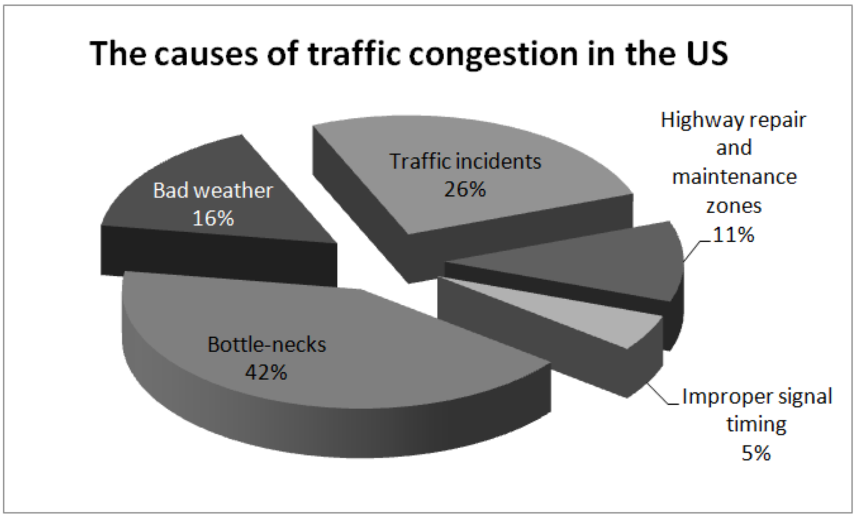

Figure 1. The causes of traffic congestion in the US 2004 (4)

Improvement of existing transportation system operations is a significant tool of urban traffic management, which has become absolutely prevalent in congestion management. The system frequent update implies the incessant necessity of periodic optimization of existing transportation systems (6).

Optimization of existing traffic signal systems usually lead to the highest benefit-cost ratios in terms of reducing congestion on surface streets if there are no other deficiencies along arteries and intersections. According to Sunkari (2004) typically, the cost to benefit ratio for signal retiming is 1:40 (7). Furthermore, a case study in Tirana by Barhani (2012) revealed that the cost benefit ratio for isolated intersection has been estimated to be 1:67 (8).

According to Hicks and Carter (2000) adaptive control strategies, which make use of mathematical algorithms to achieve real-time optimization of traffic signals with respect to varying traffic conditions, demand, and system capacity, are advantageous over traditional fixed-time/time-of-day plans in three functional areas; delay reduction, safety and operational maintenance (9).

However, the existing traffic signal control system, which governs the signal timing of the signalized intersections within the urban transportation network of Tirana, involves neither real-time adaptive control strategies nor an optimization tool that can, for instance, minimize the traffic delay or the number of vehicle stops, within a particular zone of the total network. For the time being, the application of "green wave" along a particular arterial is not applied thus the intersections movement is guided by police. Nevertheless, for a particular zone, the current measures of effectiveness (MOE's) such as traffic control delay, average number of vehicle stops and queue delay cannot be easily evaluated and has to be done through a substantial amount of field data collection. Thus, a signal coordination program regarding the minimization of those MOE's cannot be easily accomplished as can be done with traffic simulation packages. Thus, the consequences of the traffic congestion in Tirana are progressively reaching a very serious level with substantial amount of cost to the economy.

Arterial optimization involves many different tasks such as field data collection, control and improvement of arterial access and intersection geometry; signal timing which covers the selection of an optimum cycle length for the artery, optimization of offset times and phase sequences and fine-tuning in the field. A systematic approach for performing all these tasks is very significant in order arrive a good solution.

Meyer in 1997 listed five main criteria required to improve the existing signalized systems (10):

- Update of the equipment,
- Maintenance
- Improvement of signal phasing and timing corresponding to current traffic flow,
- Coordination of existing traffic signals to enhance traffic flow within a network or an artery,
- Removal of traffic signals that are no longer justified

Development and implementation of a real-time signal coordination system by means of adaptive control strategies for the urban transportation network of Tirana necessitates substantial investments that can be brought to execution in the long-run. Thus, prior to the implementation of a real-time adaptive control strategies, some related computer packages can be utilized for introducing improvements in the existing transportation systems. The major goal of this study was to investigate the signal coordination strategies and to formulate and field-test the methodology for this task. Hence, being the first arterial signal coordination study in Tirana that involves the employment of professional computer packages, this project might constitute a constructive basis as to how to utilize the selected computer packages for the incoming signal coordination projects of Tirana Metropolitan Municipality.

II. LITERATURE REVIEW AND BACKGROUND

2.1 Principal Of Signal Coordination

If the signalized intersections in an artery or a network are close enough, the vehicles proceed as platoons along the artery or within the network. In this case, it is essential that the signalized intersections within the system be coordinated. Thereby, more efficient movement of vehicles through the successful signalized intersections is achieved by providing more continuous and uninterrupted movement of the vehicle platoons. Otherwise, the green interval at a downstream intersection would be wasted meanwhile the vehicle platoon at the upstream intersection is held till the end of the red interval. In an urban network where signal coordination is to be applied, the basic requirement is that all signalized intersections within the network must have the same cycle length or twice the common cycle length in the network (5).

The time difference between the initiations of the green intervals at both intersections gives the offset for these two intersections. As demonstrated in Figure 2, when first vehicle of the vehicle platoon, which passes from intersection A without stopping, arrives at intersection B, the green interval has just started at intersection B so that it also passes from intersection B without stopping.

The amount of green time that can be used by a continuously moving vehicle platoon is called bandwidth. In other words, bandwidth is the maximum green time that enables the movement of vehicles without stopping at all consecutive intersections. For a given arterial, the number of vehicles that can pass through the series of signalized intersections along the arterial without stopping is called the bandwidth capacity. Bandwidth efficiency is found by evaluating the ratio of the bandwidth to the total cycle length.

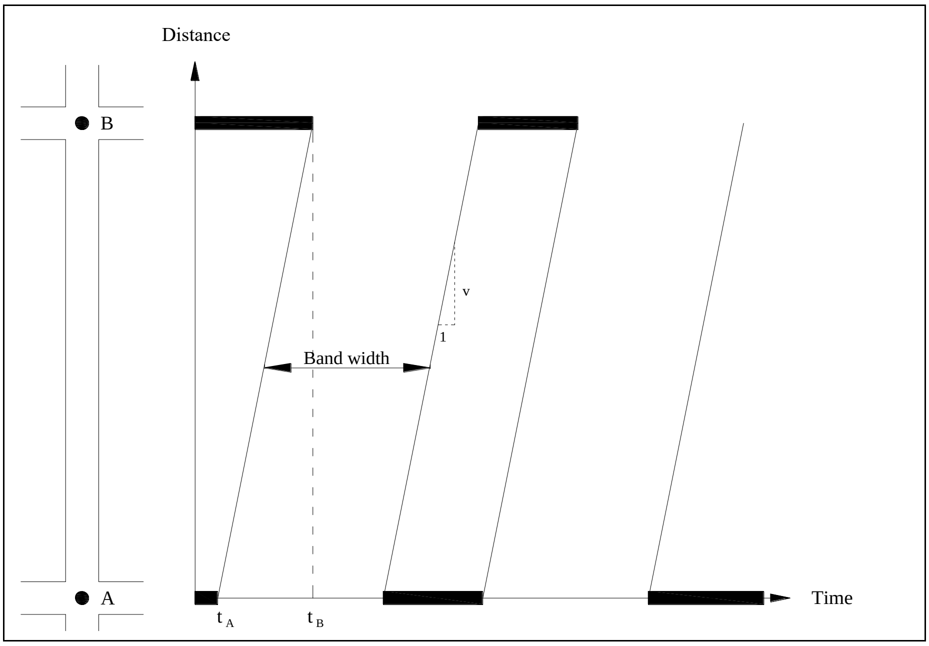

Figure 2. An example time-space diagram

The estimation of vehicle platoon speed is critical in signal coordination. If the actual platoon speed is different than the assumed platoon speed, the bandwidth diminishes remarkably. When the anticipated travel speed is faster than the actual travel speed, the bandwidth diminishes substantially and thus; the number of continuously moving vehicles along the artery decreases considerably. Generally, overestimating the vehicle platoon travel speed brings about a higher decrease in bandwidth than underestimating the vehicle platoon speed.

In many cases, the vehicle platoon comes across a vehicle queue at the downstream intersection. The vehicles in the queue are usually those that turn into the artery from driveways and side streets, come out of adjacent parking lots and parking spots, and the stragglers of the previous vehicle platoon. Consequently, the leading vehicles of a vehicle platoon have to be delayed at the downstream intersection until the queue completely discharges. In order to prevent the queue delay of the vehicle platoon, the ideal offset value has to be adjusted accordingly so that when the vehicle platoon arrives at the downstream intersection, the queue has already discharged and the vehicle platoon does not delay.

While the ideal offset calculation is quite straightforward in one-way arterials, signal coordination in two-way arterials is fairly troublesome since the bandwidth in each direction cannot be set independent of each other. In other words, when the bandwidth in one direction is established, the other is automatically determined. That's why it is hard to keep the bandwidth as high as possible in both directions.

Signal coordination may be based on different goals. For instance, According to Leonard and Rodegerdts (1998) the main goal of coordination can be the minimization of traffic delay, number of vehicle stops, fuel consumption or the most efficient flow along a particular route (11). In order to present the benefits of signal coordination quantitatively, particular measures of effectiveness (MOEs) within the coordinated system are compared by means of before and after studies. Generally, a particular performance index (PI) is defined in order to provide the quantitative evaluation of signal coordination. This performance index is generally a linear combination of some of the measures of effectiveness. This index is predefined in SYNCHRO (12). In the signal coordination of Rruga e Kavajes, SYNCHRO aims to minimize the performance index (PI) in signal coordination. Husch and Albeck (2004) defined the performance index is as follows:

$$PI = D + \frac{10 * St}{3600}$$

Where:
PI: Performance index
D: Total delay that takes place in a one-hour interval (sec.)
St: Total number of vehicle stops in a one-hour interval

The signal coordination of a two-way artery can be achieved by applying a trial and error procedure on the time and space diagram. Thereby, the bandwidth in each direction can be set efficiently as depicted through Figure 3. For some special cases, simultaneous systems, alternating systems or double alternating systems can be utilized.

Traffic signals may rarely generate the opposite effect of that intended by, for instance, increasing the number of rear-end collisions though they decrease severe right-angle collisions (13). Moreover, under a properly-timed traffic signal system, there exists a tradeoff between minimum delay and maximum bandwidth. For instance, a strategy that can either maximize the bandwidth at the expense of limiting the level of service for the side streets or minimize the delay at slight loss in bandwidth was previously developed (14).

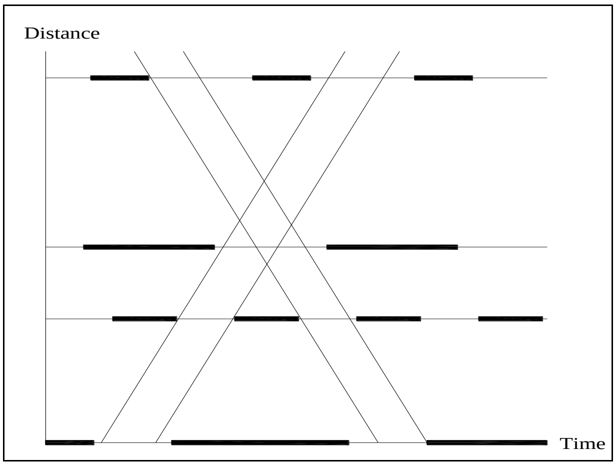

Figure 3. Signal coordination of a two-way artery by applying a trial and error procedure on the time space diagram (5)

2.2 Case Studies

Optimization of existing traffic signals is one of the most cost-effective tools of dealing with traffic congestion and various research projects have revealed that substantial improvement within the urban transportation network can be achieved by means of traffic signal optimization and coordination projects. Some of them are summarized as follow:

- According to 26 projects of a statewide signal synchronization program implemented in Texas (1995), 19.4 per cent reduction in delay, 8.8 per cent reduction in the number of stops, and 13.3 per cent reduction in fuel consumption were observed. The overall benefit/cost ratio of the synchronization program was l:38 (15).
- Reductions in average delay per signal cycle between 14 and 29 seconds were observed subsequent to the implementation of a program to improve traffic signals in Tucson in 1991 (16).
- Likewise, benefit-cost ratios in the 20:l range were accomplished owing to a similar program that was conducted in northern Virginia in 1991 for signal improvements. In terms of travel time savings and fuel costs, the annual user benefits were estimated to be just over 7 million US$ (17).
- The signal coordination project conducted in Kansas City, Missouri in 2003 involved the signal retiming and coordination of an artery that consists of nine successive signalized intersections. This signal coordination project gave rise to a 91,491-gallon decrease in annual fuel consumption, 101,455- vehicle-hour reduction in traffic delay, 2,293,084-US$ savings in time and fuel cost, and 90,100-kg reduction in total pollutant emissions (18).
- A further case expressed the benefits of signal coordination is the outcomes of signal coordination in 85 major urban areas of the US in 2004. In the 85 urban areas, over 469 million daily vehicle-miles of travel took place on about 62,626 lane-miles of principal arterial streets which involve either actuated or real-time signals in place. It is estimated that the coordination of either real-time or actuated signal systems in those areas reduced the arterial vehicular delay by 17.6 million hours (19).
- For the same type of arteries in 2000 with the same congestion level, the real-time signal coordination was found out to bring about at least twice the percentage of delay reduction that was induced by actuated signal coordination (20).

2.3 Factors That Reduce The Benefits Of Signal Coordination

For a particular artery or network, before the signal coordination is implemented, the system should be inspected against any factors that can hinder the full utilization of signal coordination. If such factors exist, then the system should be improved in order to eliminate all potential problems against signal coordination. Otherwise, even a perfect coordination cannot be fully utilized and cannot end up with the anticipated benefits. McShane et al. (2004) listed he major factors that lower the benefits of signal coordination as follows (5):

- Too much speed variance among the vehicles in platoons,
- High volume of vehicles entering the artery from side streets, driveways or adjacent parking lots,
- High number of adjacent bus stations and bus blockages,
- Too short or too long block lengths between consecutive signalized intersections,
- Insufficient capacity,
- Signalized intersections with very complicated and high number of signal phases.

The factors itemized above interrupt the continuous flow of vehicle platoons and thus reduce the benefits of signal coordination. So prior to the implementation of signal coordination, a system should be inspected against the itemized potential problems in order to ensure the full benefits of signal coordination.

2.4 Signal Coordination Software

In traffic engineering, the most widely-used signal optimization computer packages are SYNCHRO, TRANSYT-7F and PASSER. The three computer packages are utilized for providing coordinated timing plans for arteries. These computer packages make use of different optimization algorithms. The scope of this study focuses only on SYNCHRO tool.

SYNCHRO is developed by Trafficware and it deals with the signal timing of an artery or a network. The main capabilities of SYNCHRO are optimization of intersection splits and cycle length, offset optimization and network or arterial cycle length optimization. It is a delay-based program, whose objective function is to minimize a linear combination of stops and delay of vehicles. This linear function is called performance index (12).

Its most outstanding advantage is the effortless data entry and its extremely user-friendly interface (21), (22). In addition, a network or an artery can be set up in a single file. Moreover, SYNCHRO is capable of plotting detailed time-space diagrams that can indicate vehicle paths or bandwidths. The timing results obtained from SYNCHRO can be exported directly to other software (23). Last but not least, the tool enables coordination zone by zone so that one zone can be optimized independently of another.

III. 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 four different scenarios shown in the Table 2. Once adjustments were identified, changes to the field equipment could be made to implement improvements.

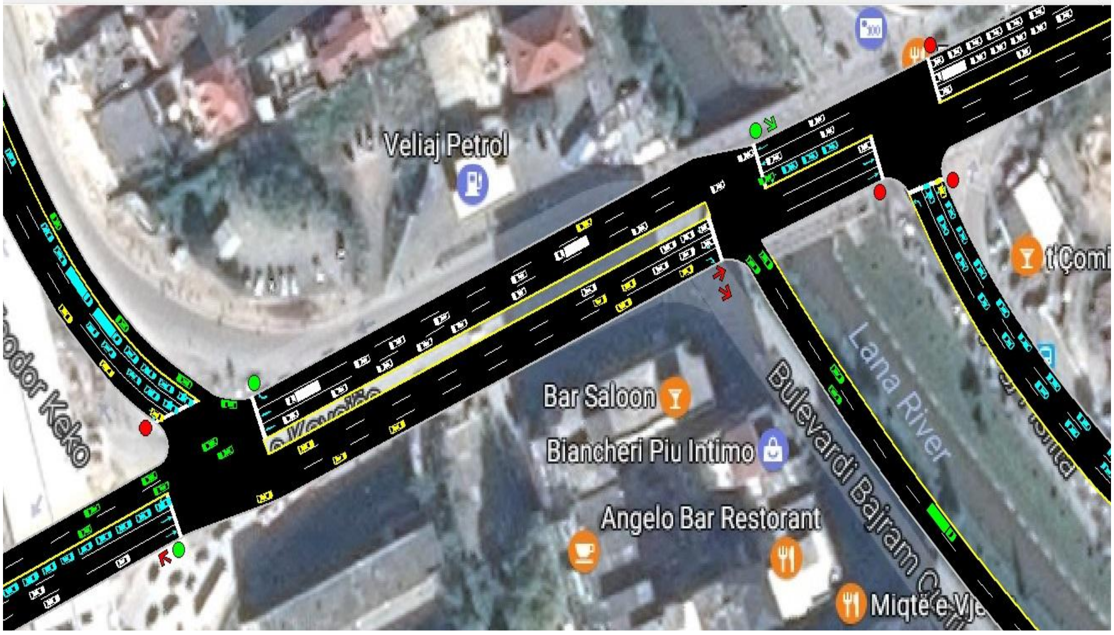

Figure 4. Aerial Photo of the artery simulated on CORSIM

These four scenarios are employed in the signal optimization in Rruga e Kavajes Artery with SYNCHRO. 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, fuel consumption and PI values were obtained.

In the second scenario a Fixed-Time signal is considered, however the signal split is optimized. The intersection is first modeled to find the most suitable signal phasing combination for each intersection separately. The morning peak hour phasing combinations and signal split has been applied to off-peak and evening peaks. However, signal coordination has not been applied. Then MOEs were evaluated.

In the third scenario a Time-of-Day signal is considered. The Time-of-Day signal type is fixed in three different signal splits corresponding to three peak hours during the day. The signal split is optimized for each peak hour. The intersection is first modeled to find the most suitable signal phasing combination, however not coordinated.

In the Fourth scenario Time-of-Day signal type is considered. Then a new phase plan is obtained for three different time intervals; morning peak, off-peak, and evening peak. This signal phases are modeled separately and optimized signal splits are obtained. Signal coordination has been optimized for each peak hour. 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.

Table 2. Summary of the scenarios employed in the signal optimization of 21 Dhjetori

Scenario No	Type of Signal	Signal Optimization	Signal Coordination
1	Fixed-Time	Actual	Actual
2	Fixed-Time	YES	NO
3	Time-of-Day*	YES	NO
4	Time-of-Day*	YES	YES

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

IV. ANALYSIS AND DISCUSSION

4.1 Vehicle Number Hourly Fluctuation Of The Study Area

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 April 22nd 2014. According to Figure 5 this study revealed that the morning peak (the highest traffic volume) was observed to be between 8:10 A.M. and 9:10 A.M., whereas the evening peak was observed between 14:10 P.M. and 14:30 P.M.. According to Figure 6, the traffic flow in this artery is pretty high during the whole day reaching its maximum of 2,520 vehicles per hour at morning peak. The maximum flow rate during evening hour was found out to be 2,435veh/hr. On the other hand, the minimum flow rate occurred between noon time and evening peak (2,120veh/hr).

Directional flow rates (east and west directions) showed to be different during the day. The number of vehicles in the east direction reached its maximum (1,502veh/hr) in the morning and followed a slight decrease during the day. On the other hand, the number of vehicles in the west direction increased slightly during the day reaching its maximum (1,324veh/hr) in the evening peak.

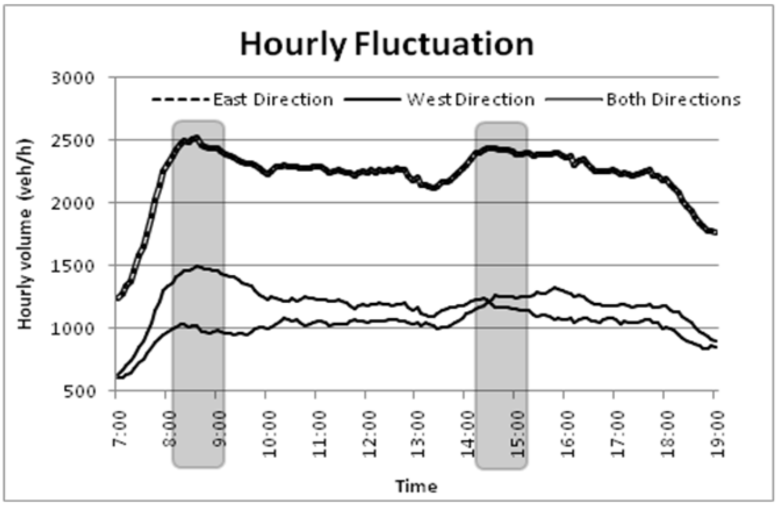

Figure 5. Hourly fluctuation

4.2 Measure Of Effectiveness (Moes) For 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, environmental pollutants and Performance Index (PI). Figure 6 shows the percentage change of PI relative to actual condition (Scenario 1).

Scenario 2 shows deteriorated MOE parameters especially during the morning and evening peak (20%) while no affect during the off-peak is observed. This is a typical case when close intersections considerd as independent units worsens the traffic congestion especially at high volume demands. In addition, Scenario 3 (variable signal split for different peak hours) showed degradation of the traffic congestion as well, although less compared to fixed time signal types. Interestingly, a significant improvement is observed for off-peak optimization reaching about 40%.

Table 3. Summary Measure of Effectiveness for each Scenario

Measures of Effectiveness (MOEs)	Scenario 1			Scenario 2			Scenario 3			Scenario 4		
	MP	**OP**	**EP**	**MP**	**OP**	**EP**	**MP**	**OP**	**EP**	**MP**	**OP**	**EP**
Control Delay / Veh (s/v)	43	53	51	41	46	44	41	30	34	50	32	35
Queue Delay / Veh (s/v)	28	8	10	46	15	30	46	12	25	5	3	11
Total Delay / Veh (s/v)	71	61	61	87	60	74	87	42	59	54	35	47
Total Delay (hr)	301	211	242	366	209	293	366	146	235	230	123	185
Average Speed (km/hr)	9	11	10	8	11	9	8	14	11	11	16	13
Total Travel Time (hr)	368	268	306	432	266	357	432	202	298	296	180	248
Distance Traveled (km)	3324	2835	3161	3324	2835	3161	3324	2835	3161	3324	2835	3161
Fuel Consumed (l)	1361	990	1147	1514	993	1286	1514	826	1133	1151	761	1008
Fuel Economy (km/l)	2.4	2.9	2.8	2.2	2.9	2.5	2.2	3.4	2.8	2.9	3.7	3.1
CO Emissions (kg)	25.32	18.41	21.33	28.16	18.47	23.93	28.16	15.37	21.07	21.41	14.15	18.75
NOx Emissions (kg)	4.89	3.55	4.12	5.44	3.57	4.62	5.44	2.97	4.07	4.13	2.73	3.62
VOC Emissions (kg)	5.84	4.25	4.92	6.5	4.26	5.52	6.5	3.54	4.86	4.94	3.26	4.33
Performance Index	327.5	227.9	264.1	388.6	227.2	314.9	388.6	164.6	257.6	254.4	141.6	209.3

MP: Morning peak, OP: Off-peak, EP: Evening peak

On the other hand, the last scenario (no 4) provided the best MOEs. Adapting the signal splits for three different types of volumes and coordinating the signals provided the lowest delays, fuel consumption and emission of this intersection. During the morning and evening peaks PI improved approximately by 30% while showing about twice for the off-peak (60%). As a result, signal optimization should be associated with signal coordination when the intersections are close with each other.

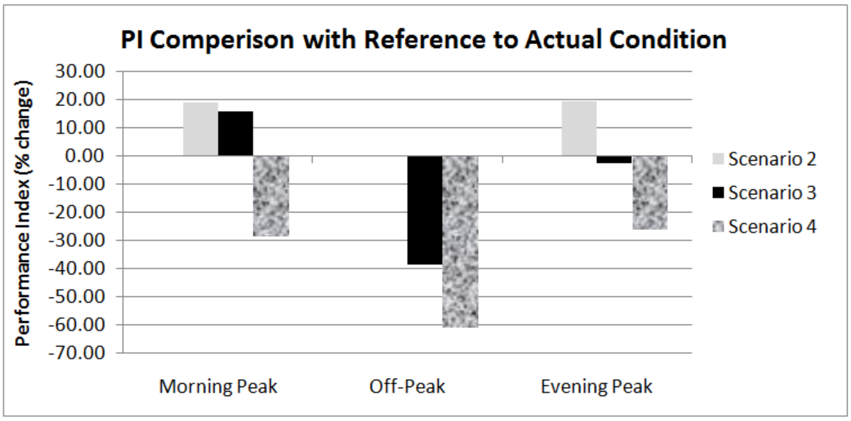

Figure 6. Percentage change of PI relative to actual condition.

4.3 The Benefits Of Signal Optimization

Figure 7 shows percentage change of average speed, fuel consumption, total delay and CO, NOx and VOC emission for each scenario. As predicted from Performance Index all the parameters are deteriorated for Scenario 2 with respect to the actual one. Interestingly these parameters seem to fall very close to the actual ones when Scenario 3 is considered. Thus, this artery could have been optimized for different times of the day however it is not coordinated. Coordinating this high volume artery has decreased the CO, NOx and VOC emissions and fuel consumption by 17%. On the other hand, average travel times has increased by one third, jumping from 10 km/hr to about 13 km/hr while total delays has been decreased by 29%.

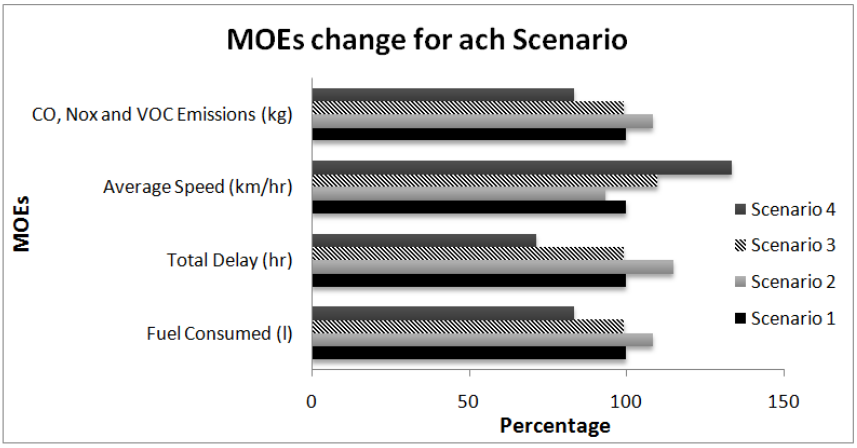

Figure 7. MOEs change for each scenario

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. The signal coordination of Rruga e Kavajes gives rise to annual fuel savings of €210,000 and annual time saving equivalent to €96,000, since the annual average income equals to €3,554 (Instat, Albanian Institute of Statistics, 2015). As far as environmental consequences of the intersection optimization are considered this signal optimization has led to an annual reduction of 2,795kg carbon dioxide emission, 540kg of nitrogen oxide emission and 644kg volatile organic compound emission.

Barhani in 2012 estimated the cost for the first year of improving and maintaining the intersections actual traffic light system from actual ones to conventional or LED signals, to be about €3.525 and €9,883, respectively. LED signals are superior to conventional ones in terms of quality since LED light usage will decrease the possibility of failure. LED light consists of various miniature diodes as well they eliminate phantom affect. With the above considerations the cost-benefit ratio for the first year of the signal coordination in Tirana for conventional and LED ones is estimated to be at least 1:29 and 1:10, respectively.

V. CONCLUSIONS AND RECOMMENDATIONS

Five percent of the traffic congestion in USA is found to be due to improper signal timing. However this study showed that improving signal timing by signal coordination improves traffic congestion in Tirana by 29%. Tirana involves neither functional 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 (5). 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.

In addition, the signal timing and phasing improvement in Rruga e Kavajes artery signal coordination brought about substantial savings in term of time and fuel consumption. Values of time and fuel consumption reductions resulted from signal coordination summarized to €306,000 annual savings for these three intersections. Taking into account that total cost of LED traffic device (material, installation and operation) is evaluated to be €9,900 the cost benefit ratio was estimated to be 1:10. If the actual conventional ones are used this ratio is estimated to be 1:29.

Furthermore, Environment improvements are obviously recognized 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. CO2, NOx, and VOCs amounts emitted from vehicles are decreased by, 2,795kg, 540kg, and 540kg, 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 SYNCHRO, TRANSYT-7F and PASSER 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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