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EFFECT OF COORDINATION SEMI-ACTUATED TRAFFIC CONTROL ON THE LEVEL OF SERVICE IN CONTEXT OF VEHICLE DELAY DECREASING AND FUEL CONSUMPTION REDUCTION ON A FOUR SIGNALIZED INTERSECTIONS ARTERY

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ABSTRACT
Fixed- time control of traffic signals pursues the regulation of phases based on historical data of traffic demand, in this way, neglecting of the random arrival rates of traffic flow on different intersection streams causes increasing of the stops and delays and fuel consumption at the same time. Coordinated semi-actuated control due to ability to respond traffic demands on both main and secondary directions, based on road detector registration saves the coordinated features, serving the unused time to the main road, while the secondary clears early. In this paper are analyzed and comparatively explained the results of LOS parameters of the current state of control (fixed-time) with the proposed control (semi-actuated coordinated) of the artery of length 2,348 km consisted of four signalized T intersections. Highway Capacity Manual and Synchro/Sim Traffic software are used for analysis and optimization of parameters in this paper.
Keywords: LOS (level of service), fixed-time control, actuated control, cycle, phase, ring-barrier, stream, capacity, delay, travel speed.

1. INTRODUCTION
During fixed-time control, due to phase regulation based on historic traffic data collections, most of isolated intersection approaches in which the demand varies during the basis of day or hour, remain un served and some of them with lower demand gaps out early but spend the time of the phase to come, causing intersection delay which results in poor LOS of intersection.
At semi-actuated coordinated control detectors are placed on the secondary streets. The signal operates on a fixed cycle length and any unused time on the cycle is added to assigned coordinated phases. Other assigned phases may skip or gap out, based on vehicle detection.

2. MEASURES OF LOS AND SYNCHRO SOFTWARE ANALYSIS
Since there is chosen the parameter of delay [1,2,3] and fuel consumption [4] as a measure of the level of service, the most compatibility software with Highway Capacity Manual , which is Synchro is used for analysis in this paper.

2.1 Delay Calculation
Synchro software uses the formula for delay calculation based on Webster model, as below:

$$d = d_1 + PF \cdot d_2 + d_3 \ (s) \qquad [1]$$

when d_1 is uniform delay and is calculated through the formula written below:

$$d_1 := \frac{0.5\cdot C\cdot\left(1-\frac{g_i}{C}\right)^2}{1-\left(\min(1,X_i)\frac{g_i}{C}\right)}$$

[2]

d_2 is the Incremental delay and is calculated thorugh the formula written below:

$$d_2 := 900T\cdot\left[(X_i-1)+\sqrt{(X_i-1)^2+\frac{8k\cdot I\cdot X_i}{K\cdot T}}\right] \quad [3]$$

d_3 is the residual demand delay caused by existing queue at the beginning of analysis period.
The progression factor (PF) is used to account for the effects of coordination which in Synchro takes into consideration the ratio of the uniform delay with coordination and uniform delay assuming random arrivals.
Evaluation for delay parameter for both fixed-time control and that of proposed control of semi-actuated is done in an 15 minutes period time analysis and results are accounted for the 50^{th} percentile scenario-as the average busiest cycle.

2.2 Fuel consumption calculation

Synchro calculates the fuel consumption using the formula:

$$F = T_{Travel}\cdot k_1 + T_{Delay}\cdot k_2 + Stops\cdot k_3 \quad [4]$$

Where:

$$k_1 = 0.07523 - 0.0015829\cdot speed + 0.000015066\cdot speed^2;$$
$$k_2 = 0.7329;$$
$$k3 = 0.0000061411\cdot speed^2$$

3. SEMI-ACTUATED CONTROL FOR ARTERY

The artery (depicted in fig.1) of length 2,348 km consists of 4 intersections of T form which are signalized through uncoordinated fixed-time control. The distances between intersections are as follows:. Intersection1-Intersection 2~398 m; Intersection 2-Intersection 3~1485 m; Intersection 3-Intersection 4 ~465 m.
A necessary settlement of the ring-barrier design for each of intersection is given (figure 1) which describes the sequences of the phases, simultaneity and barrier between themselves within a cycle length of 80 sec. The placement of the detectors only on the side streets and on the left turn lanes of main street is assumed, with the controller setting function of Call Max applied on the coordinated phases only.

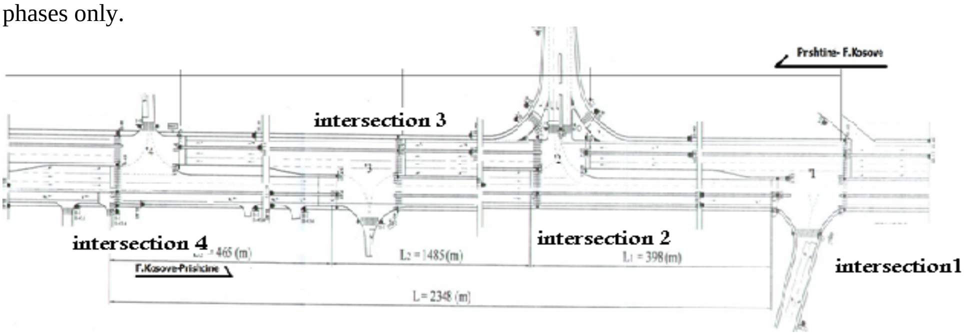


Figure 1. The geometric view of the artery

The sequences of phases in ring-barrier diagram are given with different colors for different intersections. With the squares of colors yellow, blue, violet and red are represented the phases of the intersection 1, intersection 2, intersection 3 and intersection 4, respectively.

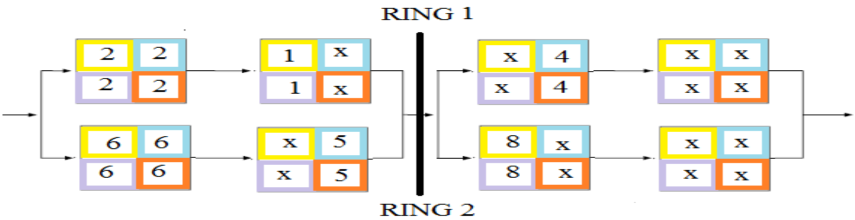


Figure 2. Ring-barrier configuration for 4 intersections

Phases 2 and 6 constitute to the coordinated phases, 1 and 5 present the left turn phases from main street and those 4 and 8 present the secondary streets. For example: in the Intersection 1, coordinated phases 2 and 6 are simultaneous in the first ring, until the left turning phase 1 indicates a call, in which cases the conflicting phase 2 pushes to end but the phase 6 continues till the end of the ring. The phase 8 activates on the other ring 2 which is separated with the barrier from the phases belonging to the ring 1.

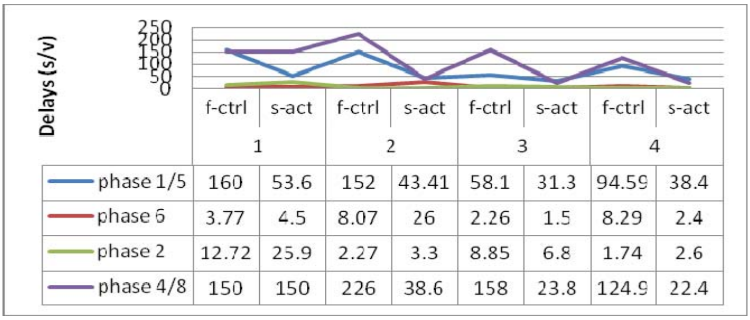
4. RESULTS AND DISCUSSION

Table 1. Delay measures for intersections approaches (s/veh)

		Left turn lane Phase 1/5	Coord(WB) Phase 6	Coord(EB) Phase 2	NB/SB Phase 4/8
Approach of intersection			←	→	
Intersection '1	Fixed-time	160	3.77	12.72	150
	Semi-actuated	53.6	4.5	25.9	150
Intersection '2	Fixed-time	152	8.07	2.27	226
	Semi-actuated	43.41	26	3.3	38.6
Intersection '3	Fixed-time	58.1	2.26	8.85	158
	Semi-actuated	31.3	1.5	6.8	23.8
Intersection '4	Fixed-time	94.59	8.29	1.74	124.9
	Semi-actuated	38.4	2.4	2.6	22.4

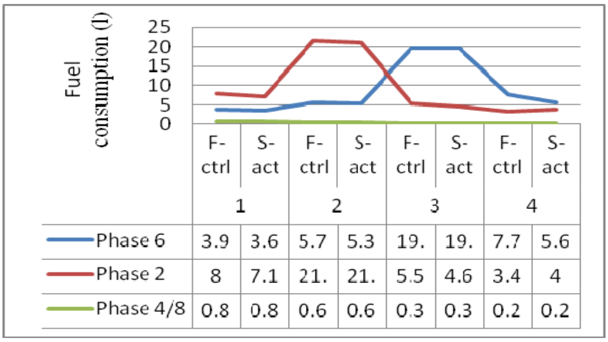
Table 2. Fuel consumption for intersections approaches (l)

		Coord(WB) Phase 6	Coord(EB) Phase 2	NB/SB Phase 4/8
Approach of intersection		←	→	
Intersection '1	Fixed-time	3.9	8	0.8
	Semi-actuated	3.6	7.1	0.8
Intersection '2	Fixed-time	5.7	21.6	0.6
	Semi-actuated	5.3	21.1	0.6
Intersection '3	Fixed-time	19.6	5.5	0.3
	Semi-actuated	19.7	4.6	0.3
Intersection '4	Fixed-time	7.7	3.4	0.2
	Semi-actuated	5.6	4	0.2



	f-ctrl (1)	s-act (1)	f-ctrl (2)	s-act (2)	f-ctrl (3)	s-act (3)	f-ctrl (4)	s-act (4)
phase 1/5	160	53.6	152	43.41	58.1	31.3	94.59	38.4
phase 6	3.77	4.5	8.07	26	2.26	1.5	8.29	2.4
phase 2	12.72	25.9	2.27	3.3	8.85	6.8	1.74	2.6
phase 4/8	150	150	226	38.6	158	23.8	124.9	22.4

Figure 3. Reduction of delay measure (s/veh) on semi-actuated traffic control



	F-ctrl (1)	S-act (1)	F-ctrl (2)	S-act (2)	F-ctrl (3)	S-act (3)	F-ctrl (4)	S-act (4)
Phase 6	3.9	3.6	5.7	5.3	19.	19.	7.7	5.6
Phase 2	8	7.1	21.	21.	5.5	4.6	3.4	4
Phase 4/8	0.8	0.8	0.6	0.6	0.3	0.3	0.2	0.2

Figure 4. Reduction of fuel consumption (l) on semi-actuated traffic control

5. CONCLUSIONS

The objective of this paper was to validate the effect of the both existing fixed-time control and of the proposed semi-actuated on the intersection delays and fuel consumption as primary measures of the artery level of the service. As a result of the findings from this study, the main conclusion that can be drawn is that the above mentioned analyzing parameters, particularly the vehicle delays, on both main and crossed streets and generally the artery level of service were improved significantly within the form of semi-actuated control. This form has shown better results not only on the main street performance. Except saving the coordination features of the artery, the semi-actuated control satisfies the performance of minor streets on the four intersection of the artery.

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