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JUNCTION SIGNAL PLAN ASSESSMENT IN RELATION TO DIFFERENT PROGRAMMING STRATEGIES

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Abstract: *Road traffic research has shown that a thorough analysis is required to identify different vehicle movement parameters within a given network. These parameters depend on a number of aspects such as: direction of travel, alternation of transport demand during a day, location of the artery in the territory, type of road and also the area analyzed. The paper aims to analyze different strategies in junction signal plan creation based on the traffic parameters. The main aspect of the different strategies analyzed in this paper is given by the comparison between two and three phases of junction signal plans*

Keywords: *signal plan, road junction, delay time.*

I. INTRODUCTION

In general, traffic flows are not uniform, they are variable in time and space. For this reason, the measurement of variables of interest for traffic flow theory consists in the sampling of random variables. In fact, traffic characteristics are average values of statistical distributions and in no way absolute numbers [1, 2].

In the case of macroscopic analysis, the behavior of the average group of vehicles is studied and the parameters investigated are represented by the strength (intensity) and density of traffic [3].

In general, successive traffic intensity assessments are required for the analysis of traffic times at different intersections by the values of the time intervals between vehicles, using the following equation:

$$q = \frac{M}{T} = \frac{M}{\sum_i t_i} \qquad (1)$$

In the same time, vehicle size and maneuverability are basic factors in the design of the intersection traffic lights, especially when the characteristics of the type of direction of traffic flows have been selected. Conflicts arising from various maneuvers at intersections can lead to a single solution of operational characteristics. Proper understanding of these features, with a focus on safety and capacity, are essential elements of traffic light intersection design. Traffic capacity analysis is based on the operational characteristics of vehicles performing movements, possibly conflicting, separated over time by traffic control devices.

II. THEORETICAL CONSIDERATION

Traffic lights can be synchronized in three different ways:

- offline. The synchronization plan is built on the basis of previous traffic measurements. Here, the length of the traffic light cycle, the division of phases, and the durations of green intervals are predetermined for a significant time interval. The advantage of this method is the low implementation costs, as there is no need for sensors to purchase real-time data, only local controllers are needed to change the colors of traffic lights. The main disadvantage is the impossibility of adapting to different traffic conditions than those in which the estimates were made [4].

- semi-online. The establishment of traffic light phases and gaps between neighboring intersections is done in real time. However, the length of the traffic light cycle remains fixed. The advantage here is to increase the ability to adapt to random traffic variations. The disadvantages are the increase in implementation costs, requiring vehicle detection sensors, and the constraint imposed by keeping the length of the traffic light cycle.
- online. The coordination is done entirely in real time, without preset values. Online coordination methods are suitable for highly variable traffic conditions. They can provide the best results, instead are required efficient decision-making, communications and detection systems. Thus, the implementation costs increase significantly, and the appropriateness of the introduction of such a coordination system must be carefully considered.

The control plans used in the intersection analyzed are calculated by first grouping the different turns according to their conflicts and fraction volume/capacity, more exactly 2 and 3 phase control plans. Once the different conflicting groups are determined and ordered, the cycle time according to Webster method is calculated given the equation bellow:

$$Tc = \frac{(1.5 * Tl + 5)}{(1-Y)} \quad (2)$$

were:

- T_c = Cycle Time
- T_l = Total lost time of cycle
- Y = Sum of fractions for conflicting signal group

III. JUNCTION DESIGN

The intersection envisaged has a form common to many existing intersections. Its geometric configuration and the complexity it present can be seen in the figure below.

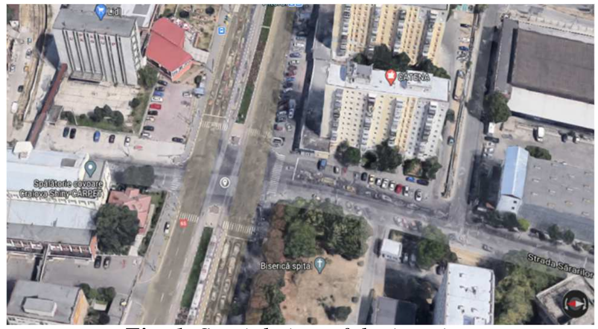


Fig. 1*. Spatial view of the junction.*

This intersection is one of the most circulated in the municipality of Craiova, with very high volumes of traffic recorded on the main artery (east-west, west-east). The volume of traffic on the other two streets (north-south and south-north) is also significant [5]. The traffic light currently used generates a very long delay time for road users and very long queues during peak periods, with drivers frequently forced to stop several times before entering the intersection.

According to the criterion of conflict movements, it is inferred that all left turns must be protected [6]. Currently, the first intersection signage plan taken into account comprises four phases as shown in Figure 2.

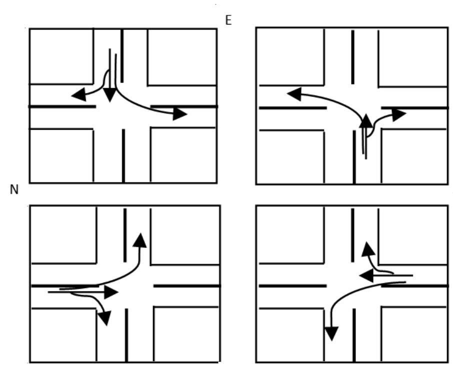


Fig. 2*. 4 phase traffic light system.*

Considering the above configuration of the junction we have begun to model 3D model in Aimsun platform (the software allows the traffic micro-modelling of the junction and the ease planification of the signal plans). The virtual model takes into the consideration the entire geometry of the junction, like tram lines, stop lines, etc. The virtual junction can be seen in the figure 3, also the intersection is set to not overcrowd if the speed of the vehicles is bellow 5km/h. The movement configuration within the intersection can be seen in the figure 4.

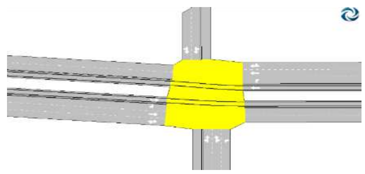


Fig. 3. *Virtual junction in Aimsun.*

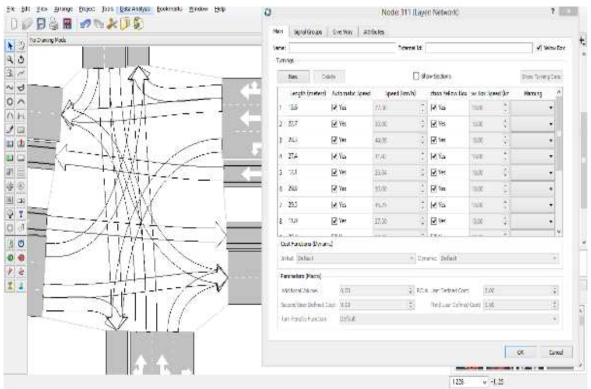


Figure 4. Movement configuration of the junction.

Another step in configuring the junction for analyzing different scenarios on 2 and 3 phases, is to setup the vehicle pollution parameter and vehicle consumption speed [7]. These parameters can be seen in the figure 5 and 6.

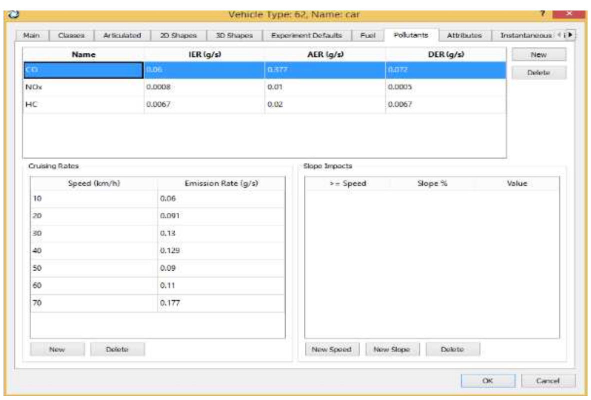


Figure 5. Chemical pollution parameters.

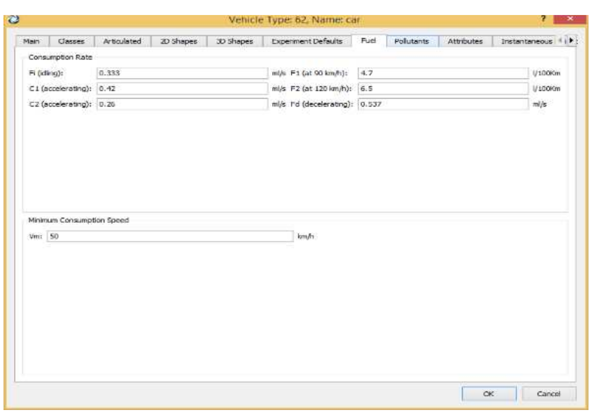


Figure 6. Fuel consumption parameters.

IV. JUNCTION SIMULATION AND RESULTS

The paper aims to analyze the junction in regards to two different aspects:

- 2 phase signal plan (Figure 7)
- 3 phase signal plan (Figure 8)

The mathematical calculation of the signal plans is not discussed in this paper but the results are implemented in Aimsun traffic light signal programming platform.

The signal plans are based on the measurements of the vehicles volumes that are passing within one hour through the intersection [8]. The O/D matrix generated, based on this measurement, defines how many vehicles will enter the simulation network at each connector from each centroid. The arrival algorithm in this case is set for uniform arrivals and control when those vehicles arrive in the simulation and the headways between them. Aimsun platform treats these arrivals of the vehicle that needs to enter the network, based on the bellow equation [9].

$$DesiredSpeed = min\langle \theta \ X \ SectionSpeed, Speed \rangle \quad (3)$$

were:

- $DesiredSpeed$ is the maximum desired speed of the vehicle that enters the network
- θ is the mean Speed Limit Acceptance
- $Speed$ is the mean Maximum Desired Speed

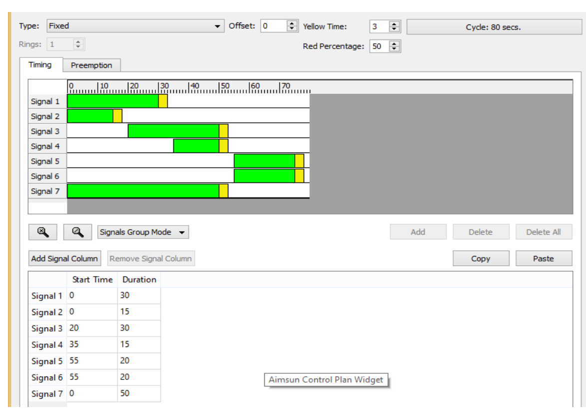
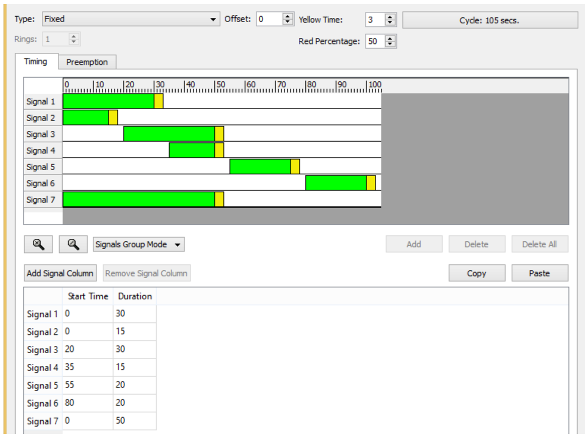


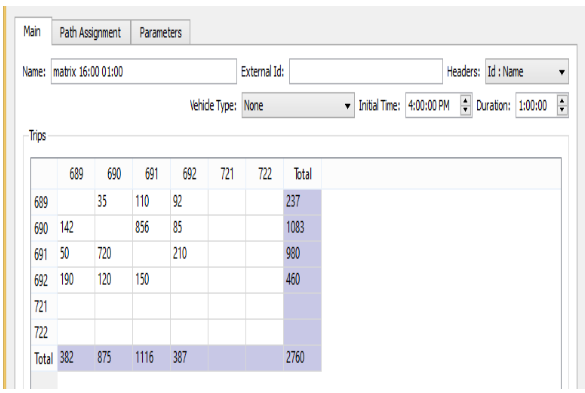
Figure 7. Signal plan – 2 phases.

The traffic volumes for the simulation are introduced into the network based on the equation 3 and on the OD matrix from the Figure 9. The matrix is for standard vehicles so the final volumes are split values based on the initial ones (60% - cars, 25% van and 15% taxi)



	Start Time	Duration
Signal 1	0	30
Signal 2	0	15
Signal 3	20	30
Signal 4	35	15
Signal 5	55	20
Signal 6	80	20
Signal 7	0	50

Fig. 8. Signal plan – 3 phases.

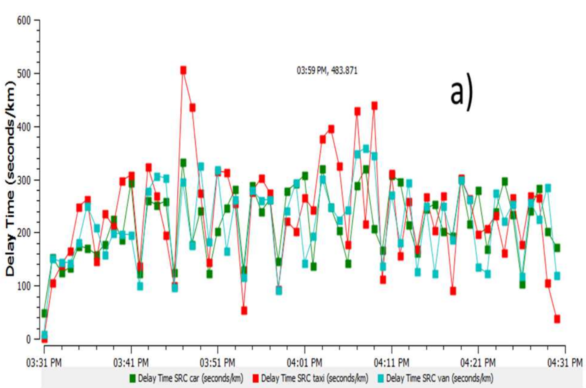


	689	690	691	692	721	722	Total
689		35	110	92			237
690	142		856	85			1083
691	50	720		210			980
692	190	120	150				460
721							
722							
Total	382	875	1116	387			2760

Fig. 9. Standard vehicles OD matrix.

The final step is the micro-simulation of the junction and compare the results based on the following parameters:

- Delay time (seconds/km)
- Stop time (seconds/km)
- Fuel consumption (liter/km)
- CO_2 (kg)



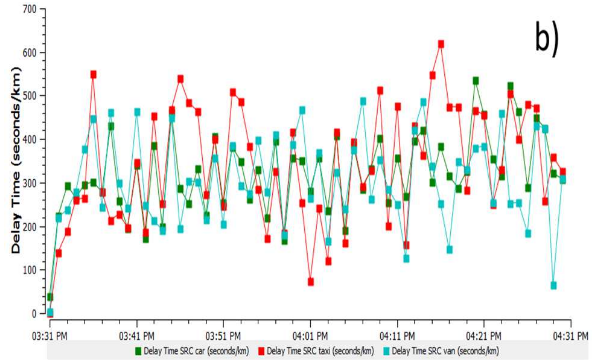
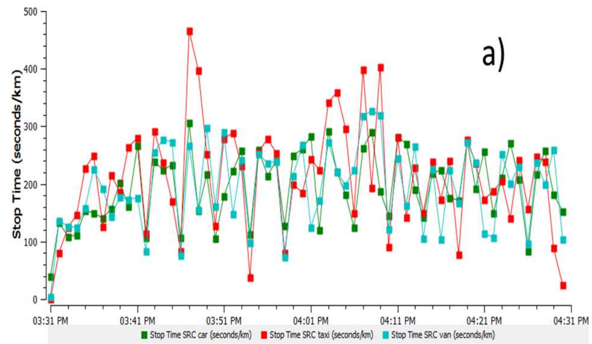


Fig. 10. Delay time – 2 phases (a), 3 phases (b).



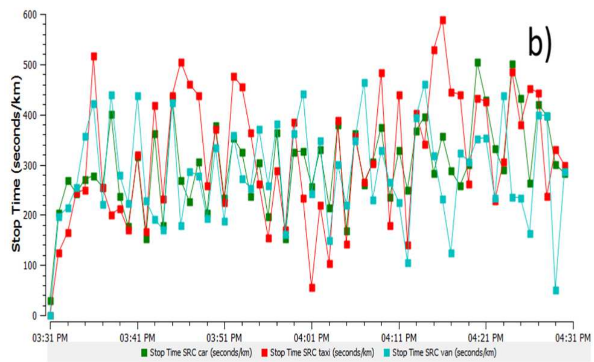
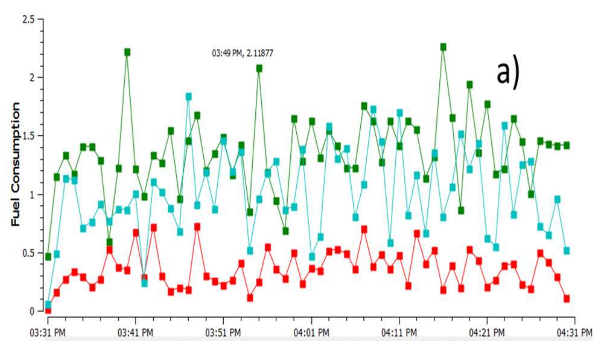


Fig. 11. Stop time – 2 phases (a), 3 phases (b).



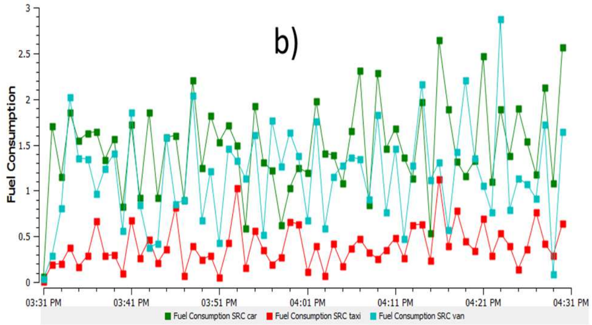


Fig. 12. Fuel consumption – 2 phases (a), 3 phases (b).

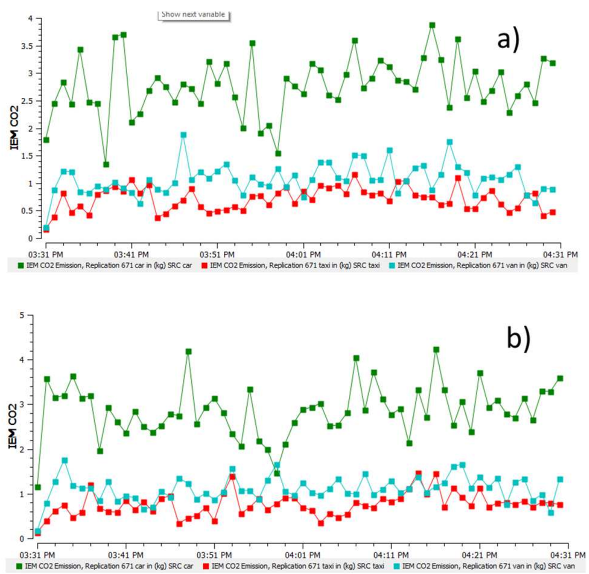


Fig. 13. CO_2 pollution – 2 phases (a), 3 phases (b).

V. CONCLUSIONS

Following the results of this paper, some conclusions can be drawn on the functionality of the intersection for the case with 2 and 3 phase traffic lights.

According to the simulation carried out on the two cases on the time span from 03:30 – 04:30 pm (the time range with the highest flow of vehicles) we can see that the 2 phases scenario is better that the 3 phases one.

In the case of the scenario with 2 phase traffic lights it is noted that the average delay time for the class of vehicles "car" is around 250 sec/km and for the 3 phase scenarios is much higher to about 350, so the difference is past a minute and a half sec/km delay, Figure 10.

The stop time for “car” vehicle class is situated in the vicinity of 180 sec/km for the 2 phases scenario and for about 250 sec/km in the 3 phases scenario (Figure 11).

Another big difference is in the fuel consumption of the entire simulation. In the first scenario the fuel consumption is maintained on the 1.2 litters zone, in the second scenario the fuel consumption rises to about 1.5 litters, values seen in the Figure 12.

Again, the difference in the delay time and stop time is seen in the chemical pollution for the entire junction. In regards to the 2 phases scenario the CO_2 pollution 2.5 kg and for the 3 phases scenario the CO_2 rises with around 20% from the first scenario as can be seen, Figure 13.

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[9] *** Aimsun Next20 User Manual.

EVALUAREA PLANULUI DE SEMNAL ÎN INTERSECȚIE ÎN RELAȚIE CU STRATEGII DE PROGRAMARE

Rezumat : Cercetările de trafic rutier au arătat necesitatea unei analize aprofundate pentru a identifica parametrii de mișcare a vehiculului în rețea. Acești parametri depind de: direcția de deplasare, alternarea cererii de transport pe parcursul zilei, localizarea arterei în teritoriu, tipul de drum și zona analizată. Lucrarea își propune să analizeze diferite strategii în crearea planului de semnal. Principalul aspect al strategiilor analizate este dat de comparația dintre planuri de semnal cu 2 respectiv 3 faze.

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