Case Study on Street Traffic Management in Intersections from the City of Craiova

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Abstract: The impossibility of road infrastructure development in accordance with the accelerated rhythm of transport necessity increasing results in sharpening of road congestion phenomenon, with adverse effects in all areas of life. An efficient street traffic control through junctions can significantly ameliorate this phenomenon's negative effects maintaining traffic fluidity. In this paper we present the two street traffic control strategies currently available and how to implement them at an intersection. Finally, a comparative case study on an intersection in the city of Craiova for three different signal plans: the fixed signal plan utilized in present, an alternative fixed plan and the adapted plan based on signals actualization in real time, also evaluating their efficiency relying on quality indicators.

Keywords: signal plan, default control, actuated control, delay time, sensor network.

1. INTRODUCTION

Passengers and merchandise street transport represents a key element for developing a performing economy, dynamic factor of its good operation and ascendant evolution. Recent years show a significant increase in the number of the motor vehicles in traffic, yielding a growing pressure on the road system, whose capacity tends to be outdated. Negative phenomena generated by this more and more discordant correspondence between the growing demands of population and goods mobility, also shown by the increasing motorization index (vehicle per capita) and by the current road infrastructure, unprepared to cope with such pressure, become increasingly acute, affecting different areas of life.

Data reported in traffic show that road circulation is getting more and more agglomerated and slow, favouring production of numerous congestions. The main effect felt daily by all participants in traffic is about the travel time (usually between home and work), which increases as time passes and the number of motor vehicles per capita grows. Urban traffic congestion creates stress among road users, by the impossibility of achieving the proposed targets timely or accurately calculate the travel time. This "road rage", mainly caused by congested traffic, leads to an increased number of accidents, because of driver's inattention or failure to comply with traffic regulations (Baniaş, 2009).

Since free and efficient transport of persons and goods represents a mobile for developing a healthy economy, all adverse consequences that traffic congestion phenomenon could have on different economic branches should be taken into consider. Economic losses caused by this phenomenon may be expressed in time, additional fuel consumption, high transport costs, emissions and an increasing number of accidents (Pintiliei, 2009). They are, in their turn, causes of other significant economic losses.

Junctions represent the most sensitive elements for street circulation, because they occasion the most frequent conflict situations between road users, who move on different directions or change their direction when they enter the intersection and, then, leave it. Intersections are areas where frequent traffic jams appear. These occur at times when the intersection's circulation capacity is exceeded- the flow entering the intersection has big values, determining a very high density of motor vehicles which attempt to pass through the junction. In the case of signalized intersections, long waiting queues of motor vehicles which wait at traffic lights, intersection release being achieved with great difficulty. Sometimes it comes to cases where a motor vehicle in the column which is about to cross the intersection can pass through only after several traffic light cycles.

Indiscipline in traffic generated by drivers stress, caused by road congestion influences, in turn, road traffic fluency. Thereby, many drivers having the idea of reducing the waiting time, force the crossing on semaphore's yellow after green signal, maintaining a far too small distance from the following vehicle, change moving direction without signalling their intention, exceed by far permissible speed limit- generating traffic situations which favour production of traffic jams and accidents.

From those mentioned above, one can deduce that the phenomenon of sharply increasing road congestion adversely affects both quality of life and economic aspects arising from transport. Junctions, meeting points of several motor vehicle flows, favour the apparition of road congestion phenomenon. Intelligent control is necessary for ensuring a fluent traffic. As in most cases road infrastructure development doesn't represent a viable solution for mitigating this phenomenon, road circulation's fluency must be achieved through intelligent systems, capable to realize street traffic management.

2. STREET TRAFFIC CONTROL SYSTEM'S PARAMETERS

At most intersections, in order to ensure effective crossing, without significant delays, in terms of safety, eliminating potential conflicts that may be caused by vehicle's crossing paths intersection, street traffic control is realized through light signals (traffic lights). These are complex equipments, which can operate in a variety of modes.

Traffic light cycle represents the fundamental unit in signals designing and synchronization. The next terms succinctly describe parts of a traffic light cycle:

- *Cycle* - a complete scrolling of all information provided.
- *Cycle length (C)* - time, in seconds, necessary to complete a full cycle of indications
- *Interval* - is a period of time when no indication changes. The following types of intervals are distinguished:
  a) *Changing interval (y)* - is associated to yellow colour indications for a set of moves. It is a part of the transition from green to red, aiming movements on the point of losing priority (green signal) while every other movements have the red signal. This interval is necessary to ensure "legal" crossing for a motor vehicle which cannot brake safely.
  b) *Releasing interval (ar)* - Is also part of green to red transition. Its role is to allow a motor vehicle legally entering the intersection to safely pass through before releasing other streams of motor vehicles.
  c) *Green interval (G)* - Every movement has a green interval in a cycle. During a green interval, permitted movements have a green light signal, and all other moves have a red light signal.
  d) *Red interval (R)* - Every movement has a red interval during a cycle. Red intervals overlap with green intervals for all other sets of movements in intersection.
- *Phase* - consists of the green interval, plus changing and releasing intervals. It is a number of intervals which allow safely crossing and releasing of motor vehicles flows on a set of non conflicting set of movements (which do not intersect).

For the most common type of intersections, those with for streets, one can identify not less than twelve moving directions (see figure 1). Generally, intersections have from one to six phases, the most encountered signalization policy having four phases, for example, like in Fig. 1:

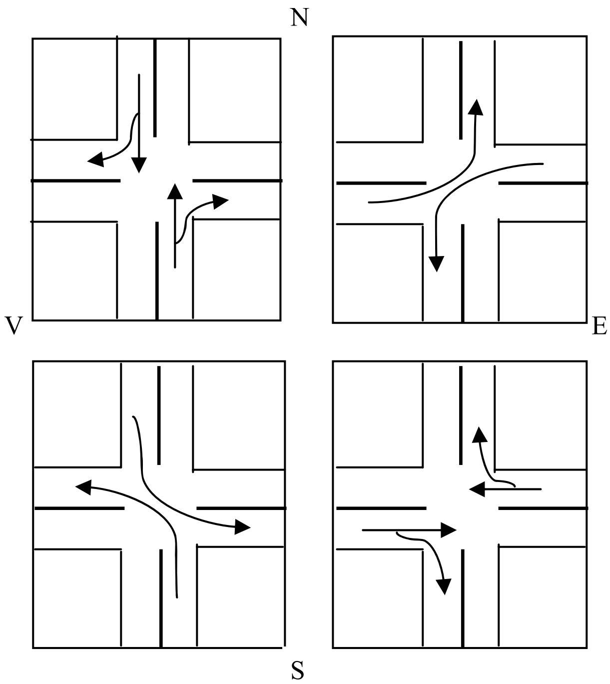

Fig. 1. Intersection with four phases

2.1. Traffic control through default signals

It is the most encountered way of routing traffic in an intersection. In this situation, cycle length, phase sequence and duration of each interval are constant. Each signal cycle follows the same predetermined plan. Through traffic statistics, one attempts to model traffic variations, introducing some coefficients adequate to its state (for example, for morning traffic, more dense, or for traffic in the interval around noon, more relaxed.

For determining semaphoring cycle's length, average interval of time (saturation headway) between motor vehicles, maximum traffic demands for every set of movements and total lost time during a cycle are particularly important.

When the flow of motor vehicles moves in some direction that had received the green signal, vehicle headways tend to become constant (approximately after the forth or fifth vehicle which enters the intersection). This constant interval of time represents the *saturation headway* (h). One can define, starting from this definition, the *saturation flow* (s), representing the number of motor vehicles which can cross the intersection in an hour, on condition that they always have the green signal.

$$s = \frac{3600}{h} \tag{1}$$

In order to determine the total lost time during a semaphoring cycle, we must determine the changing and releasing intervals. ITE (Institute of Transport Engineers) recommends utilizing the following relations to determine these intervals (Transportation Research Board, 2000):

$$y = t + \frac{0.14 \cdot S_{85}}{a} \tag{2}$$

$$ar = 3.59 \cdot \frac{w + L}{S_{15}} \tag{3}$$

where we have:

$y =$ yellow interval's length

$t =$ driver reaction time (1 s)

$S_{85} = 85^{th}$ percentile speed of vehicles approaching the intersection, that is the speed limit exactly 85% of vehicles will not exceed. For a speed $v \in [40, 50] km/h$ one can approximate $S_{85} \cong v + 5$.

$a =$ vehicle deceleration (10m/s^2)

$ar =$ releasing interval's length

$w =$ the distance from the stopping line to the farthest lane storing motor vehicles that may conflict

$L =$ motor vehicle standard length (6m)

$S_{85} = 15^{th}$ percentile speed of vehicles approaching the intersection, that is the speed limit exactly 15% of vehicles will not exceed. For a speed $v \in [40, 50] km/h$ we can approximate $S_{15} \cong v - 5$.

We can now write the relation that expresses the lost time for a semaphore phase:

$$t_l = y + ar + t - e, \tag{4}$$

where t is the time utilized for departure and e the interval while drivers keep entering the intersection on yellow signal. It is recommended to utilize the values $t = 2s$ and $e = 2s$, leading us to the following relation:

$$t_l = y + ar. \tag{5}$$

Total lost time for a semaphoring cycle can be expressed through the following relation:

$$t_L = \sum_{i=1}^{n} (y_i + ar_i), \tag{6}$$

where n represents the number of phases, y_i and ar_i are changing interval and, respective, release interval lengths for phase i.

In order to determine the maximum demands for a semaphore phase, it is necessary to identify the demands for every direction which consists the phase, measured in standard unit vehicles. For example, in figure 1, for phase 1, the flows of motor vehicles moving straight ahead or turning right coming from directions N and S are released. Assuming that there are two lanes for each street which can be used to move in these directions, the maximum traffic demand can be obtained as:

$$V_1 = \max\left(\frac{n_i + n_l}{2}, \frac{s_i + s_l}{2}\right), \tag{7}$$

where n_i and n_l are the hourly traffic volumes (flows) from direction N and moving forward, respective turning right and s_i and s_l are the hourly volumes of vehicles arriving from direction S and moving forward, respective turning right.

To correctly determine traffic volumes for each direction it is necessary to use tables of conversion to standard vehicles. For example, for a truck a multiplying factor equal to 2 (i.e. a truck equals two standard vehicles), for motor vehicles which turn left the multiplication factor is 1.05, or for motor vehicles which turn right it equals 1.32.

Once the maximum demands for each semaphoring phase were determined, we can calculate their sum (parameter known as *the critical volumes sum*):

$$V = \sum_{i=1}^{n} V_i, \tag{8}$$

where n is the number of phases and V_i represents the maximum traffic demand for phase i.

Semaphoring cycle length can be determined now with the following formula:

$$C = \frac{t_L}{1 - \frac{V}{1615 \cdot vf \cdot r}}, \tag{9}$$

where vf and r are coefficients introduced to adjust the cycle's duration to peak hours circulation, respective to special manoeuvres needed to cross the intersection. It is recommended to use the following values for these two coefficients: $vf=0.92$ and $r=0.9$.

If the cycle's length is known, *the effective green time* should be split at each phase. The effective green time is calculated with the formula:

$$g_t = C - t_L. \tag{10}$$

This is allocated to semaphoring phases proportionally with the maximum demands for each of them:

$$g_i = g_t \cdot \frac{V_i}{V}, \tag{11}$$

where g_i is the duration of green interval for phase i and g_t the effective green time.

2.2. Traffic control through real-time actuated signals

Through this traffic routing strategy, real-time information regarding current crossing demands, obtained from sensors, are utilized. Unlike default signals, green intervals and cycle length are variable, allowing adjusting the green signal to serve the current number of motor vehicles that wait to enter the intersection. This way, delay times and queue lengths are significantly reduced, ensuring a fluent circulation through the intersection.

The following parameters must be set for each controller carrying out this type of routing (Roess et al., 2004):

a) *Minimum green interval(G_{min})*- the minimum duration of a green phase
b) *Unit extension (U)* - the maximum interval between two consecutive detection signals taken into consider for maintaining the green signal.. Represents the time interval added to current phase when a detection signal is received after an interval shorter than the maximum interval and it is necessary to have duration long enough to ensure a motor vehicle crossing the intersection.
c) *Maximum green interval (G_{max})* - limits green phase's length. even if a signal of detection that could lead to its extension in normal conditions. This maximum interval is activated when there are detections for other phases.
d) *Changing and releasing intervals* - ensure safe transition from green to red. They represent fixed intervals and their lengths can be determined with relations 2 and 3.

When a green signal is activated for a phase, its duration is at least equal to the length of the minimum green interval G_{min}. The controller divides the minimum green interval in an initial portion and a portion equal to unit extension U. If a detection signal is received during the initial portion, no amount of time is added, because there is enough time for a motor vehicle to cross the intersection. Then, if a detection signal is received during the U seconds of the unit extension, an additional period of U seconds is added to the phase from the moment when the detection is realized.

The green signal ends the unit extension's U seconds pass without recording any detection signal or when the maximum green interval's duration is reached. During periods with intense traffic, there are continuously demands for crossing the intersection for all phases and the green interval is limited between G_{min} and G_{max}. However, during periods with low vehicle flows, the length of green phases may be unlimited.

The minimum green intervals for each phase are determined depending on detectors location. If a presence detector is placed at *d* meters from the stopping line, minimum green time has to be long enough to release a queue of vehicles occupying distance *d*.

$$G_{\min} = l + 2 + 2 \cdot \left[\frac{d}{6.5} \right], \qquad (12)$$

where:

- G_{min} is the minimum green interval
- *l* is the lost time when leaving
- (*x*) represents the whole part of number *x*
- 6.5 is a motor vehicle's standard length plus the distance from the vehicle in front of it

For all types of controllers, unit extension has to be at least equal to the time a motor vehicle crosses the distance from the sensor to the stopping line

$$U \geq \frac{d}{4.4 \cdot S_{15}}, \qquad (13)$$

where *d* is the distance from the sensor to the stopping line.

Therefore, two strategies for sensors positioning can be drawn:

- placing sensors so a desired minimum green time is obtained;
- placing sensors so the time during a motor vehicle reaches the stopping line is equal to the unit extension.

Maximum green intervals are established determining the length of a cycle and the initial durations of green times as in the case of default signalling taking into consider a period with dense traffic. Relations 9 and 11 are utilized, the only difference appears regarding the recommended value for peak hours adjusting coefficient *vf=0.96* here. To provide enough flexibility for controller's decisions in case of significant traffic fluctuations, the green times determined with relation 11 are multiplied with a factor between 1.25 and 1.50.

3. EQUIPMENTS FOR TRAFFIC CONTROL

Most controllers utilized in present for traffic routing in intersections have the following hardware components (U.S. Department of Transportation, http://ops.fhwa.dot.gov /publications /fhwahop06006):

- User-interface devices- keyboard and monitor
- Central processing unit- dedicated processor, memory, etc.
- Communication devices- serial ports, network card, USB ports, cables, etc.
- Power supply
- Optionally, serial communications modem
- Auxiliary components which interact with the controller, as: monitoring device for controller proper functioning ,sensors for motor vehicles or optionally, external communications devices (external modem, wireless/radio transmitter and receiver, switch Ethernet).

3.1 Sensors for motor vehicle detection

For acquisition of real-time traffic data, measurements in a point are necessary, that is sensors capable to detect motor vehicle's presence. Nowadays, to collect real-time traffic data, detection technologies are utilized, as: inductive rings, pneumatic tubes, video cameras, microwaves, magnetometers, ultrasonic or infrared sensors, radar. The most indicated sensors for motor vehicles detection, taking into account the relation between measurements quality and installing and maintaining costs are the magnetic sensors. They utilize the magnetic induction principle, generating a voltage signal proportional with the earth magnetic fields variation every time a ferromagnetic object crosses the sensor. They should be installed in road along every lane of every roadway which enters the intersection. Depending on the performance of the software system which utilizes the traffic information acquisitioned in real time, one can install a greater number of sensors along a bigger distance (hundreds of meters) or just a few on each lane.

Fig. 2 shows sensor network's components positioning in a simple cross-shaped intersection. The sensors for vehicle's detection, installed in road for each lane, send impulses to the signals amplifiers. In order to save energy and simplify their maintaining, they are passive sensors, connected through cables to the appropriate signal amplifiers, an own energy source becoming unnecessary. The signal amplifiers transmit wireless the signals received towards the traffic controller. The transmission is realized radio, requiring that they are equipped with a powerful radio emitter.

Since traffic lights need a continuous energy source to function uninterruptedly being connected to the electrical network, the signal amplifiers are installed beside the devices which realize semaphores coupling to the power supply. Where appropriate, the amplifiers can be installed close to the traffic lights or in the green space between lanes. Amplifiers supply with energy problem is therefore solved.

However, other energy sources should be considered, like batteries or UPSs, to prevent situations when the electrical network's functioning is temporarily interrupted.

Traffic lights and electrical panels are command elements that execute the controller's decisions. The drivers will be permanently informed about semaphoring through information posted on electronic panels.

It could be noted that through this sensors network organization it is made an attempt to assure a high reliability, ensuring a continuous energy supply for amplifiers and simplifying maintenance of the network's nodes. The distances between the passive sensors and the signal amplifiers are small, so the length of the cables which connects them is just a few meters. The signals are transmitted wireless through the radio emitters from the signal amplifiers, these having access to a continuous energy source.

A node in the sensors network has the following components:

- magnetic sensor
- microcontroller- dedicated processor (Atmega128L)
- radio emitter (MICA2DOT)
- battery
- protection cover

These equipments are offered by Crossbow Company. Figure 3 shows the structure of a node in the network.

The inductive sensor, installed in road, is passive, not requiring an energy source to operate. The tension induced by magnetic field's modification, when a motor vehicle crosses above the sensor, is transmitted through a cable to amplification modules, connected to a continuous energy source.

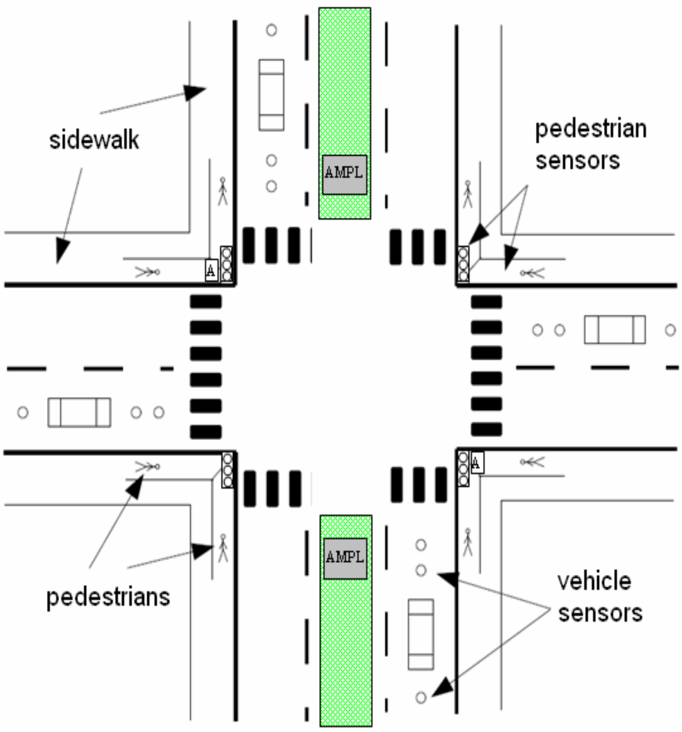

Fig. 2. Placement of sensors network's components

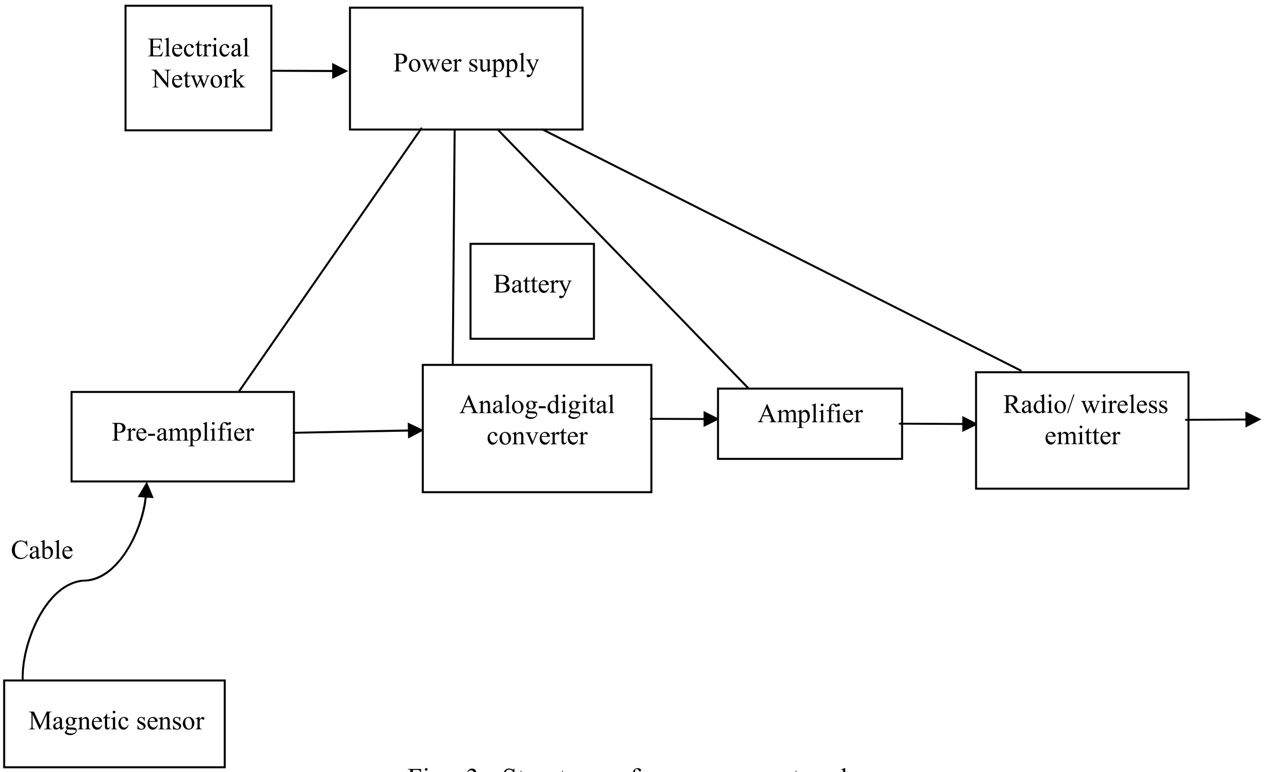

Fig. 3. Structure of a sensor network

When a motor vehicle crosses the sensor on a distance of 7m, the signal detected by the magnetic sensor is about $e_{max} = 3\mu V$. Being very difficult to process it's necessary to amplify it before transmission to the analogue-digital converter. After the conversion from voltage signal to numerical signal is realized, the resulting signal is amplified again and transmitted wireless to the controller. We can observe, in the picture, that the amplifiers, the analogue-digital converter and the radio emitter are all connected to the electrical network, the battery being a backup energy source.

3.2. Signalling devices

Traffic lights and electronic panels are utilized for directing traffic at an intersection. The electrical panels have led screens, being included in semaphores structure or installed along the road, connected to the electrical network. They must be able to operate independently of weather conditions and must have dimensions which allow viewing from traffic.

The electronic panels have the following roles:

- to inform road users about traffic conditions along the portion where they are installed- information regarding waiting queues length, medium travel times towards a
- certain destination on different routes, the recommended circulation speed
- to transmit regulation messages that attempt to fluidize traffic (for example, imposing some certain speed limits)
- to display information about any sudden incidents on the route like accidents or works
- to offer alternative routes when the traffic in the area is congested

Traffic lights with three colours (red, yellow, green) are utilized for traffic directing at an intersection. In present, semaphores use timers, which decrement their value as each second passes, showing the amount of time remaining until the current signal changes. Since traffic control decisions are established in real time, the amount of time remained until the colour changes from red to green cannot be exactly indicated. Therefore, a maximum waiting time threshold is set for each direction and for every semaphoring phase, information about this remaining maximum interval is displayed.

A semaphore consists of (Semafor Trafic Lider cu Numarator 3SC1-TL-N 3SC1-TL-N-LED):

- special incandescent lamps with bases for sockets or modules with red, green and yellow leds, ranged in a matrix which permits numbers display on three positions (hundreds, tens, units)
- electronic timer, the colour of displayed digits corresponding to the colour of optical active semaphore's compartment
- device which regulates leds' light intensity during day and night
- optionally, wireless receiver
- semaphore's plastic body, resistant to ultraviolet radiations, on which joints are mounted
- aluminium sheet reflector, socket

- semaphore door and visor, which are fixed on the plastic body by means of a jointing system.

The semaphore is mounted on pillars using joints. The joints have holes for screws and channel for fixing with 10mm wide flat bar. Semaphore connecting to electrical network is realized by the superior connector.

4. CASE STUDY ON STREET TRAFFIC CONTROL IN AN INTERSECTION FROM CRAIOVA CITY

To illustrate the applicability of the results mentioned above, an intersection from Craiova city, with a very common form, is taken into consider. The intersection's geometric configuration is shown in Fig. 4.

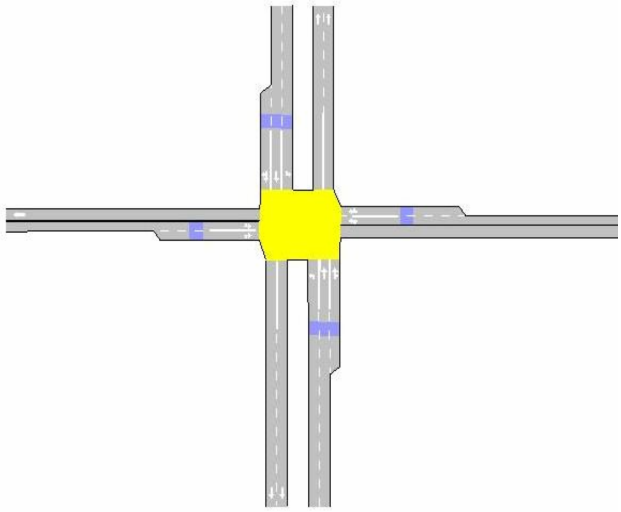

Fig. 4. The intersection's geometric configuration

To simulate street traffic control in this intersection using various signalling strategies, the integrated software environment for modelling complex traffic applications Aimsun was utilized.

It integrates three types of traffic models - microscopic, mesoscopic and macroscopic - in a single software application.

It permits 2D and 3D visualization of traffic situations, offering a complete set of data (qualitative and quantitative) after simulating any traffic scenario.

In present, the intersection's signalling plan (denoted *prez* in this paper) consists of four phases, as shown in Fig 5. Therefore, the four phases refer to the following directions of travel:

Phase 1: N-S, N-V, N-E, (E-N);
Phase 2: S-N, S-E, S-V,(V-S);
Phase 3: V-E, V-S, V-N, (N-V);
Phase 4: E-V, E-N, E-S, (S-E).

Travelling directions between parentheses are not taken into consider for determination maximum demands of the respective phases. In addition, it is offered blinking green signal for S-E direction during phase 1, for N-V direction during phase 2, for E-N direction during phase 3 and for V-S direction during phase 4.

It is observed that, through this phases construction, it has been attempted to release, in succession, the traffic coming from points N, S, V and, respective, E. The yellow interval has 3 seconds, and the releasing interval isn't taken into account. The regulations of this signalling plan (determined based on traffic measurements performed during an hourly interval when the circulation is intense) lead to a cycle length of 154 seconds and to the following values for the green intervals: phase 1- 52s, phase 2- 42s, phase 3- 24s, phase 4- 24s.

Another mode of default traffic control involves a signalling plan having the semaphoring phases as shown in Fig. 6 (this plan is denoted *fix* in this paper). The phases consist of the following directions:

Phase 1: N-S, S-N, (N-V),(S-E);
Phase 2: N-E, S-V, (V-S), (E-N);
Phase 3: V-E, V-S, V-N, (N-V);
Phase 4: E-V, E-N, E-S, (S-E).

In addition, it is offered blinking green for directions N-V and S-E during phase 2, for E-N direction during phase 3 and for V-S direction during phase 4.

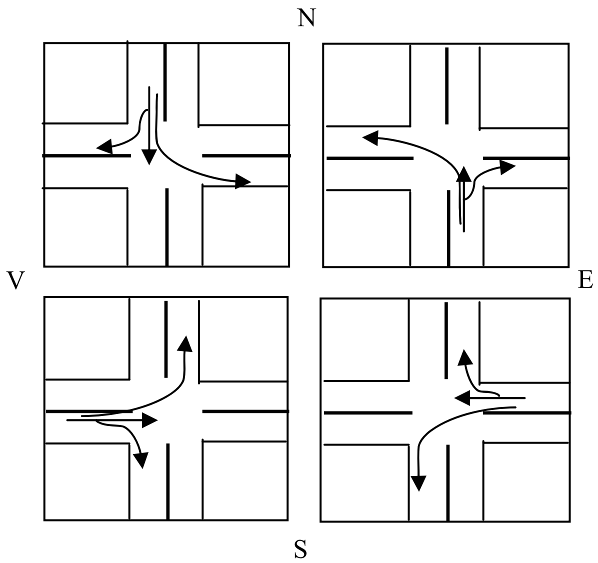

Fig. 5. Phases grouping for signalling plan *prez*

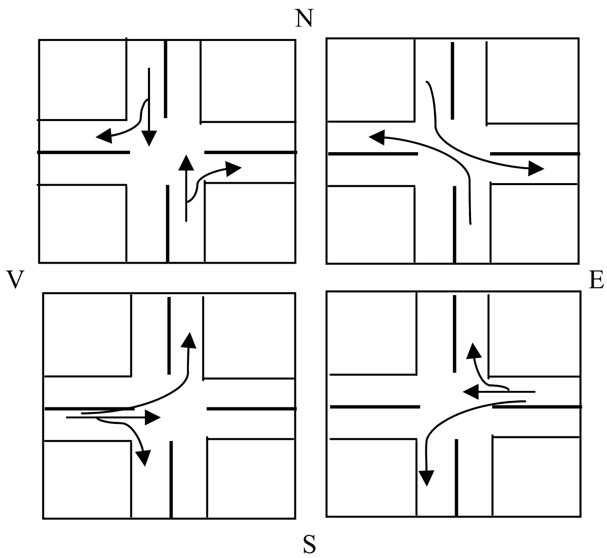

Fig. 6. Phases grouping for signalling plan *fix*

Through this phase grouping it has been attempted to release traffic on the main street (N-S, S-N), with the largest volumes of traffic. The semaphoring phases intervals durations are established based on traffic measurements in intense circulation conditions. Using relations (2) and (3) we obtain a yellow interval duration of 3.3 seconds and the lengths of releasing interval of 2.2 seconds on direction N-S, respective 2.6 seconds on direction V-E. Since drivers use approximately 2 seconds from the yellow interval to enter the intersection, a releasing interval (all signals show red) of 1 second for each phase for this signalling plan.

Through relation (9) we determine the cycle length of 111 seconds and, through relation 11, green intervals as follows: phase 1- 38 seconds, phase 2- 15 seconds, phase 3- 21 seconds and phase 4- 21 seconds. The signalling plan *fix* is presented in Fig. 7:

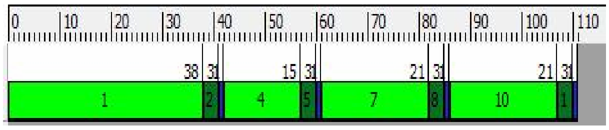

Fig. 7. Signal plan fix

Relying on this pre-established signal plan we will develop a semaphoring plan based on real-time signals actuation (denoted *actual* in this paper). As the maximum speed allowed for the motor vehicles entering the intersection is 50 km/h, that is approximately 13.9 m/s, the unit extension has 3 seconds. The length of yellow interval is 3 seconds and the length of releasing intervals is 2.2 seconds for direction N-S, respective 2.6 seconds for direction V-E.

Because when a motor vehicle passes over the presence sensor, the green interval is extended with 3 seconds, and at least 1 second from the yellow interval is utilized to release the intersection, the sensors are placed so the releasing intervals utilization necessity is eliminated. This means they are placed at an interval of 2 seconds from the stopping line, which leads to a distance of about 27 meters (see Fig. 4). Utilizing relation 12 the length of minimum green time intervals is determined: 12 seconds.

The lengths of maximum green intervals are established starting from signal plan *fix* and using a multiplication factor of 1.25: for phase 1- 45 seconds, for phase 2- 18 seconds, for phase 3- 25 seconds and for phase 4- 25 seconds. Fig. 8 shows the phase sequence and the lengths of maximum green intervals for this signal plan:

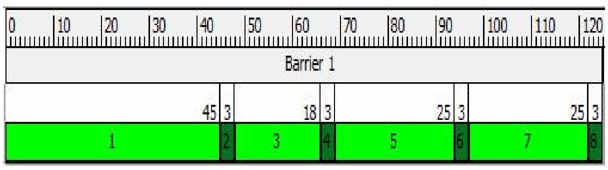

Fig. 8. Signal plan *actual*

The three signal plans performance is evaluated and compared by simulating their behaviour during dense traffic conditions in one hour interval. Figs. 8 and 10 show snapshots of simulations realized in Aimsun for signal plan *actual*.

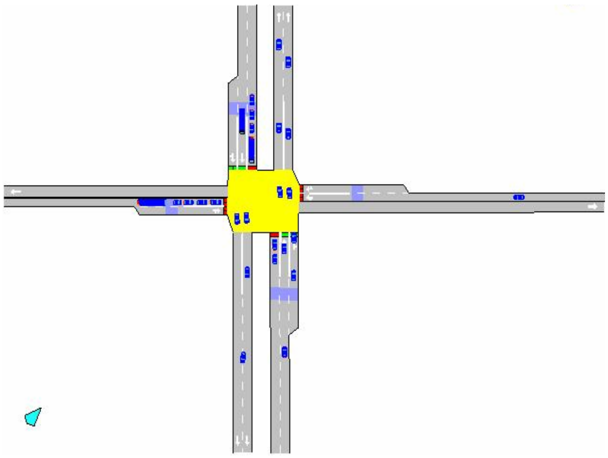

Fig. 9. Simulation snapshot 1

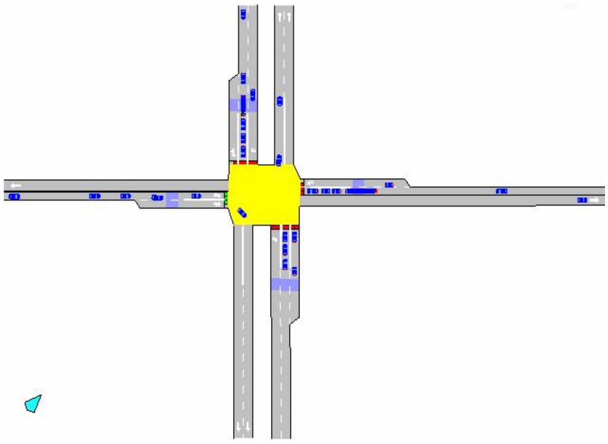

Fig. 10. Simulation snapshot 2

In order to evaluate signals plan performance, quality indicators are taken into account, as: delay time (*DT*), average speed (*V*), medium waiting queues length (*L*), mean of maximum waiting queues length (*ML*) and number of stops (*NS*) - determined as ratio between the number of vehicles forced to stop at traffic lights and the total number of vehicles that cross the intersection. The graphs shown in Figs. 11, 12, 13, 14 and 15 present the variation of these indicators at 10 minutes intervals for each street entering the intersection from direction N, for signal plan *actual*.

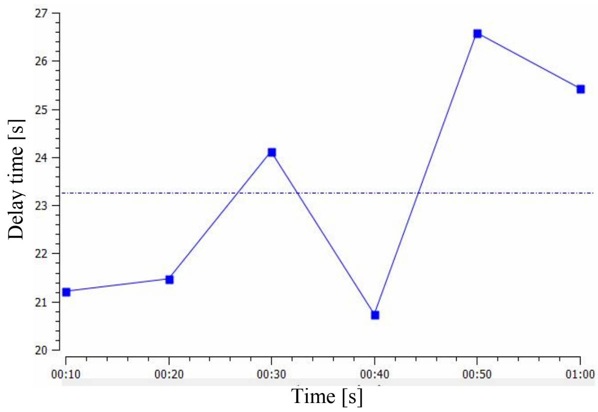

Fig. 11. Delay time

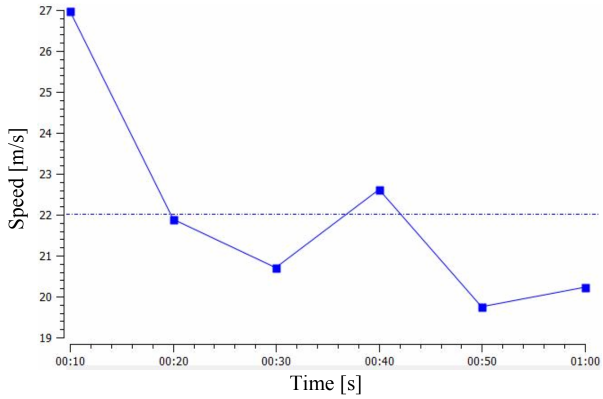

Fig. 12. Average speed

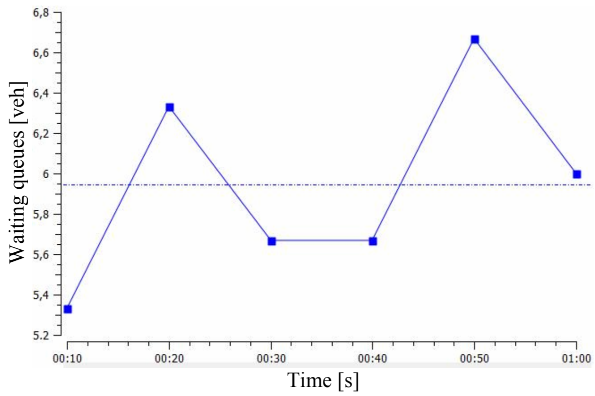

Fig. 13. Maximum length of waiting queues

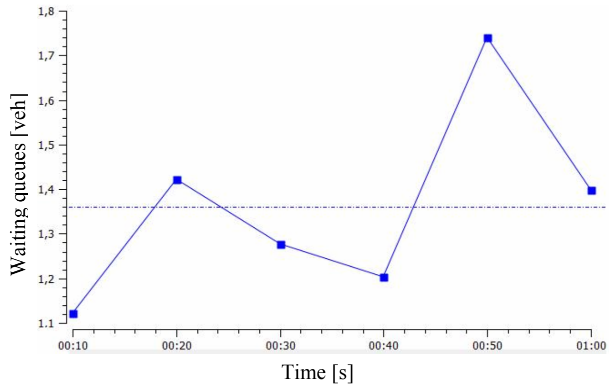

Fig. 14. Medium length of waiting queues

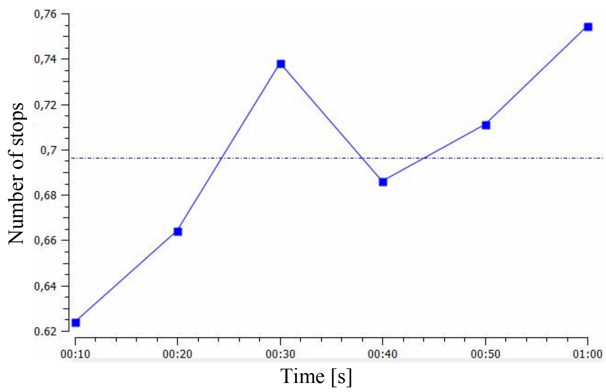

Fig. 15. Number of stops

Values on graphs marked with bold dots are average values calculated for each 10 minutes interval. The traffic variations are visible if the graphics displayed are interpreted: for example, one can deduce that the most significant increased demand for vehicles attempting to cross the intersection is in interval 00.40-00.50, leading to higher values for delay time, length of waiting queues, number of stops and to lower values for average speed, during this interval.

The Table 1 shows the values of these indicators for each street in the intersection.

Table 1. The efficiency indicators values for the three signal plans

Di-rec-tion	SIGNAL PLAN											
	PREZ				FIX				ACTUAL			
	DT	V	ML	NO	DT	V	ML	NO	DT	V	ML	NO
N	39.8	17	9.3	0.83	35.2	14.7	7.9	0.89	23.2	22	5.9	0.69
S	44.3	17.4	9	0.82	28.6	20.7	6.6	0.76	19.2	26.1	4.9	0.62
V	48.4	17.7	7.7	0.75	37.6	17.2	6.1	0.84	27.7	20.9	5.2	0.75
E	44.8	22.1	7.2	0.72	29	23.5	5.3	0.71	30.1	22.2	5	0.79

Analyzing the numerical values in Table 1, one can easily compare the efficiency of the three signal plans. Therefore, one can observe high delay times and waiting queue lengths for traffic entering on all streets entering the intersection for signal plan *prez*.

They are ameliorated when using signal plan *fix* and significantly improved when using signal plan *actual*.

The values of average speed and number of stops are close for signal plans *fix* and *prez*, the best values (high for average speed and low for number of stops) being achieved with the actuated strategy again.

Therefore, an hierarchy for the three signal plans can be easily created, the signal plan utilized in present being the least efficient, and the signal plan based on real-time actualization offering the best values for the efficiency indicators.

5. CONCLUSION

In the present paper strategies of traffic control in intersections in the city Craiova were presented.

The first part emphasized the necessity of having a fluent traffic through junctions and then, the operating mode, traffic parameters and calculation relations utilized in designing the default, respective actuated, signal plans were described.

Next, a description of the equipments necessary for implementing the real-time actuated strategy is offered, also indicating a modality of positioning them in intersection.

The last part presents a case study about the signal plans that can be utilized for traffic routing in an intersection from Craiova city.

Utilizing software package Aimsun, designed for modelling and simulating street traffic applications, two fixed signal plans and one real-time actuated are developed. These plans efficiency, as expressed by the values of some qualitative indicators, is evaluated by simulating the circulation movement for each of them, in the same intense traffic conditions. Thereby, graphs showing variation of these indicators at 10 minutes intervals during an hour are obtained, their values being easy to compare.

Analyzing the simulation results, one can directly reach to the conclusion that the signal plan utilized in present is not very efficient, generating long waiting queues, increased delay time, numerous stops at traffic light and low average speeds. The fixed signal plan proposed as alternative to the current signal plan ameliorates these indicators values.

However, one can observe that utilizing the real-time actuated signal plan significant improvements are obtained, offering, for example, compared to the alternative fixed plan, a diminution of waiting queues length of approximately 25%, a reduction of delay time of approximately 33%, a number of stops decrease of approximately 23% and an average speed increasing of approximately 27% for the main arterial road (directions N-S and S-N). There by, it becomes obvious that the real-time actuated strategy is the most efficient regarding the quality of road circulation through junctions.

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