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MONITORING, CONTROL AND IMPROVEMENT OF TRAFFIC FLOW IN A BUSY URBAN NETWORK

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Abstract **-** The paper presents the research and analyze of traffic flow and its characteristics in a busy traffic zone which make the connection between the downtown Sibiu and the exit to Brasov. Six intersections are analyzed along the main artery raising this problem.
The main objectives of this paper are to reduce delays, optimization of the traffic lights timing and intersection geometry changes. By synchronizing traffic signals ensure a better flow of traffic minimizes fuel consumption and reduce pollutant emissions. The simulations performed with the software Synchro shows that decisions to optimize traffic lights intersections can be applied very well in a larger area.

Keywords **-** monitoring traffic flow, optimization traffic signal timing, delay, Synchro Studio 7.0

I. INTRODUCTION

ROAD transport is an important factor regarding the development of society. In addition to economic development that provides transport, they attract negative effects such as congestion, environmental pollution, increased delays at intersections, etc. According to the study [1] on the specific problems of transport we can say that the most important are traffic jams created by congestion, accidents that threaten the security of passengers and goods transported and the harmful effects of transport on the environment.

In most cases, traffic jams occur at certain times of day when traffic flow increases significantly, due to increasing population necessity of moving in the same direction on the same road sectors. Other reasons for jams may be the inability of the infrastructure to take the volume of existing traffic, bad synched signal systems or no longer corresponding to the traffic requirement, adverse weather conditions, traffic ban on a particular section of road due to works in the area of carriageway or the occurrence of traffic accidents.

Solving these problems in large cities involves a thorough analysis of traffic conditions, taking into account all the parameters involved. Sibiu is a rising economic zone. This draws itself and therefore the development of road jams and traffic delays.

Presented papers analyzing the traffic flow using a "platoon based delay model" [2], it is possible even to deal with non stationary traffic demand and non synchronized signal settings. The Synchro traffic model simulates the movement of traffic through a network and takes into account of the platoon dispersion effect, [3], [6].

II. MONITORING AND TRAFFIC ANALYSIS

A major artery of Sibiu, which connects downtown and major shopping area (exit to Brasov) is General Vasile Milea Boulevard, figure 1. According characteristics and its complexity artery is crossed daily by a large influx of vehicles creates problems in terms of fluency at the intersections. Average peak hour factor is about 0,95. This is due to aging infrastructure and unoptimized traffic light timings. During peak complex intersections artery G-ral Vasile Milea Blvd are most affected by congestion, traffic being carried on by strain.

Fig. 1. Analyzed artery

The artery includes 6 main thoroughfare intersections, other small intersections feeding the main artery, but low traffic flow. The 6 intersections considered are:

- Calea Dumbravii – Str. C. Noica – Gneral Vasile Milea Blvd (Intersection 1);
- Str. Nicolae Iorga - Str. Moldoveanu - General Vasile Milea Blvd (Intersection 2);
- Str. Luptei - Str. Paltinului - General Vasile Milea Blvd (Intersection 3);
- Str. Vasile Aaron - General Vasile Milea Blvd (Intersection 4);
- Str. Semaforului - Str. Rahovei - General Vasile Milea Blvd (Intersection 5);
- Str. Mihai Viteazul - Extension of General Vasile Milea Blvd (Intersection 6);

Traffic in the area is crowded for the following reasons:

- Takes a great deal of traffic from the central and historical area;
- Is a way out / input in city;
- Has an area of economic interest (leads to great shops: Real, Carefour, Penny Market XXL, Baumax, Shopping City, along the artery are residential areas and points of interest: Bank Carpathian Army Academy, Police Inspectorate Square Vasile Aaron, Petrom gas station, gas station MOL El Gringo restaurant, service stations and car showrooms, etc.).
- Vasile Aaron connects neighborhoods –Trei Stejari – Downtown– Hipodrom I and II.

Despite the Boulevard seems well organized and have made improvements over time in terms of structure can be observed queues at peak hours when capacity of the intersections is exceeded.

These queues are formed especially in the morning when most city residents traveling to work, respectively to schools, in the afternoon when returning to home and on weekends.

Traffic data collection was used by a video camera mounted in each intersection, to accommodate variations in traffic.

During data collection was followed:

- Registration of the number of vehicles per lane;
- Record of traffic light cycle times (time of red, green time, yellow time and intermediate).

Table I
EXAMPLE:NUMBER OF VEHICLE FOR INTERSECTION 1

Artery / Time interval	C-tin Noica	Vasile Milea (downtown)			Calea Dumbravii			Vasile Milea (to Braşov)		
	←	←	↑	→	←	↑	→	←	↑	→
7:30-7:45	42	93	112	32	137	28	43	30	97	73
7:45-8:00	87	114	153	41	180	32	84	42	149	133
8:00-8:15	51	107	165	43	189	41	76	48	158	142
8:15-8:30	44	86	97	32	152	22	39	32	110	76
number of minibuses (#15 min)	6	9	15	-	18	-	9	-	17	-
number of trucks (#15 min)	-	-	3	-	18	-	9	-	14	-
number of buses (#15 min)	-	15	8	-	15	-	-	-	6	-
Conflicts with pedestrians (#h)	-	-	-	-	-	-	304	-	-	408
Conflicts with bicycles (#h)	4	-	9	6	-	3	-	-	-	2
TOTAL standard vehicles (hour 7:30-8:30)	253	508	669	148	796	123	316	162	597	424

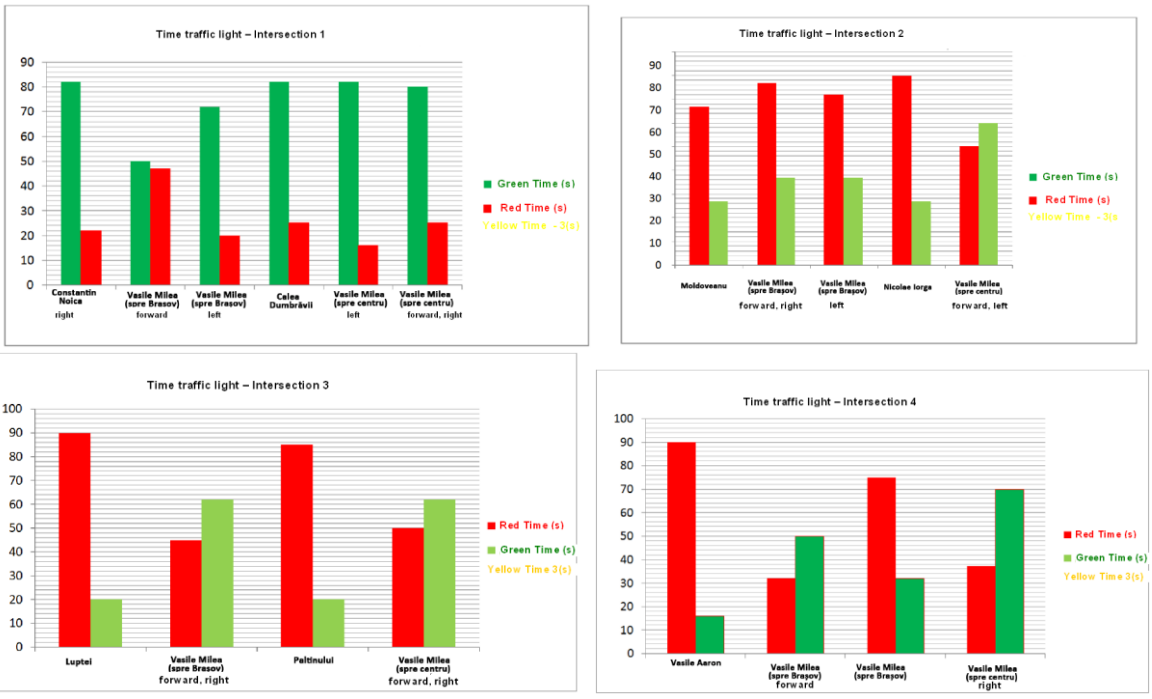

Fig. 2. Differences between times of traffic lights

- pedestrian-record
- queue length
- means of transport frequency

Since traffic flows have a variable component identifying the vehicles from different categories, we started to homogenize transforming the physical vehicles into standard vehicles through equivalence coefficients according to the formula 1,[4].

Transforming physical vehicle in standard vehicles using the formula:

$$N_{echiv} = N_1 \times C_1 + N_2 \times C_2 + \ldots + N_i \times C_i = \sum_{1}^{i} N_i \times C_i \quad (1)$$

where:
N- number of standard vehicles in time unit;
N_i- number of vehicles in group „i" in the same time unit;
C_i- the equivalence coefficient for group „i" in physical vehicles, in the table of equivalence ratios of standard gauge vehicles.

For each intersection it was calculated the peak hour factor:

$$F = \frac{V}{4 \cdot V_{15\,max}} \quad (2)$$

where:
V- total number of vehicles recorded in that hour
V_{15max} - maxim number of the vehicles recorded in respective quarter hour
and total delay on each direction of the artery, [5], [7]:

$$T_D = (1-\omega_l)\cdot\left(\omega_1 \sum_{i=1}^{n} \omega_i D_i^j + (1-\omega_l)\sum_{i=1}^{n} \omega_i D_i^{-j}\right) + \omega_1 \sum_{i=1}^{n} \omega_i D_{ih}^t \quad (3)$$

where:

D_i^j - total delay at node i in one direction of the artery j

D_i^{-j} - the total delay at node i in the opposite direction of the artery j

D_{ih}^t - the total delay at node i of queue h in lateral approach t

ω_i - the weight of node i

ω_t - the weight of the delay in lateral approach

TABLE II
PEAK HOUR FACTOR FOR INTERSECTIONS ANALYZED

Intersection	Artery	Peak hour factor		
		←	↑	→
Calea Dumbrăvii - Str. Noica - General Vasile Milea Blvd	Str. C. Noica	-	-	0,72
	General Vasile Milea Blvd (downtown)	0,95	0,97	0,90
	Calea Dumbrăvii	0,97	0,96	0,84
	General Vasile Milea Blvd (to Braşov)	0,84	0,88	0,79
General Vasile Milea Blvd – Str. Semaforului – Str. Rahovei	Str. Rahovei	0,70	0,74	0,76
	General Vasile Milea Blvd (to Braşov)	0,76	0,77	0,84
	Str. Semaforului	0,76	0,81	0,78
	General Vasile Milea Blvd (downtown)	0,84	0,81	0,92
General Vasile Milea Blvd – Str. Mihai Viteazu	1	0,59	0,86	0,69
	2	0,64	0,49	0,84
	3	0,72	0,77	0,56
	4	0,58	0,40	0,45

TABLE III
REPORT FLOW / CAPACITY OF THE INTERSECTIONS ANALYZED A AND B

Intersection A	Saturated flow rate [veh/h]	Capacity [veh/h/lane]	Report flow rate/capacity	Intersection B	Saturated flow rate [veh/h]	Capacity [veh/h/lane]	Report flow rate/capacity
Calea Dumbravii	1060	297	1,38	Str. Rahovei	1852	392	0,82
General Vasile Milea Blvd (to Braşov)	1350	635	0,62	General Vasile Milea Blvd (to Braşov)	1064	458	0,81
Str. C. Noica	239	62	2,03	Str. Semaforului	1296	311	1,57
General Vasile Milea Blvd (downtown)	2035	468	0,70	General Vasile Milea Blvd (downtown)	1268	342	1,15

From the above table we see that the values of the ratio (v/c) close to 0 indicates very low traffic flows. Values of the ratio (v/c) around 1 indicates a request for traffic close to capacity. The high values obtained in flow-capacity ratio is due primarily to the high volume of vehicles using the intersection (given that data acquisition was performed in the busiest time and infrastructure is outdated) and improper influence of the traffic light with time green very small compared to the times of red. This aims at increasing the capacity of the intersection arms to cope with the volume traffic through optimization of traffic light timings.

III. INTERSECTION OPTIMIZATION PROBLEM

Because during peak traffic artery G-ral Vasile Milea Blvd takes place with strain, work supported by data from ground and above (many standard vehicles) they started to analyze intersections 1: Str. C-tin Noica - Calea Dumbravii - G-ral Vasile Milea Blvd, which has a complex character. Resulting in accumulation of vehicles in the central and district area Hipodrom.

Of flow rate calculation - capacity was found that the factor that has a negative impact on traffic fluency in cycle traffic light intersection is not smeared ad new traffic conditions and is not balanced in terms of time green and red each maneuver, [9].

Traffic data collected by each band were introduced in Synchro and SimTraffic program with existing traffic light time, [8]. Software calculating delay times for each direction of the drive vehicles in part (fig. 3).

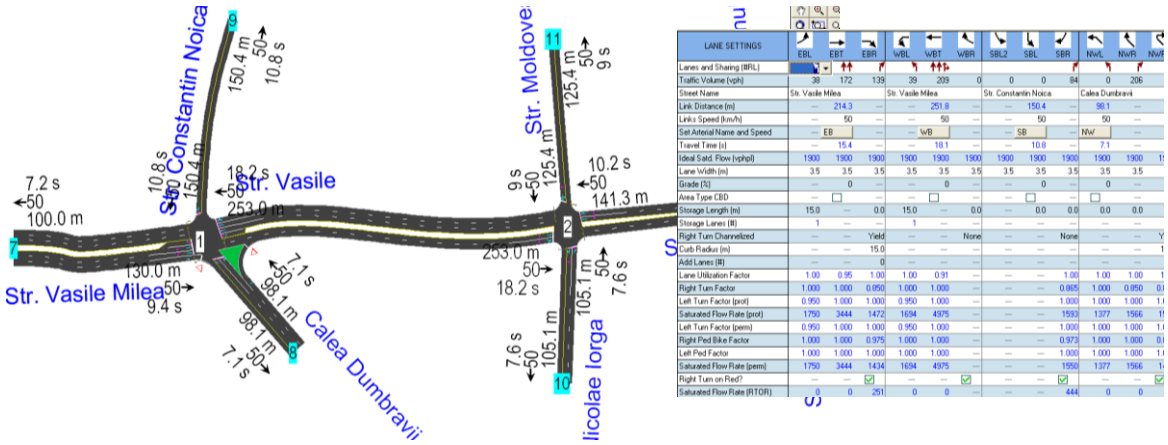

Fig. 3. Intersection geometry in Synchro Studio

TABLE IV
EXISTING TRAFFIC LIGHT TIMES FOR INTERSECTION A

Street	Red time (s)	Green time (s)	Yellow time (s)
Constantin Noica (right)	82	22	3
V.Milea – to Brasov (forward)	50	47	
V.Milea – to Brasov (left)	72	20	
Calea Dumbravii	75	30	
V. Milea – to downtown (left)	82	16	
V.Milea - to downtown (forward, right)	80	25	

Based on all data, it have been calculated the delays (eq.3) for each band or group of bands obtaining the following values:

Calea Dumbravii - phase 2

- left turn phase 570,2 s / h
- forward 139,8 s / h
- right turn 0s / h (moving under rule give the way)

G-ral Vasile Milea Blvd (towards downtown)

- turn left • 430,4 s / h - phase 3
- forward and turn right 137,3 s / h - phase 8

Str. C-tin Noica - phase 6

- right turn only 0,4 s / h

G-ral Vasile Milea Blvd (direction to Brasov)

- turn left 150,1 s / h, - phase 7
- forward 119,8 s / h, -phase 4
- turn left 24,3 s / h, - phase 4

The diagram below illustrates the traffic light cycle for each phase. We can see the existence of unallocated time in phase 6, respective phase 4.

Also volume-capacity ratio (v/c) is greater than 1, which means that it is now beyond the capacity of the intersection.

Fig. 4. Timing settings existing for intersection A

Optimization propose two variants, one for optimizing the recalculation intersection cycle traffic light, reduction delays and second by changing the geometry of the intersection.

TABLE V
PROPOSE TRAFFIC LIGHT TIMES FOR INTERSECTION "A"

Street	Red time (s)	Green time (s)	Yellow time (s)
Constantin Noica (right)	82	18	3
V.Milea – to Brasov (forward)	40	58	
V.Milea – to Brasov (left)	40	51	
Calea Dumbravii	40	60	
V. Milea – to downtown (left)	50	41	
V.Milea - to downtown (forward, right)	50	48	

For the calculus of delays the traffic model used is Colombaroni [3], which states that the delay caused by a signalized intersection is strictly defined as the difference in the road section travel time in the presence of traffic lights compared to the travel time of the same section if a vehicle could travel along a trajectory at constant speed v (speed of synchronization).

Compared to traditional delay formulations, this model includes both the upstream and the downstream node delay. This model is based on the "platoons" representation and it simulates congested road with propagation of the queue between nodes (spill-back phenomena).

The delay computation requires an iterative procedure that classifies the different platoons progressively, [2].

Under the new traffic light time delay decreased as follows:

Calea Dumbravii - phase 2

- left turn 138,6 s / h
- forward 97,9 s / h
- right turn 0 s / h (moving under rule give the way)

G-ral Vasile Milea Blvd (towards downtown):

- turn left 134,4 s / h - phase 3
- forward and turn right 104,0 s / h- phase 8

Str. C-tin- Noica - phase 6

- right turn only 0,4 s / h

G-ral Vasile Milea Blvd (direction to Brasov):

- turn left 106,3 s / h, - phase 7
- forward103,5 s / h, - phase 4
- turn left 21,5 s / h - phase 4

Following changes are observed that cycles are synchronized, and the ratio v/c has a value below 1 to 0,83.

Thus the intersection capacity is properly utilized not being exceeded.

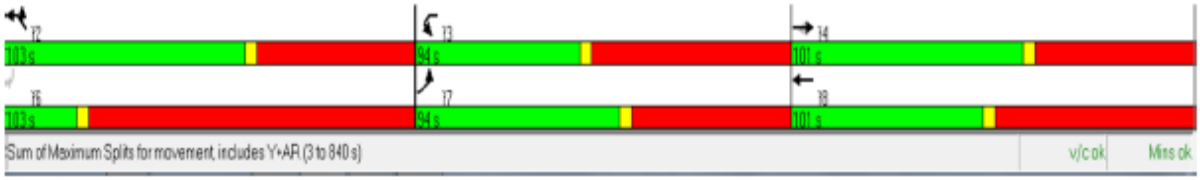

Fig. 5. Timing settings proposed

Implementing option 1 proposed average intersection delay will decrease by 60% (from 250,9 s to 100 s), and total traffic light cycle will decrease from 313 to 298 s. This will lead to significantly streamline traffic in the intersection.

And if the modification roundabout intersection geometry (fig. 6) ratio v/c has a value of 0,76 is less than 1 and intersection capacity is 66,7% versus 246,3%. Even in this case queues were reduced.

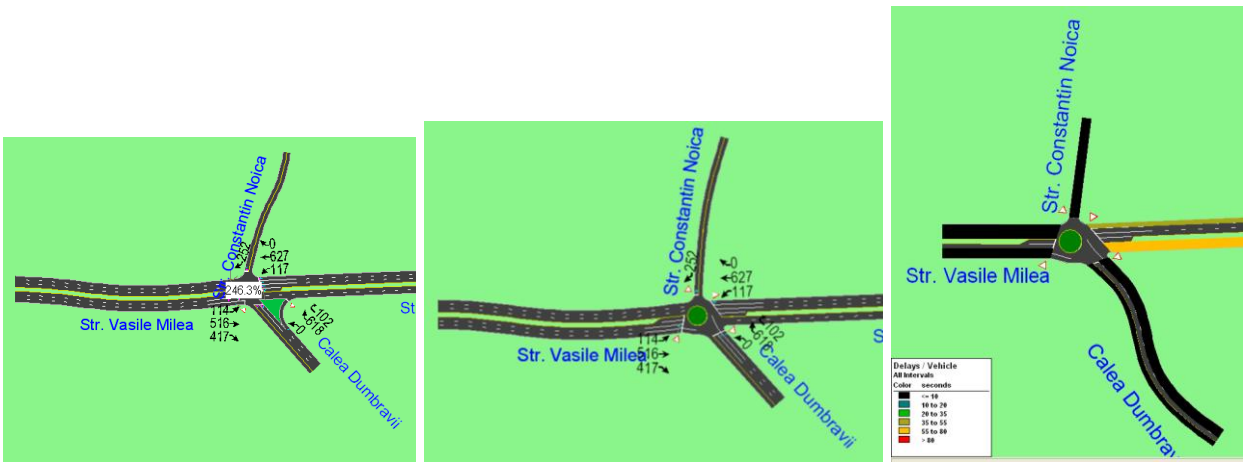

Fig. 6. Changing the geometry of the intersection and reduce vehicle delays

IV. CONCLUSIONS

Usual traffic signal optimization methods seek either to maximize the green bandwidth or to minimize a general objective function that typically includes delays, number of stops, fuel consumptions and some external costs like pollutant emissions.

After monitoring and optimizing traffic artery studied can see a reduction in the required time trips up to 35,21%, reducing queues with 13,7%, reduction in fuel consumption for cars up to 0,2 liters (fig 7). Emissions will be reduced accordingly, due to the decrease in the number of accelerations and has beneficial effects on the environment.

SimTraffic Performance Report
Baseline

1: Str. Vasile Milea & Str. Constantin Noica Performance by approach

Approach	EB	WB	SB	NW	All
Fuel Used (l)	0.5	2.0	0.2	0.9	3.6
HC Emissions (g)	1	4	0	2	7
CO Emissions (g)	45	139	17	109	310
NOx Emissions (g)	5	15	2	9	31
Density (m/veh)	398	132		324	187

2: Str. Vasile Milea & Str. Moldoveanu Performance by approach

Approach	EB	WB	NB	SB	All
Fuel Used (l)	1.4	2.0	0.6	0.8	4.8
HC Emissions (g)	1	4	0	1	6
CO Emissions (g)	91	122	25	37	275
NOx Emissions (g)	6	13	2	3	24
Density (m/veh)	102	33	58	27	53

3: Str. Vasile Milea & Str. Paltinului Performance by approach

Approach	EB	WB	NB	SB	All
Fuel Used (l)	2.0	1.3	0.8	0.1	4.3
HC Emissions (g)	1	1	0	0	2
CO Emissions (g)	52	35	20	8	115
NOx Emissions (g)	5	3	2	1	11
Density (m/veh)	32	27	23	119	31

4: Str. Vasile Milea & Str. Vasile Aaron Performance by approach

Approach	EB	WB	SB	All
Fuel Used (l)	1.5	2.3	0.9	4.7
HC Emissions (g)	1	1	0	3
CO Emissions (g)	97	85	19	201
NOx Emissions (g)	7	6	2	15
Density (m/veh)	33	32	12	28

5: Str. Vasile Milea & Str. Semaforului Performance by approach

Approach	EB	WB	NB	SB	All
Fuel Used (l)	1.5	2.2	1.0	1.2	6.0
HC Emissions (g)	1	2	1	1	6
CO Emissions (g)	89	154	53	40	335
NOx Emissions (g)	6	10	6	4	27

Fig. 7. Report on fuel consumed

Another benefit from implementing proposed solutions is considerably lower vehicle delay times and increase travel speeds. After viewing comparative graphs on speed, delay in stopping the vehicle, delays per vehicle, stops per vehicle it was observed that they did not fully improved.

Utilization of each intersection has increased in each of the six intersections of the artery with the implementation of the proposed optimization solutions and time required for crossing intersections were reduced. Service quality levels increased in the analyzed intersection where the level of service ”F” reached the “D”.

Noted that traffic in this area is taking place at the moment with some difficulty due to the number of cars especially during peak hours.

Reducing the number of cars would improve traffic flow, and that solution would be to encourage the use of public transport in place of personal transportation that would have many advantages. Compared to other means of transport, a car deals compared to a person carrying a much larger area of road network, about 15 m^2 and carrying an average of 2,5 persons, while a public transport bus deals while driving approximately 30 m^2 and carrying an average of 50 people.

From the realized simulations it has proved that the proposed solutions gave better results than the real ones, but not enough for the number of cars traveling in this area during the day, which is very high.

It proposes the use of means of public transport instead of individual which would contribute greatly to a fluent movement in the studied area and beyond.

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