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SIMULATION AND OPTIMIZATION OF URBAN TRAFFIC FLOW, BY THE USE OF PROGRAMS SYNCHRO AND SIMMTRAFFIC

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Abstract: *Traffic simulation is an increasingly popular and effective tool for analyzing a wide variety of dynamical problems which are not amenable to study by other means. These problems are usually associated with complex processes which can not readily be described in analytical terms. Usually, these processes are characterized by the interaction of many system components or entities. Often, the behaviour of each entity and the interaction of a limited number of entities, may be well understood and can be reliably represented logically and mathematically with acceptable confidence. However, the complex, simultaneous interactions of many system components cannot, in general, be adequately described in mathematical or logical forms.*

In my research paper I would like to present Synchro which is a modern traffic simulation program. This is not a general presentation of this program but an attempt of choosing a real application from the urban area, more precisely from Brasov city, where I have noticed some problems in the urban traffic: congestions, conflict points. Firstly, I picked the data from one of the city's busiest route; the data was introduced in Synchro, which simulated the urban traffic and secondly I solved some of the problems and tried to optimize it using the simulation program Synchro.

Keywords: *Traffic simulation, urban mobility, ecologyzation of transport, traffic flow.*

1.INTRODUCTION

Nowadays, there is a major variety of instruments and soft wares for analyzing and modelling of an existent signalized intersection or even for optimizing a proposed one. The majority of the analyzing instruments give all the information (regarding the lost time in intersections, storage lengths, the level of service and so on) for the traffic engineer, but it does not exist one single program that can precisely estimate all of the important measures for the actual conditions. For example, if the distance between intersections is very small, some of the techniques of the soft wares are good for the delay estimation and improper for the determination of information like, storage length or its dissipation.

2. SYNCHRO 6 A MODERN TRAFFIC SIMULATION PROGRAM

Synchro 6 is a complete software package for modelling and optimizing traffic signal. timings. Here is a summary of its key features:

2.1 Capacity analysis

Synchro implements the ***I****ntersection* ***C****apacity* ***U****tilization (****ICU****) 2003* method for determining intersection capacity. This method compares the current volume to the intersections ultimate capacity. The method is very straightforward to implement and can be determined with a single page worksheet. Synchro also implements the methods of the *2000 Highway Capacity Manual*, Chapters 15, 16, and 17; Urban Streets, Signalized Intersections, and Unsignalized Intersections. Synchro provides an easy-to-use solution for single intersection capacity analysis and timing optimization. In addition to calculating capacity, Synchro can also optimize cycle lengths and splits, eliminating the need to try multiple timing plans in search of the optimum. All values are entered in easy-to-use forms. Calculations and intermediate results are shown on the same forms. If the intersection is coordinated, Synchro explicitly calculates the progression factor. With the *Highway Capacity Software (HC)*, it is necessary to estimate the effects of coordination. Synchro calculates the effects of coordination automatically and accurately. Synchro allows you to quickly generate optimum timing plans. Synchro optimizes the split, cycle length, and offsets. Synchro optimizes to reduce delays and stops. It is fully interactive, when you change input values, the results are updated automatically. Timing plans are shown on easy to comprehend timing diagrams.

2.2 Actuated signals

It provides detailed, automatic modeling of actuated signals. Synchro can model skipping and gapping behavior and apply this information to delay modelling.

2.3 Time space diagram

It has colorful, informative Time-Space Diagrams. Splits and offsets can be changed directly on the diagram.

Synchro features two styles of time-space diagrams. The bandwidth style shows how traffic might be able to travel down an entire arterial without stopping. The vehicle flow style shows individual vehicles that stop, queue up, and then go. The traffic flow style gives a much clearer picture of what the traffic flow actually looks like. For a complete analysis of an intersection the following conditions are taking into account:

1) **Geometrical conditions :**
   - Total width
   - Lane width
   - Number of lanes
   - Storage length
   - Parking conditions
   - Grade

2) **Traffic conditions:**
   - Traffic volume
   - The lane which has the maximum volume
   - Ideal saturated flow
   - Peak hour factor PHF
   - Heavy vehicle’s percentage
   - Conflicting pedestrian’s flow rate
   - Bus blockages
   - Growth factor

3) **Timing conditions:**
   - Cycle length
   - Green time
   - Time interval between yellow and all red
   - Controller type

3. CHOOSING THE APPLICATION FROM THE URBAN AREA

We proposed to analyze a network of signalized/unsignalized intersections situated in Braşov (Fig.3.1) using the modelling and simulation software.

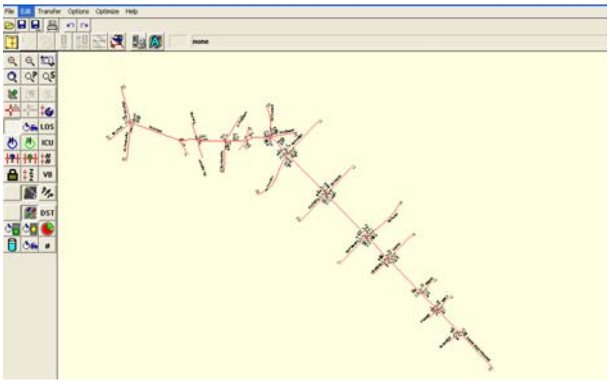


Fig. 3.1 The analyzed network from Brasov city

The map above was made in Synchro 6 but in this research paper we have chosen to analyze an intersection.

Fig. 3.2 The analyzed intersection

For the analysis of the intersection the following information had to be collected: traffic volumes on each lane, the width of each lane and the timing plan.

4. DATA COLLECTION AND PROCESSING PHASE

The data from the sheets was introduced in the Microsoft® Excel worksheet (Table 4.1) presented in the table below. The explanation of the table:

The first row represents the streets of the intersection. Below it the lanes of each street are presented. In the third row C means passenger Car, T means Truck, T/B means Truck or Bus. Under this the number of each type of vehicle is written that passes through the intersection on every cycle. As we can conclude, in the first column the number of the cycle is appearing. In the T/B columns the Busses are highlighted with light yellow, the articulated Busses with yellow background and the Trucks with red fonts.

Table4.1

The data introduced in table

	On 15 Noiembrie street												From the Police Dep.				Castanilor street			
No.	C	T/B	C	T	C	T/B	C	T	C	T/B	C	T	C	T	C	T	C	T/B	C	T/B
1	8	2	2		18		14		6	4	5		5		1		13	1	12	
2	12	2			22		18		8	1	6		9		1		10	2	8	
3	10	1	2		25	1	21	1	10	1	5		6		4		12	5	6	
4	10	1			29		22	2	11	3	8		11		2		14		13	
5	10	2	1	1	15		22		10	2	5		13		2		14		17	
6	14	1	2		22		26		13	1	5		13		3		19		7	
7	11	1	1		23		25	3	12	2	4		5		3		12		10	
8	12				27		20		10	6	6		9		3		15	2	14	
9	14		3	1	20		22		10	2	3		13		2		23	1	13	
10	10	1	2		26		18		9	1	5		12		3	1	22	1	13	
11	10	1	2	1	22		24	1	12	3	1		4	1	4		17	2	14	
12	13	1	5		20		22	3	10	6	6		13		3		13	1	12	
13	16		2		25		28	2	13	4	7		13		4		19	2	11	
14	14	1	4		20		27	2	13	3	4		8		6		21	2	12	
15	8	2	4	1	16		19	2	9	2	8	1	11	1	2		19	2	17	
16	15		3		24		22	2	10	4	6		12		3		17	4	10	1
17	12	2	5		19		24	3	11		10		9		4		20	2	10	
18	13		2	1	19		22	1	10	3	7		12		2		19	1	12	
19	11	1	6	1	18		20	2	10	3	9		9	1	3	1	16	1	17	
20	15		2	1	22		31		15		4		9		1	1	16	2	7	
21	11	1	4		14		22	1	11	2	7		11		3	1	19	2	13	1
22	11		3	1	13		27	3	13	2	3		12	1	4		20	1	7	
23	14	1	5	1	18		22	1	10	2	6	1	6	1	4		15	3	13	
24	12	1	3		16		21		10	1	8		5		2		17	2	9	1
25	13	1	4	1	21		20	2	10	4	5	1	7		6		22	2	10	1
26	12	1	1	1	18		21		10	1	12	1	8		3		19		9	
27	12	1	3	1	19		22	2	11	1	9	1	12		3	1	22	1	9	
28	8	2	2		14	1	18	2	8	2	7	1	15		1		18		11	
29	14		1		23		26	1	12		3		11	1	1		19	2	11	
30	9	1	3		22		18	1	8	2	10		18		1		17	3	9	
31	11	2	1		20		21		10	4	4		13	1	3		24	1	10	
32	8	4	1		22		21	2	10	3	3		12		2		18	2	11	1
33	13		2	1	20		18	1	9	1	7		11	2	2		21		15	1

After the introduction of the data sets in the table, the next step was to make the some interesting indicators. In Table 4.2. the sum of each column is calculated and in its first column there are explained

Table4.2

The summation on columns

		On 15 Noiembrie street												From the Police Dep.				Castanilor street				TOTAL
	No.	C	T/B	C	T	C	T/B	C	T	C	T/B	C	T	C	T	C	T	C	T/B	C	T/B	
Total on columns	Sum	386	34	81	13	672	2	724	40	344	76	198	6	337	9	91	5	582	50	372	6	
Total on a direction/lane		420		94		674		764		420		204		346		96		632		378		
Total on a lane		420		768				764		624				346		96		632		378		4028
Total light vehicles on lane		386		753				724		542				337		91		582		372		3787
Total heavy vehicles on lane		34		15				40		82				9		5		50		6		241

The first representation of the calculated values is the total number of vehicles that went trough the intersection in an hour on each lane (Fig. 4.1).

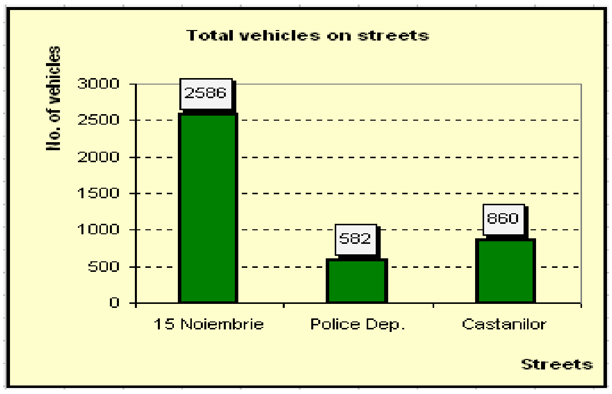


Fig. 4.1 Total vehicles on lanes

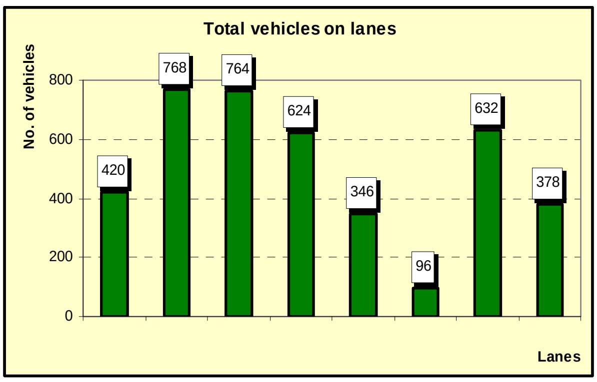


Fig. 4.2 Total vehicles on streets

The second graph (Fig 4.2) shows the total number of vehicles on each street.

From the above values comes the proportion on each street (Fig. 4.3):

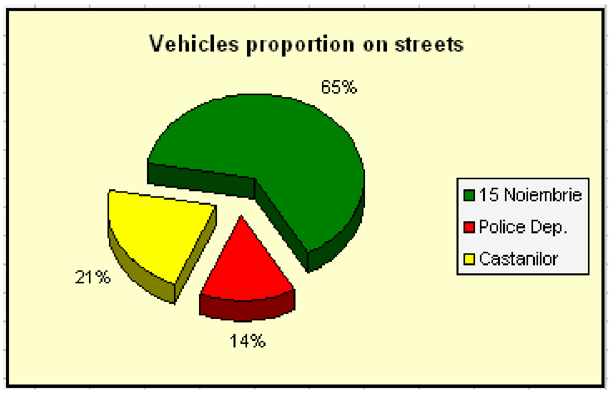


Fig. 4.3 The proportion of the vehicles on streets

The below presented table (Table 4.3) shows the number of vehicles in the intersection on each cycle. After which the graphical representation (Fig. 4.4) can be seen.

Table 4.3.

No. of vehicles on each cycle

Cycle	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
No. of veh.	91	99	110	126	114	126	112	124	127	124	119	128	146	137	124	133	131

Cycle	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
No. of veh.	124	129	126	123	121	123	108	130	117	130	110	125	122	125	120	124

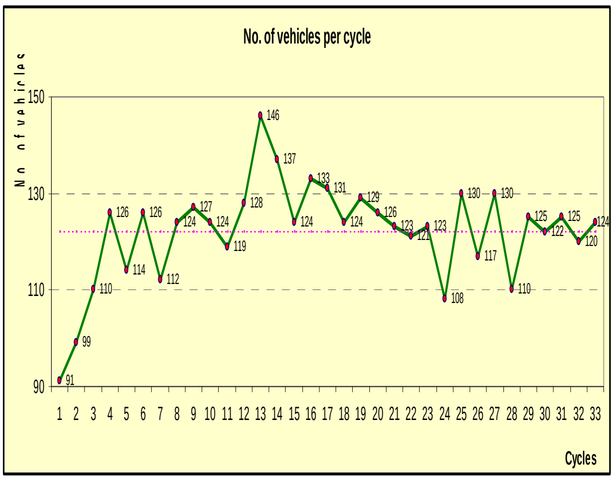


Fig. 4.4 No. of vehicles on each cycle

The numbers of heavy vehicles are presented in the below table (Table 4.4):

Table 4.4

No. of vehicle types on each street

15 Noiembrie				Castanilor (Pol. Dep.)				Castanilor				Whole intersection			
Car	Bus	A Bus	Truck	Car	Bus	A Bus	Truck	Car	Bus	A Bus	Truck	Car	Bus	A Bus	Truck
2420	87	14	55	428	0	0	14	954	6	9	41	3802	93	23	110

The values from the above table are illustrated in the following four graphical representations (Fig 4.4, 4.5, 4.6, 4.7):

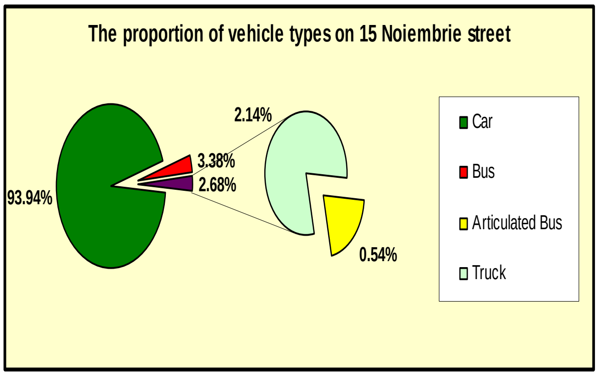


Fig. 4.4 The proportion of vehicle types on 15 Noiembrie Street

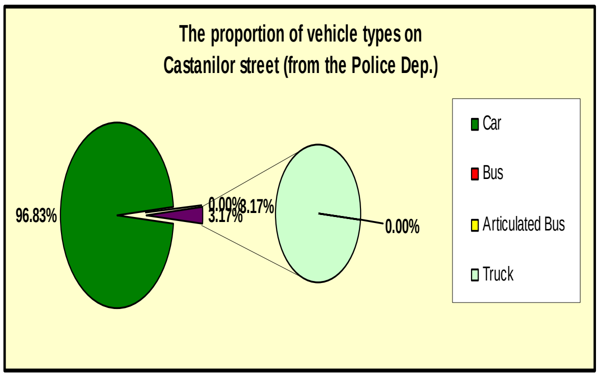


Fig. 4.5 The proportion of vehicle types on Castanilor Street (from the Pol. Dep.)

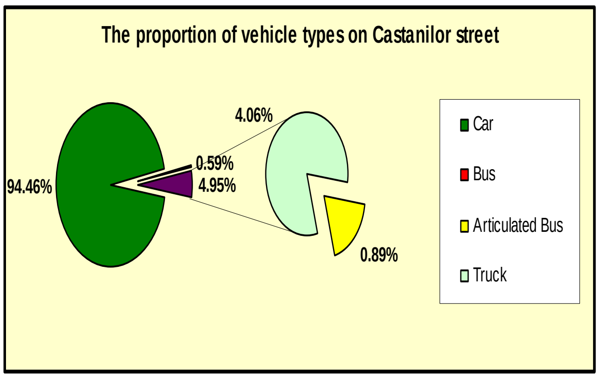


Fig. 4.6 The proportion of vehicle types on Castanilor Street

The number of heavy vehicles on the streets is represented also with values on the figure represented below (Fig. 4.8).

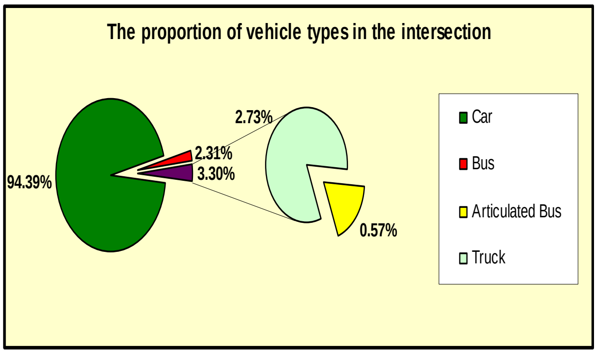


Fig. 4.7 The proportion of vehicle types in the intersection

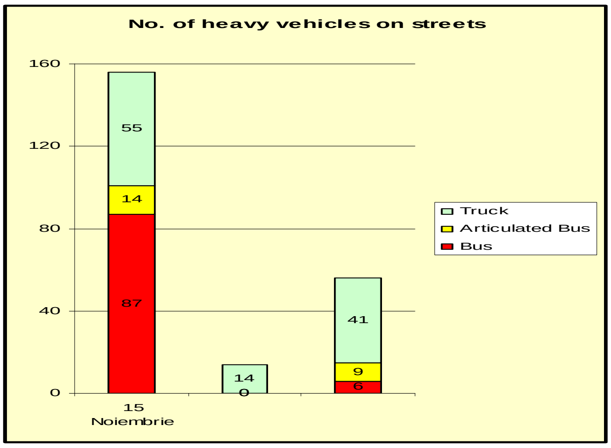


Fig. 4.8 The proportion of vehicle types in the intersection

5. OPTIMIZING THE INTERSECTION

Synchro contains a number of optimization functions. It is important to understand what each function does and use the optimizations in the correct order. These commands can be accessed from the Optimization menu of the main window. Table 5.1 shows the six types of optimizations and which parameters they optimize.

Table 5.1

Optimization commands

Optimization Type	Scope	Values Optimized	Values needed for input
Intersection Cycle Length	Current Intersection	Cycle Length, Splits	Volumes, Lanes, Fixed Timings
Intersection Splits	Current Intersection	Splits	Volumes, Lanes, Left turn type, Cycle Length, Fixed Timings
Partition Network	Network	Zone	Volumes, Lanes, Fixed Timings
Network Cycle Lengths	Network or Zone	Cycle Lengths, Splits, Offsets , Lead/Lag Order	Volumes, Lanes, Fixed Timings
Intersection Offsets	Current Intersection	Offsets, Lead/Lag Order	Volumes, Lanes, Fixed Timings, Cycle Lengths, Splits
Network Offsets	Network or Zone	Offsets, Lead/Lag Order	Volumes, Lanes, Fixed Timings, Cycle Lengths, Splits

5.1 Modifying the parameters

The first step was to optimize the intersection by the changing of the Cycle length, splits and offsets. Doing this the whole plan was ruined and resulted that the current timing plan is more or less accurate for the available intersection. Thus a greater modification has to be done to influence the characteristics in a better way.

The first idea that works is to make a through lane from the shared lane on the 15 Noiembrie Street, thus obtaining a single left lane, two through lanes and one shared. The idea is shown on the figure below (Fig. 5.1):

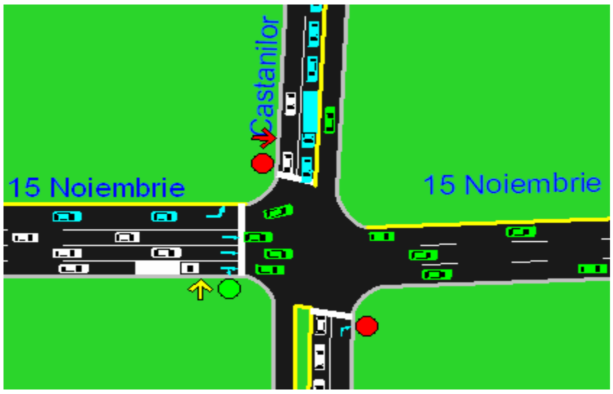
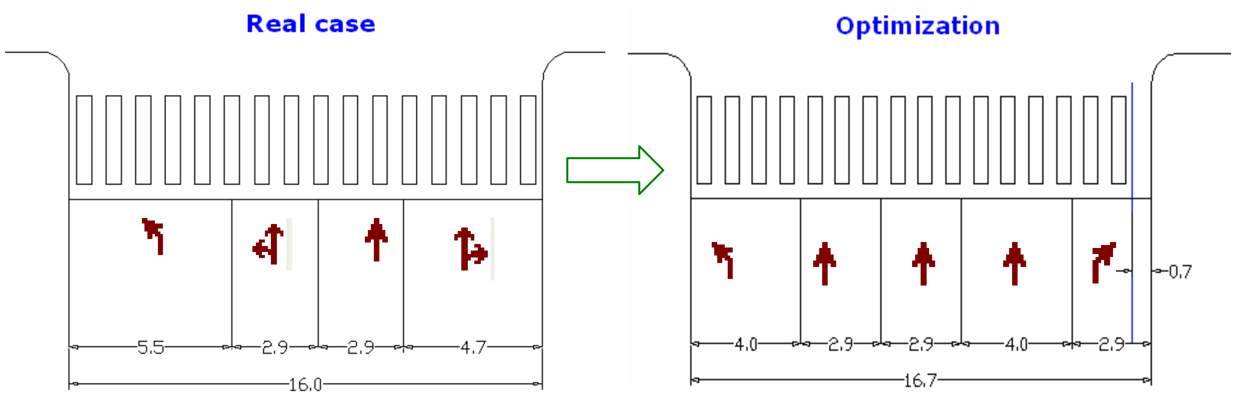


Fig. 5.1 The first optimization plan

The second idea is to make a lane in addition for the right turn on the 15 Noiembrie Street. This can be realized by adding a storage lane. For a better understanding the idea is shown on the following figure:

Fig. 5.2 The second optimization plan

This modification affects the width of every lane. To have a good compromise the width of every lane has to be modified on the 15 Noiembrie Street. The next figure presents the solution for the second idea:



The lane widths of the real case are presented on the left side of the above figure. The lane widths after the modifications on the 15 Noiembrie Street can be seen on the right.

In the following steps the modifications done in Synchro are illustrated comparatively. At first only the lanes are modified on the 15 Noiembrie Street. It has to be mentioned that at the second solution the lane widths are modified according to the figure presented above. The two figures below refer to the two solutions: Fig.5.3 to the first, Fig.5.4 to the second.

TIMING WINDOW	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)	↰	↑↑↱						↑	↱	↰	↑	
Traffic Volume (vph)	514	1858	204	0	0	0	0	346	96	632	378	0
Turn Type	Prot	–	–	–	–	–	–	–	Perm	Prot	–	–
Protected Phases	3	4 7	–	–	–	–	–	2		1	6	–
Permitted Phases		7	–	–	–	–	–		2			–

Fig. 5.3 First solution

TIMING WINDOW	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)	↰	↑↑↑	↱					↑	↱	↰	↑	
Traffic Volume (vph)	514	1858	204	0	0	0	0	346	96	632	378	0
Turn Type	Prot	–	Perm	–	–	–	–	–	Perm	Prot	–	–
Protected Phases	3	4 7		–	–	–	–	2		1	6	–

Fig. 5.4 Second solution

The second modification consisted in optimizing the Cycle length, splits and offsets, thus the following timing plans resulted:

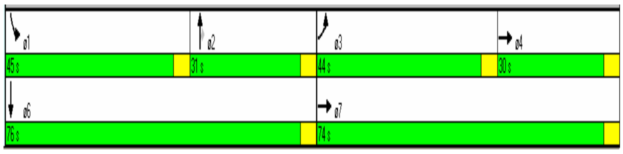


Fig. 5.5 Optimization for the first solution

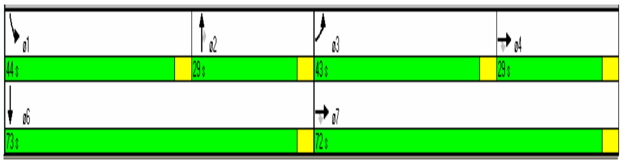


Fig. 5.6 Optimization for the second solution

5.2. The results obtained

By the modifications done, the most affected values appeared in the Timing window. In the following, the reports and the graphical representations are presented comparatively. The modifications are presented in form of figures taken out from Synchro 6 report files. The first four figures indicate the values for each of the four solutions:

Direction	EB	NB	SB	All
Volume (vph)	2576	442	1010	4028
Queue Delay / Veh (s/v)	0	0	0	0
Total Delay / Veh (s/v)	232	143	211	217
Total Delay (hr)	166	18	59	243
Stops / Veh	0.75	0.82	0.69	0.74
Stops (#)	1936	362	695	2993
Average Speed (km/hr	4	9	3	4
Total Travel Time (hr)	182	21	63	266
Distance Traveled (km)	791	182	206	1178
Fuel Consumed (l)	579	74	199	852
Fuel Economy (km/l)	1.4	2.5	1.0	1.4
CO Emissions (kg)	10.77	1.38	3.70	15.84
NOx Emissions (kg)	2.08	0.27	0.71	3.06
VOC Emissions (kg)	2.48	0.32	0.85	3.65
Unserved Vehicles (#)	782	67	245	1094

Fig. 5.7 MOEs for the first solution

EB	NB	SB	All
2576	442	1010	4028
0	0	0	0
209	158	216	205
150	19	61	230
0.76	0.82	0.68	0.75
1963	362	686	3011
5	8	3	5
165	23	65	253
791	182	206	1178
533	79	203	815
1.5	2.3	1.0	1.4
9.92	1.47	3.77	15.17
1.91	0.28	0.73	2.93
2.29	0.34	0.87	3.50
687	70	244	1001

Fig. 5.8 MOEs for the second optimized solution

Direction	EB	NB	SB	All
Volume (vph)	2576	442	1010	4028
Queue Delay / Veh (s/v)	0	0	0	0
Total Delay / Veh (s/v)	169	143	211	177
Total Delay (hr)	121	18	59	198
Stops / Veh	0.79	0.82	0.69	0.77
Stops (#)	2033	362	695	3090
Average Speed (km/hr	6	9	3	5
Total Travel Time (hr)	137	21	63	222
Distance Traveled (km)	791	182	206	1178
Fuel Consumed (l)	457	74	199	730
Fuel Economy (km/l)	1.7	2.5	1.0	1.6
CO Emissions (kg)	8.49	1.38	3.70	13.57
NOx Emissions (kg)	1.64	0.27	0.71	2.62
VOC Emissions (kg)	1.96	0.32	0.85	3.13
Unserved Vehicles (#)	538	67	245	850

Fig. 5.9 MOEs for the second solution

EB	NB	SB	All
2576	442	1010	4028
0	0	0	0
151	174	212	169
108	21	59	189
0.81	0.80	0.69	0.77
2075	354	692	3121
6	7	3	6
124	25	63	213
791	182	206	1178
422	84	199	706
1.9	2.2	1.0	1.7
7.84	1.57	3.71	13.12
1.51	0.30	0.72	2.53
1.81	0.36	0.86	3.03
427	82	240	749

Fig. 5.10 MOEs for the second optimized solution

After presenting the detailed Measures of Effectiveness (MOEs) reports for each solution, a detailed multifile comparison was made for a better evaluation. This report is illustrated on the figure below:

Scenario #	1	2	3	4	5
Number of Intersections	1	1	1	1	1
Most Popular Cycle (s)	110	110	110	150	145
Alternative	Baseline	Baseline	Baseline	Baseline	Baseline
Timing Plan ID	Default	Default	Default	Default	Default
Data Time					
Queue Delay / Veh (s/v)	0	0	0	0	0
Total Delay / Veh (s/v)	331	217	177	205	169
Total Delay (hr)	371	243	198	230	189
Stops / Veh	0.66	0.74	0.77	0.75	0.77
Stops (#)	2665	2993	3090	3011	3121
Average Speed (km/hr	3	4	5	5	6
Total Travel Time (hr)	394	266	222	253	213
Distance Traveled (km)	1178	1178	1178	1178	1178
Fuel Consumed (l)	1198	852	730	815	706
Fuel Economy (km/l)	1.0	1.4	1.6	1.4	1.7
CO Emissions (kg)	22.29	15.84	13.57	15.17	13.12
NOx Emissions (kg)	4.30	3.06	2.62	2.93	2.53
VOC Emissions (kg)	5.14	3.65	3.13	3.50	3.03
Unserved Vehicles (#)	1495	1094	850	1001	749
Performance Index	378.0	251.2	206.5	237.9	197.7

Fig. 5.11 Detailed multifile comparison

Explanations for the detailed multifile comparison report (Fig. 5.11):

In the first row (Scenario#) of the report every numbered column contains the values of a solution. *Scenario 1* means the real case. *Scenario 2* means the first solution. *Scenario 3* means the second solution. *Scenario 4 and 5* mean the optimized version for the first and the second solution respectively.

5.3. Graphical representation of the solutions

The effects of the modifications done can be seen on the next eight graphical representations. These representations refer to the best possible solutions. The first four (Fig. 5.12, 5.13, 5.14, 5.15) refer to the first optimized solution:

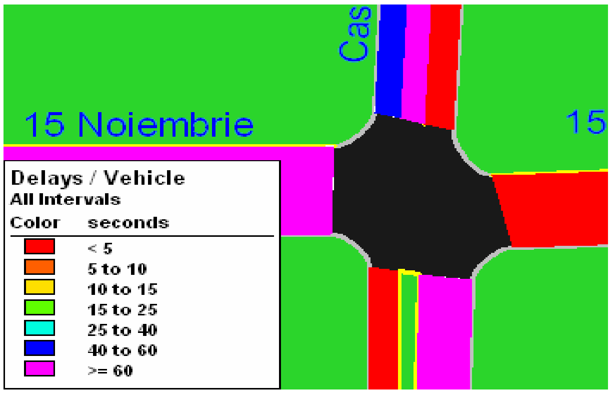


Fig. 5.12 Delays per vehicle

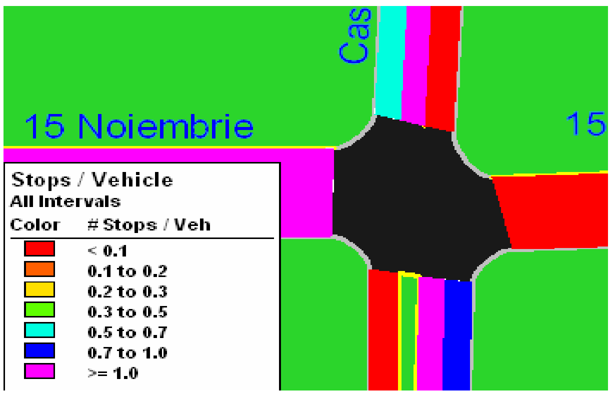


Fig. 5.13 Stops per vehicle

After the first optimized solution presented above the second optimized solution is presented below, offering the best solution from all the four optimizations presented earlier.

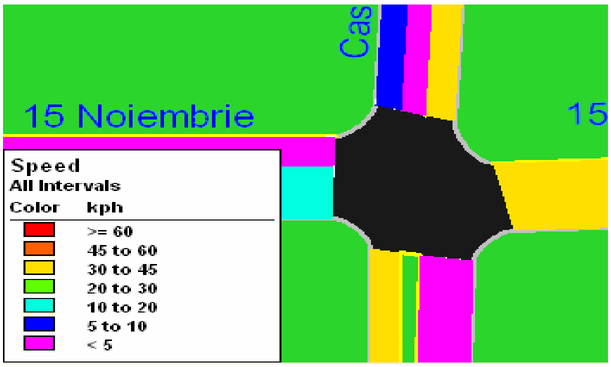


Fig. 5.14 Average speeds

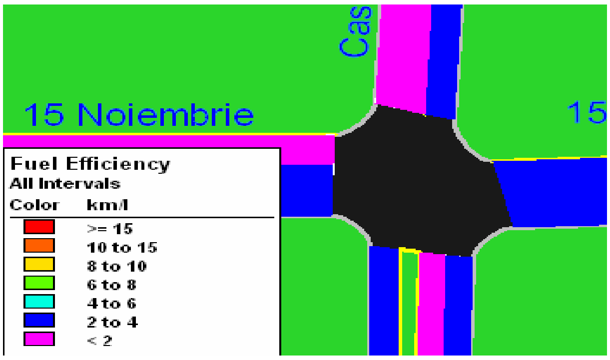


Fig. 5.15 Fuel efficiency

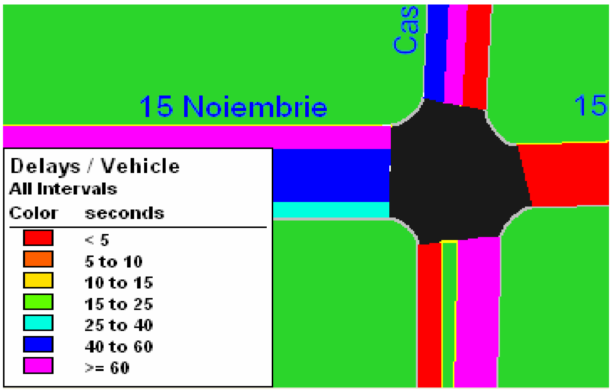


Fig. 5.16 Delays per vehicle

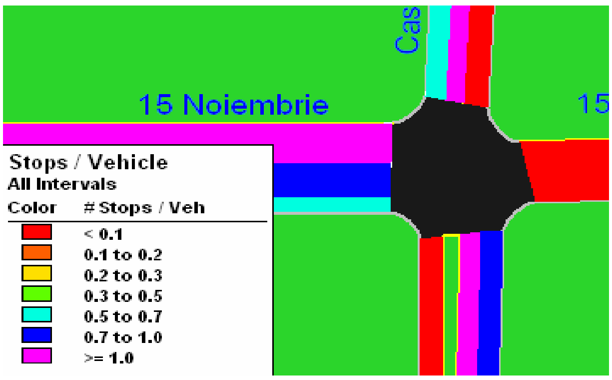


Fig. 5.17 Stops per vehicle

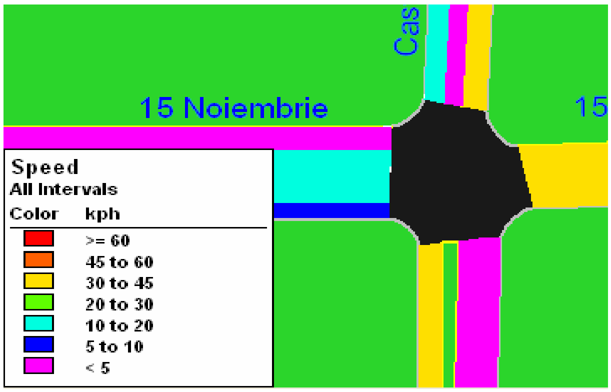


Fig. 5.61. Average speeds

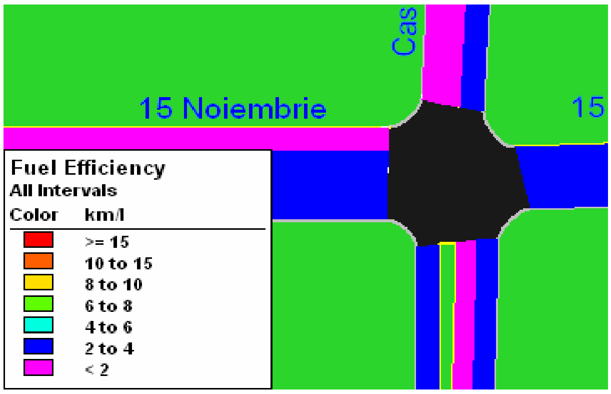


Fig. 5.18 Fuel efficiency

6. CONCLUSIONS

The first solution (transforming the shared lane into a trough lane) can be the most easily realized. But if the idea would be implemented it is suggested to do an optimization for the timing plan, because this leads to another increase in performance (see Table 6.2.).

The second solution requires the modification of the 15 Noiembrie Street. But it can increase the performance even more than it does the first solution. Because in this case we have five lanes instead of 4 from the real case, the lane widths have to be modified. This solution requires that a length of 0.7 meters from the side walk has to be cut off. This length can be realized also, according to a similar procedure done in the “15 Noimembrie-Calea Bucuresti” intersection. It is compromise in which the pedestrians are disadvantaged. But if it would be implemented it will increase the performances by a very high rate. In this case the optimization of the the timing plan is obligatory.

Advantages of the solutions:

1. The total delays (Fig. 6.1) are reduced by 35 up to 49%, which is significant.

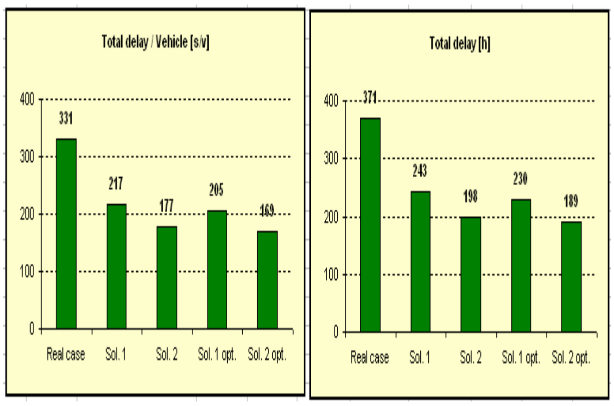


Fig. 6.1. Total delays

2. The travel time (Fig. 6.2) in the intersection is reduced by 32 up to 46%.

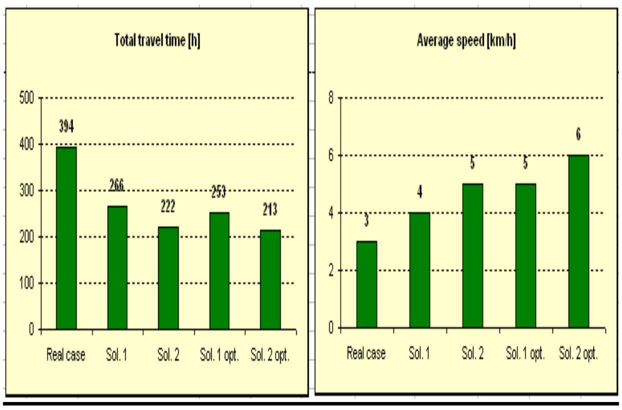


Fig. 6.2. Total travel time and average speed

3. The average speed (Fig. 6.2) is increased by 33% in the first case and it has doubled in the last case.

4. The fuel consumption (Fig. 6.4) is reduced by 29 up to 41%, leading to an increased fuel economy by 40 up to 70%.

5. The emissions (Fig. 6.5) are reduced by 29 up to 41%.

On the illustration (Fig. 6.5.): CO means carbon-oxides, NOx means Nitrogen-oxides (noxes) and VOC means Volatile Organic Compounds.

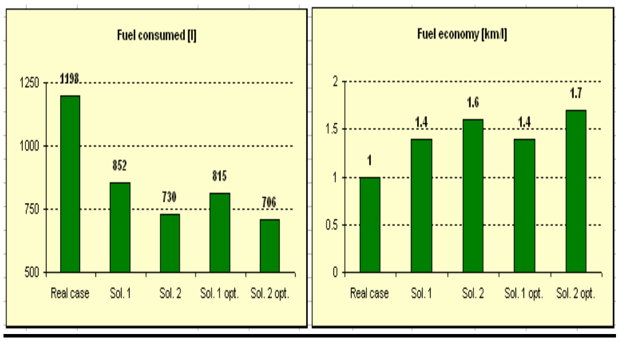


Fig. 6.4. Fuel consumption

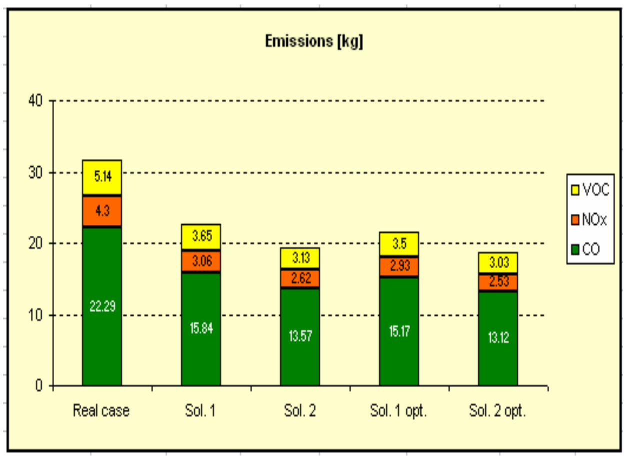


Fig. 6.5. Emissions

6. The number of Unserved vehicles (Fig. 6.6) is reduced by 27 up to 50%.

7. The Performance index (Fig. 6.6) is a combination of the delays, stops and queuing penalty. A lower value for the performance index indicates a higher level of service; a higher value for the performance index means a less good condition for an intersection. This measure is reduced by 34 up to 48%.

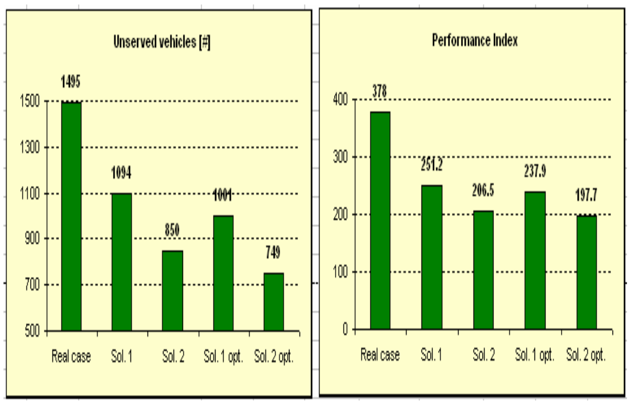


Fig. 6.6. Unserved vehicles and performance index

Back draws of the solutions:

The only disadvantage of the solutions is that the number of stops and the stops/vehicle (as the effect of the no. of stops) have increased (Fig.6.8) by 12 up to 17%.

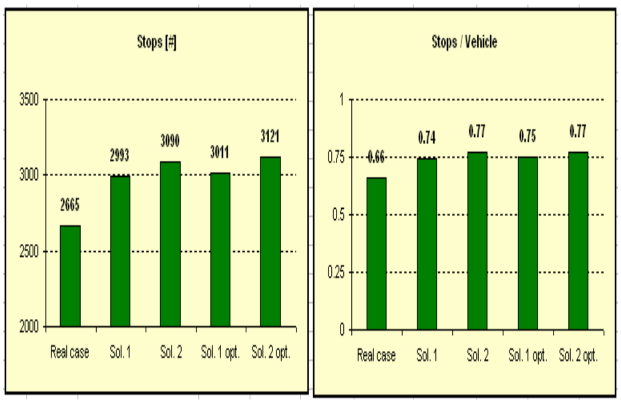


Fig. 6.8. Stops

7. REFRENCES

[1] Daniela, F., *Aplicații telematice în sistemele avansate de transport rutier,* Editura Universității „Transilvania din Brașov", ISBN 973-635-258-7, 2004

[2] Daniela, F., Cornel C., Adrian S., *Managementul traficului rutier, Ediția a II-a,* Editura Universității „Transilvania din Brașov", ISBN 973-9474-55-1, 2004

[3] Transportation Research Board (TRB)*, Highway Capacity Manual 2000,* Washington, DC: (TRB), National Research Council (NRC), 2000

[4] Federal Highway Administration, *Signalized intersections: Informational Guide,* U.S. Department of Transportation, 2004

[5] Trafficware Ltd., *Synchro 6,* http://www.trafficware.com

[6] Trafficware Ltd., *SimTraffic 6,* http://www.trafficware.com

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