Proposals for the reorganization of road traffic in the central area of Pitesti municipality based on microsimulation-performed traffic analyses

A A Boroiu, E Neagu, A Boroiu and I Vieru

Automotive and Transports Department, University of Pitesti, Pitesti, Romania

E-mail: elena.neagu@upit.ro

Abstract. In order to identify the possibilities for solving the traffic problems in the central area of Pitesti municipality - from improving traffic-light intersections to the proposal to redirect some of the traffic flows outside the area under analysis - a Vissim application, consisting of a microsimulation of road traffic in the central area, was performed. Based on the research conducted, a perspective of great interest proved to be the identification of the possibilities by means of which, to an extent as large as possible, the road traffic coming from Calea Depozitelor or the bridge over Arges and going to the Maior Sontu traffic-light intersection should follow the route between the railway and the Arges River, so as to reduce the impact load on the Podul Viilor roundabout intersection and circumvent the central residential area of the municipality of Pitesti. But, in the long run, the only viable solution that will completely eliminate the traffic congestion phenomenon at Maior Sontu intersection is to create the conditions for redirecting some of the traffic flows, and this can be done by arranging a road passage over the railway in the Prundu neighbourhood. Thus, a significant part of the road traffic - the one going to the Prundu, Craiovei and Războieni neighbourhoods, as well as to the periurban area in the east and south of the city, will follow this route, thus alleviating the traffic in the central area of the municipality of Pitesti.

1. Traffic problems identified in the central area of the municipality of Pitesti

The monitoring of the road traffic in the central area of the municipality of Pitesti (the area delineated on the map in figure 1) carried out before the commissioning of the road artery overpassing Calea Bucuresti near the Podul Viilor railway bridge revealed the occurrence of traffic congestion during the peak traffic periods (morning and afternoon) on the road sections coloured in blue in figure 1.

The road network is made up of road arteries and road intersections, but it is to be noted that, in almost all cases, the phenomenon of congestion is determined only by the unsatisfactory service level of the intersections [3]. This observation also applies to the central area of Pitesti: solving the road congestion problem requires the analysis of the road traffic in the main intersections from this area.

2. Traffic analyses for traffic-light intersections in the central area

The method of determining the capacity and service level for traffic-light intersections is presented in the paper [8], in accordance with the relevant manual in the field, [7], and a series of considerations regarding road intersections from the central area of the Pitesti municipality are presented in the paper [2].
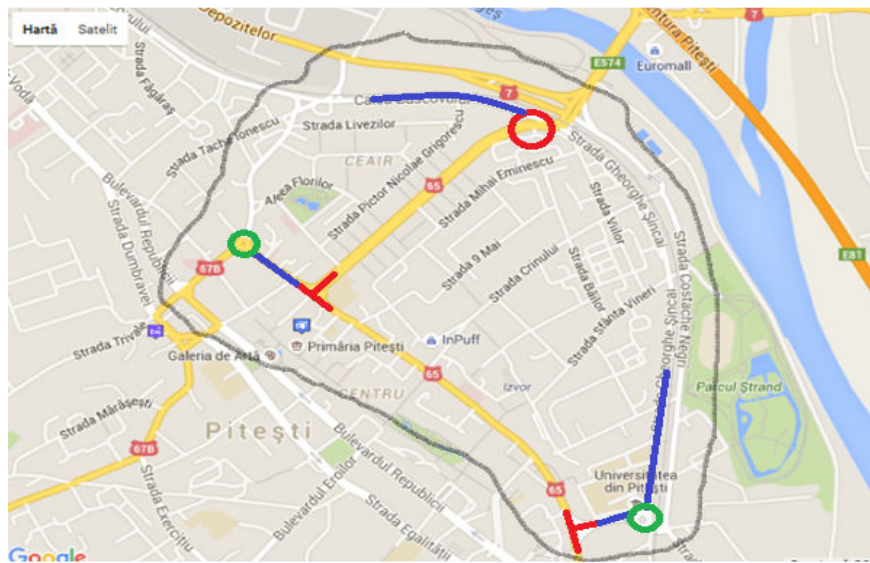
Figure 1. Intersections in the central area of Pitesti and road sections where road congestion occurs (blue colour) [13].

For the Maior Sontu - Targul din Vale traffic-light intersection (which is one of the traffic-light intersections aimed at by the topic of the present work), the intersection geometry and the road facilities identified by means of field observations are illustrated in figure 2 [3]. Road traffic is regulated by means of a traffic light, the total time for the traffic light cycle being $T_C = 94$ s.
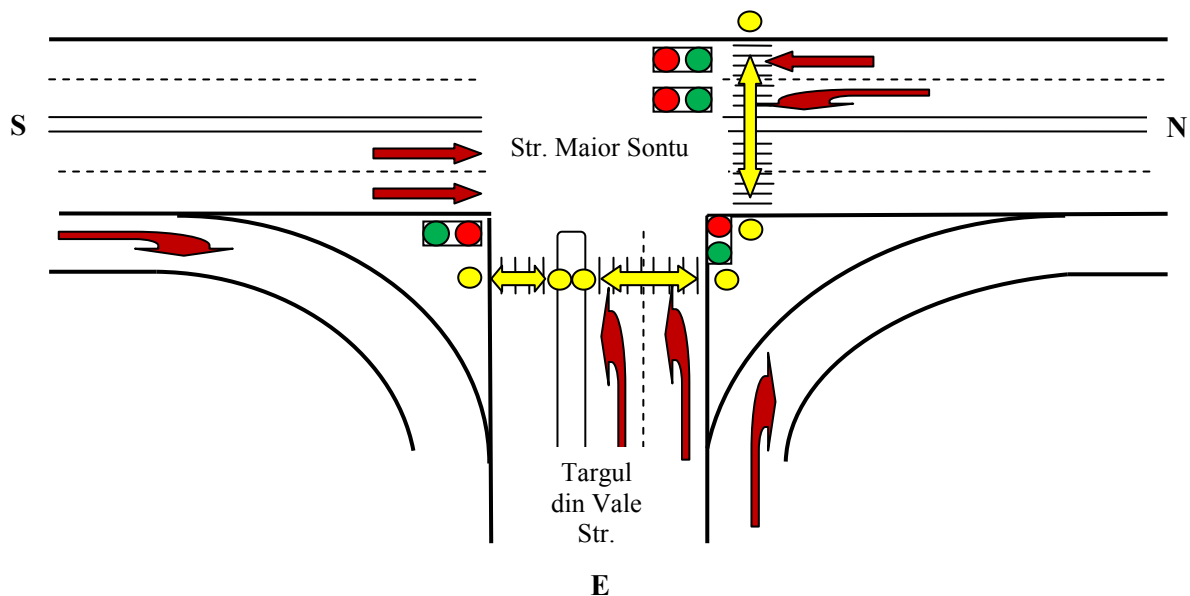

Figure 2. Traffic organisation at the traffic-light Maior Sontu intersection [2].

There are various methods for setting the programs for the traffic light (determining the duration of the traffic light cycle and the duration of the phases - among which Green Time is the active time that allows the passage of vehicles or pedestrians), taking into account both the geometric elements of the intersection and the traffic volumes and the pattern of arrivals.

The allocation of the Green Time duration can be made, function of the criterion used, in accordance with the following methods [6]:

- levelling the saturation degrees of critical movements;

minimizing the average waiting times of the vehicles crossing the intersection;

- ensuring the principle of "Average waiting time equal for all users (equity)";
- minimizing the amount of saturation degrees.

The working algorithm for determining the service level [8], adapted after the model presented in the relevant paper [7], is based on the criterion of minimizing the average waiting for the vehicles crossing the intersection, which represents the foundation of the Webster method.

The working algorithm operates with two components that are determined for each set of lanes i, shown below:

- flow-to-capacity ratio (X_i);
- the average waiting time of a vehicle d_i;

In the case identified by means of observations (the capacity is exceeded for one of the traffic movements), the first indicator: the flow-to-capacity ratio (X_i) is considered of relevance.

The flow-to-capacity ratio X_i is defined as the ratio between the actual traffic flow and capacity. It is calculated independently for each set of lanes with the relation:

$$X_i = \frac{v_i}{c_i} \tag{1}$$

Low values, close to 0, mean very low traffic flows, while high values close to 1 mean traffic demands close to the traffic capacity of the respective set of lanes. In this case, the value is over-unitary, which makes the method in [8] not applicable, so that a service level assessment is reached based on this flow-to-capacity ratio.

To determine the service level, the maximum traffic flow values for each set of lanes (peak traffic periods) will be taken into account. Thus, the observations made for all phases of the traffic-light cycle at the intersection revealed that congestion only occurs on the flow from the roundabout intersection (and even propagates upstream, as illustrated in figure 1), while for the other traffic movements capacity is not exceeded (even below 80% of the capacity is used for these phases of the traffic light).

As a result, after these traffic observations, the single proposal that can be put forward in order to remedy this situation is to increase the green duration for the respective traffic movement to the detriment of the other green phases [3].

In what the second roundabout intersection that creates the same kind of problem is concerned, the Bvd. I.C. Bratianu - Calea Bucureşti intersection, things are similar: congestion occurs on lane 1 on the north-south direction (forward direction) and propagates upstream to the roundabout intersection from the Diagnostic Centre.

As a result, examining the traffic-light cycle, which is similar to that from the intersection of Maior Sontu, it is proposed to solve the problem in a somewhat similar way: increasing the green duration for the respective traffic movement to the detriment of the other green phases [3].

In conclusion, solving the traffic problems in the two areas where the inappropriate capacity of the traffic-light intersections interferes with the smooth functioning of the roundabout intersections in the proximity can be solved by adapting the traffic light cycles to the structure of the traffic flows during peak periods: increasing the duration of the green time for the traffic movement where capacity has proved to be insufficient and reducing the other green phases from the traffic movements where there is an excess of capacity.

3. Traffic analyses for roundabout intersections in the central area

In what the roundabout intersections in the central area of Pitesti municipality (see figure 1) are concerned, for the two intersections from the Diagnostic Centre and the Rectorate it was demonstrated [2] that the direct effect of solving the traffic problems from the traffic-light intersections in proximity will lead to the improvement of the service level of these intersections and, therefore, to solving the traffic problems from these intersections.

In the case of the Targul din Vale roundabout intersection, the observations showed that the issue it not an insufficient capacity of this intersection, but rather the fact that the intersection becomes inoperable during peak traffic periods due to the insufficient capacity of the Maior Sontu traffic-light intersection on the arm coming from Targul din Vale. This can be solved by improving the traffic light cycle or by redirecting the road flows that pass through the respective intersection.

These findings regarding the functionality of the two intersections continue to exist after the setting up of the third roundabout intersection - the Podul Viilor roundabout (figure 3).

Figure 3. The roundabout intersection within the new road infrastructure at Podul Viilor [12].

Thus, the only roundabout intersection which, for reasons related to itself, does not have a sufficiently high service level is the Calea Bucureşti intersection, which has recently appeared as a component of the complex road development including the overpass road artery next to the railway bridge.

Here we find that, since it has a very wide annular path, instead of ensuring a high capacity of the intersection, the effect is quite the opposite: on the Podul Viilor - Calea Bucuresti arm, the visibility is so favourable, the radial connections of the arm to the annular path are so large that the vehicles enter the annular path from this arm at very high speeds, which makes it impossible to secure the entry of the vehicles coming from the Calea Bascovului arm and want to go forward or to the left.

The fact that the lanes on the annular path are not materialized, not even by road markings, favours the indiscipline of the drivers who entered the intersection in the sense that they do not enter and do not follow the annular path lane according to the rules of the Road Code [1].

For the Podul Viilor intersection, traffic measurements were made prior to the commissioning of the overpass artery and the values corresponding to the traffic peak have been retained.

As in the case of traffic-light intersections, to determine the service level of the roundabout intersection, control delays are calculated, but in this case an appropriate formula is to be used.

It is noted that the principle is similar to determining the length of the waiting strings (in standard vehicles). Control delays are determined by means of the relation:

$$d = \frac{3600}{c_a} + 900 \cdot T \cdot \left[\frac{v_b}{c_a} - 1 + \left[\left(\frac{v_b}{c_a} - 1 \right)^2 + \frac{\left(\frac{3600}{c_a} \right) \cdot \left(\frac{v_b}{c_a} \right)}{450 \cdot T} \right]^{1/2} \right] + 5 \qquad (2)$$

where:
- d is the value of control delays [sec/veh];
- c_a is the capacity of the arm [veh/hour];
- v_b is the arm entry volume [veh/hour];
- T is the analysis period [hours].

Service level identification was based on control delays, according to [7].

But in the case of the intersection under analysis, where the congestion phenomenon arises on the arm from Calea Bascov Street, the cause does not relate to the capacity of the arm or of the annular path - an annular path which is actually very wide -, but rather to the impossibility of the vehicles on that arm to safely reach the annular path, given that the vehicles circulating on the left-hand annular path (and which must be given priority of crossing) circulate at very fast speeds and without complying with the traffic rules in the roundabout intersection.

This problem, however, does not exist for vehicles on the Nord arm which turn to the right (they have a specially-arranged belt - figure 3), but for those running forward or turning to the left.

Also referring to the recommendations stated in the reference paper [7], as a first solution for solving the problem revealed one can note the preselection of traffic and the visible marking of the annular lanes, possibly followed by the physical separation of the lanes by special profiles.

4. Road traffic analysis by microsimulation

Microsimulation is a common term used in traffic modelling, known by the name of various software packages used in the field: TransModeler, PTV Vissim, TSIS-Corsim, Cube Dynasim, LISA+, Quadstone Paramics, SiAS Paramics, Simtraffic, Aimsun. Complex analytical modelling programs like Linsig, Transyt, Transyt-7F or Sidra represent a distinct class of models based on mathematical algorithms that combine elements of traffic patterns.

Traffic microsimulation patterns simulate the behaviour of individual vehicles within a predefined road network and are used to predict changes in traffic structure resulting from changes in traffic flows or changes in the physical environment. Microsimulation has the greatest utility in shaping traffic in congested road networks, due to its ability to simulate the forming conditions of the waiting strings [10].

In recent years, there has been an increasing interest in microsimulation modelling, as it allows the visual representation of traffic predicted through 3D animations, with increased power of conviction for decision-makers in what the proposed solutions are concerned.

The microscopic modelling of road traffic requires more data than macroscopic modelling, but this analysis reproduces traffic conditions more accurately.

There are numerous microsimulation software programmes for traffic flows based on various mathematical vehicle tracking models, the ones most frequently used being the Gipps model and the Wiedermann model [4]. In the Gipps model, developed in 1970, it is believed that a driver estimates the speed at which he can safely stop based on the distance from the front vehicle. The Wiedermann model, developed since 1974, is more complex, taking into account the physical and psychological

behaviour of the drivers. The model is based on the driver's perception of the traffic patterns of other motor vehicles in the traffic and his/her response to changes in distance from the other vehicles [9].

5. Microsimulation of road traffic in the central area of Pitesti with the Vissim software

The purpose of the application is to identify the possibilities of solving the traffic problems in the central part of Pitesti municipality - from the improvement of the traffic light cycles of the intersections to the proposal to redirect certain traffic flows outside the area under analysis. Also, the application made with this program allows the visualization of 3D animations of road traffic at the level of the entire area under analysis - very useful in illustrating the traffic problems for the traffic controllers in the Pitesti municipality, as well as for the decision-makers.

The application consists of a microsimulation of road traffic in the central area (for which a 3-minute film with 3D animation was made), which includes:

- two major traffic-light intersections (the traffic-light intersection from Calea Bucureşti and the Maior Sontu traffic-light intersection) - intersections that have been transposed into the Vissim programme both in terms of intersection development and of traffic-light cycles;
- three roundabout intersections with 3 arms: Podul Viilor, the Rectorate and the Diagnostic Centre;
- the road arteries linking these main nodes of the road network in the central area.

With the Vissim programme, for which the University of Pitesti has an educational license, the stages for the microsimulation of the traffic in the central area of Pitesti municipality were conducted:

- loading the background image with the road map of the area under analysis over which the road arteries and road intersections were formalized;
- defining the parameters of each artery designed (number of lanes per direction of movement, length, width of the lanes, drivers' behaviour, markings between the lanes – continuous line, interrupted line, category of vehicles not allowed to circulate on the artery, etc.);
- making the connections between the lanes;
- formalization of pedestrian traffic (the pedestrian walkways and the pedestrian crossings are marked);
- specification of values for incoming hourly flows (both for vehicles and pedestrians) and composition of traffic (types of vehicles: trucks, buses, cars etc.);
- vehicle routing (percentage of vehicles travelling in different directions: to the right, forward, to the left);
- traffic management (settlement of conflict zones and setting of crossing priorities);
- Introduction of traffic lights in two intersections (definition of traffic lights and red/green times for both vehicles and pedestrians): Maior Sontu – Targu din Vale (figure 4) and I.C. Bratianu Bvd. - Calea Bucuresti;
- making screenshots (print screens) with intersections in 2D (two-dimensional) or 3D (three-dimensional) format to reveal traffic problems – figure 5.

With the application made, the Vissim microsimulation program was used for the central area of the municipality of Pitesti, and the validation of the pattern was made by comparing the results obtained in this virtual way with the results obtained through a real traffic measurement.

After introducing the measured traffic data into the application, the Vissim report has been generated with the values of the road traffic dimensions, including: the length of the waiting lines, the average vehicle delay, the average transit speed, the average number of stops per vehicle, the service level, the total number of vehicles crossing the intersection.
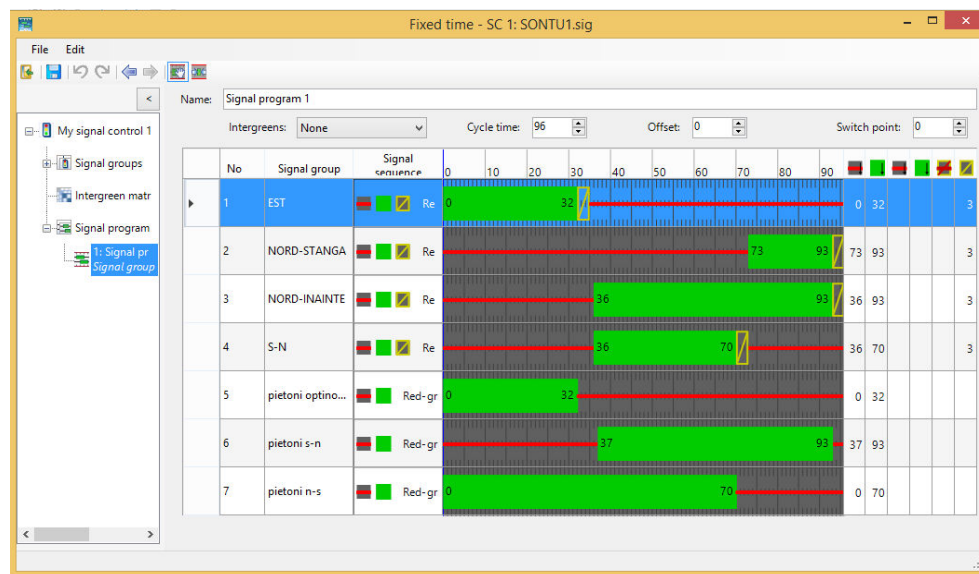
Figure 4. The traffic-light cycle for the Maior Sontu – Targul din Vale intersection.

Figure 5. Road congestion at Maior Sontu - Targul din Vale intersection, presented in a 3D image.

6. Results. Proposals for the reorganisation of road traffic

For the Maior Sontu - Targul din Vale traffic-light intersection, where the capacity is by far exceeded by traffic demand at peak hours (traffic) on the arm coming from the Rectorate (from the two lanes for the left turn), but not for the entire intersection, where it was found by recent observations that the overall demand is significantly lower than the capacity, there emerged the need for an alternative method of assessing the intersection capacity based on the flow-to-capacity ratio, taking into account the maximum traffic flow values for each set of lanes (traffic peaks). Thus, the observations made for all phases of the traffic light cycle from the intersection revealed that the congestion only appears on the flow coming from the Rectorate, while for the other traffic movements the traffic demand is below 80% of the capacity.

As a result, the only proposal that could be advanced in order to alleviate this situation was to increase the duration of the green time for the respective traffic movement by 10s (33%), to the detriment of the other phases of green time.

In what the second roundabout intersection creating the same problem is concerned, the I.C. Bratianu Bvd. - Calea Bucureşti intersection, things are similar, so in this case as well the only

possible proposal was to increase the duration of the green period for the deficient traffic movement - on the 1st lane from the North-South direction (in the direction ahead), to the detriment of the other phases of green time.

In conclusion, solving the traffic problems (only to a partial extent) in the two traffic-light intersections from the central area can be achieved by adapting the traffic light cycles to the structure of traffic flows during the peak periods: increasing the duration of the green for the traffic movement where the capacity proved to be insufficient and reducing the other green phases from the traffic movements where there is an excess capacity.

Concerning the roundabout intersections in the central area of Pitesti municipality, the following conclusions were obtained:

- for two intersections, the intersection from the Diagnostic Centre and the one from the Rectorate, it was demonstrated that, if the traffic problems at the traffic-light intersections in proximity are fully solved, the level of service of these intersections will be improved and, therefore, the traffic problems at these intersections will disappear;

- the only intersection in the roundabout which, for reasons of its own, does not have a sufficiently high service level is the Podul Viilor intersection, which has recently appeared as a component of the complex road development including the overpass road artery near the railway bridge.

The theoretical analyses on the capacity of roundabout intersections indicate that by reducing conflict volumes, the capacity on the intersection arms is increased. These observations lead to the conclusion that, for large intersections (with many lanes on the annular path) and with quasi-equal flows on arms, their capacity can be increased by transforming them into traffic-light roundabout intersections, when access times are reduced to the maximum because there are no longer conflict volumes, so it is no longer necessary to secure the entrance and give way to the platoons of vehicles that will enter the intersection during the green phase. But in the case of the Podul Viilor intersection, the traffic studies demonstrated that, in order to solve the problem revealed (the impossibility of the vehicles on the Nord arm to safely reach the annular path, given that the vehicles circulating on the left-hand annular path - which must be given priority of crossing - circulate at very fast speeds and without complying with the traffic rules in the roundabout intersection), it is necessary as a first solution to preselect the movement on each arm according to the direction to be followed at the intersection by visible longitudinal markings.

At present, this proposal (execution of longitudinal markings) has already been put into practice by the local administration of Pitesti municipality, but a problem that remains to be solved at the level of the central area of Pitesti municipality is the fact that during some working days the traffic demand exceeds the capacity of the road network. The studies have demonstrated that there is no other resource to increase the capacity of the central road network, so the only way to solve this traffic problem remains to redirect part of the road traffic so as to bypass the central area - as will be presented in the following chapters. Based on the research conducted, a perspective of great interest proved to be the identification of the possibilities by means of which, to an extent as large as possible, the road traffic coming from Calea Depozitelor or the bridge over Arges and going to the Maior Sontu -Targul din Vale traffic-light intersection should follow the route between the railway and the Arges River (rendered in black in figure 6), so as to reduce the impact load on the Podul Viilor roundabout intersection and circumvent the residential area of the Popa Sapca neighbourhood, with the purpose of reducing noise pollution. In this regard, the first proposal that ensued was directing the heavy traffic by means of „to the right only" roadside signalling, before the Podul Viilor intersection, for the

vehicles entering the city over the Arges Bridge, before entering the Rectorate intersection, for vehicles coming from Calea Craiovei through the Maior Sontu – Targul din Vale intersection.

A second concern is to identify, based on the traffic patterns and the formulas proposed for the analytical determination of the traffic flows in roundabout intersections, the possibilities to organize the traffic in the central area of Pitesti municipality so as to reduce the impact load on the Maior Sontu – Targul din Vale intersection, where traffic congestion is not yet eliminated.

While for the Podul Viilor roundabout intersection the expectations that the implementation of the already formulated proposals will lead to the elimination of the traffic congestion phenomenon have been fulfilled (due to the adequate horizontal signalling of the entire intersection - recently made by the Pitesti City Hall following the proposals formulated), the issue of road congestion at peak hours on the eastern arm of the Maior Sontu – Targul din Vale traffic-light intersection will require a much more complex solution in order to facilitate the choice of the better and the more sustainable (in the prospect of a more and more intense road traffic) of the two possible solutions: either another arrangement of this intersection, with the traffic being eventually organised in a roundabout movement, to sensibly increase its capacity, or a reorientation of a part of the traffic flows entering this intersection on one of the three paths represented in figure 6.
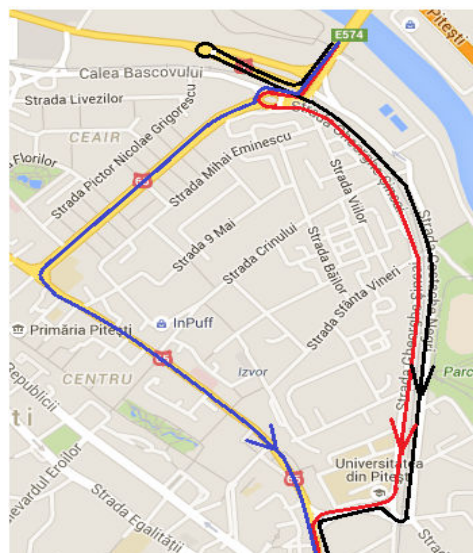

Figure 6. The 3 alternative routes for the Podul Viilor - Maior Sontu intersection route [13].

The measurements carried out in the research presented - given the limited capacity of this traffic-light intersection, even if there were an attempt to adapt the traffic light program at peak traffic on the eastern arm [3] or even to develop this intersection in a different manner, eventually with the traffic being organised in a roundabout movement-have revealed that the Maior Sontu-Targul din Vale traffic-light intersection will not be able to provide the necessary capacity during the peak periods of traffic.

As a result, the only viable solution that will completely eliminate the road congestion phenomenon at Maior Sontu – Targul din Vale intersection is creating the conditions for redirecting some of the traffic flows and this can be done by arranging a road passage over the railway from the Prundu neighbourhood (figure 7), so as to eliminate the current drawbacks („Railroad crossings in Pitesti represent a problem for drivers. Both the frequent moments in which the barrier is put, 19 times a day, of which the longest time is 17 minutes, and the poor state of the railroad crossings…" [11].

An important part of the road traffic - the one going towards the Prundu, Craiovei, Războieni neighbourhoods and the periurban area in the east and south of the city (up to DN 65) - will follow this route, thus alleviating the situation in the central area of Pitesti municipality.

Figure 7. Redirecting part of the road traffic by arranging the Prundu passage [13].

This proposal follows the first steps to be put into operation by the Pitesti City Hall: „The feasibility study for the construction of a road passage on Lânăriei Street in Prundu neighbourhood, over the railway, is also ready… The passage would start on Basarabiei Street, cross the intersection with Petrochimiştilor Boulevard and the railway from Lânăriei Street. Its total length will be 447.8 meters. The construction of the passage would eliminate the waiting times at the railway barrier on Lânăriei Street, which have caused road jams for years in a row" [12].

These solutions proposed for the reorganization of the road traffic will also be useful for predicting the noise pollution in the central area of Pitesti municipality.

7. References

[1]   Boroiu A 2003 *Road Traffic* (Pitesti: University of Pitesti Publishing House)
[2]   Boroiu A A and Neagu E 2015 *Traffic and Road Safety. Applications* (Pitesti: University of Pitesti Publishing House)
[3]   Boroiu A A 2017 *Studies and research on reducing phonic pollution of automotives by organization of road circulation* Ph. D. Thesis, University of Pitesti
[4]   Mitran G 2012 *Modeling of air pollution associated with road traffic flows in urban areas* PhD thesis, University of Pitesti
[5]   Neagu E 2003 *Traffic and Road Safety* (Pitesti: University of Pitesti Publishing House)
[6]   Roşca M A and Dinu O 2012 Aspects concerning the optimization of traffic lights in isolated intersections *AGIR Bulletin Supplement no. 1/2012*
[7]   Transportation Research Board (TRB) of National Academies of Science 2010 *Highway Capacity Manual* (Washington: National Academies of Science)
[8]   CNADNR 2010 Standard for the Development of Intersections at Public Roads *Road Technical Bulletin, no.4/2010, Designer Search Corporation*
[9]   PTV AG 2014 Vissim 7 - *User Manual* PTV (Planung Transport Verkehr) AG Karlsruhe (Berlin: epubli GmbH)

[10]   *https://en.wikipedia.org/wiki/Traffic_simulation*
[11]   *https://epitesti.ro/stiri/administrativ*
[12]   *http://www.primariapitesti.ro The Plan of Sustainable Urban Mobility of the Municipality of Pitesti* Project in public debates
[13]   *https://maps.google.com/*