

Solutions to Improve Road Circulation in the Pitesti City Based on Analysis-Diagnostics of Road Traffic

A Vilcan¹, E Neagu², H Badarau Suster² and A A Boroiau²

¹ AV Transport Planning srl, 9 Ionel Perlea Street, Apt 1, Sector 1, 010208, Bucharest, Romania

² Automotive and Transports Department, University of Pitesti, 1, Targul din Vale Street, 110040, Pitesti, Romania

E-mail: adrian@vilcan.com

Abstract. Road traffic congestion has become a daily phenomenon in the central area of Pitesti in the peak traffic periods. In order to achieve the mobility plan of Pitesti, an important stage is the diagnostic analysis of the road traffic. For this purpose, the urban road network was formalized through a graph containing the most important 40 intersections and traffic measurements were made at all these intersections and on the main roads connecting the peri-urban area. The data obtained by traffic macrosimulation confirmed the overloading of the street network during peak traffic hours and the analyzes made for various road traffic organization scenarios have shown that there are sustainable solutions for urban mobility only if the road network is fundamentally reconfigured (a belt outside the city and a median ring). Thus, the necessity of realizing the road passage in the Prundu neighbourhood and the finishing of the city belt by realizing the "detour West" of the city is argued. The importance of the work is that it brings scientific arguments for the realization of these road infrastructure projects, integrated in the urban mobility plan, which will base the development strategy of the Pitesti municipality.

1. Introduction

A comprehensive analysis of the traffic in the municipality of Pitesti is generated by the achievement of the *Plan of Sustainable Urban Mobility of the Municipality of Pitesti*, for which the transport model has been made and subjected to public debates [11]. The model is conceived for the base year 2017 and, depending on the scenarios applied, forecasts are made for 2023 and 2030.

The studies conducted have taken into account the existing road network, with the main arteries of entering the city (figure 1) and regulating the movement in the major road intersections (figure 2).

2. Developing the transport model for Pitesti city

A transport model allows the estimation of the way in which the movements of people and goods will respond, in time, to changes in what concerns:

- *the transport supply*: both services (introduction of new bus routes, increase or decrease in frequency, improvement of the services offered, changes in public transport prices) and the infrastructure (construction of a ring road, optimization of an intersection, construction of a new tram line, etc.);



- *the transport demand*: increase or decrease in population, change of its spatial distribution, change of the socio-economic (e.g. the degree of motorization) or demographic characteristics, growth or decline of economic activities, etc.

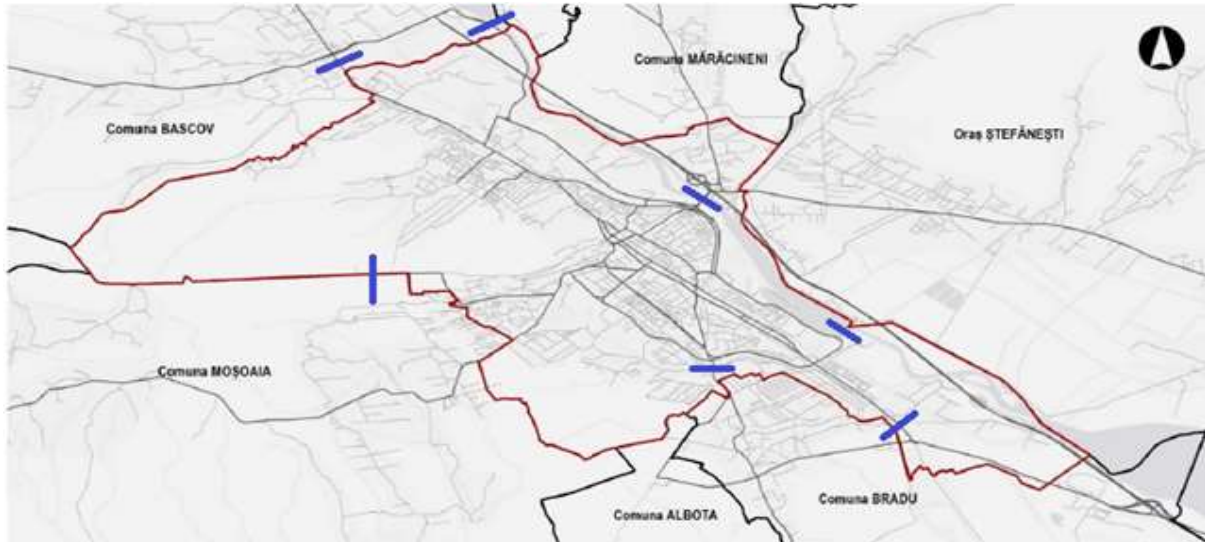


Figure 1. The road network in the municipality of Pitesti and the main arteries of entering the city.

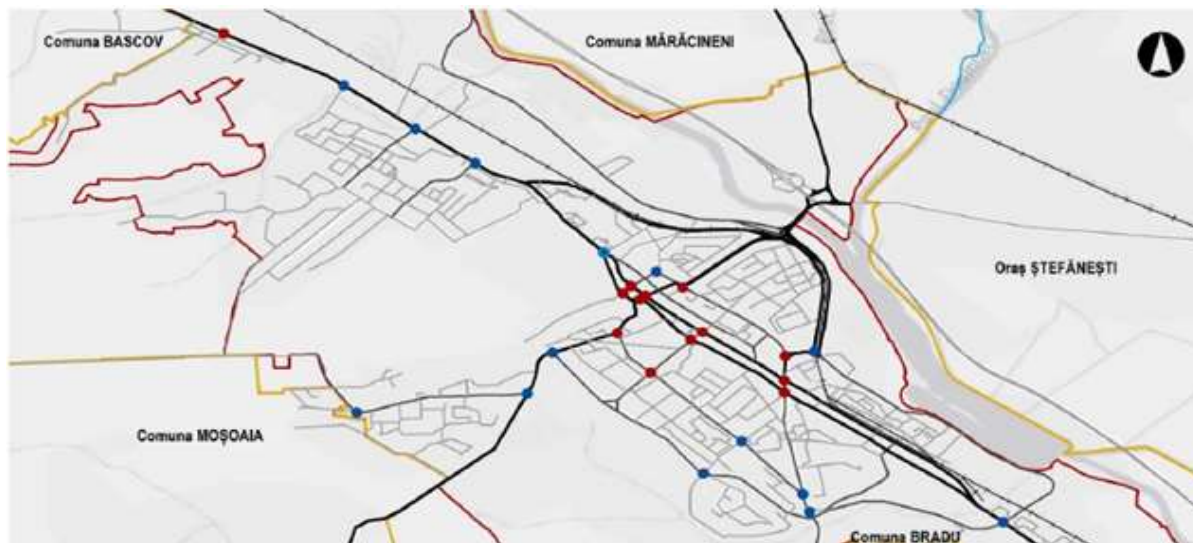


Figure 2. Roundabout intersections (blue) and traffic lights intersections (red) in the municipality of Pitesti.

An important component in the transport model approach is to select the most appropriate modelling software. PTV Vision software was chosen because it possesses the ability to satisfy all conditions studied, being widely used in Eastern Europe and featuring a wide range of applications in the region. In addition, PTV VISUM software has been used in recent years for most of the growth poles (Bucharest, Constanta, Brasov, etc.), so it is advantageous to perform the study with the same software [10].

2.1. Data collection

This first stage of creating the model was carried out for the following components:

2.1.1. Road network. An analysis of the network of roads and intersections in the city was performed with the purpose of defining the attributes of the road network from the transport model. These are the number of traffic lanes in each direction, the speed limit or the average speed, one-way or two-way road/street, lanes dedicated to public transport or priority lanes, parkings on the road, road signs, road markings, types of intersections and times of configuration/channelling/signalling.

2.1.2. The public transport system in the municipality of Pitesti. The transport network of the municipality of Pitesti has developed mostly in a linear direction following the North-South direction, as a consequence of the geographical location of the city (terraced parallel to the central axis), which did not allow the radial development of transport lines [1]. The bus network length is 41.07 kilometres, double track, and the length of the other tracks is 168.03 km, there being 100 bus stations; the 8 linebreaks are: Arpechim, Doja, Razboieni, Gara Sud, Trivale, Gavana, Alprom, Bascov (Peco Mol) [2].

2.1.3. Home interviews on population mobility. Interviews at home on population mobility have been carried out in accordance with the standard procedures normally used in transport studies. Family structure was identified, from the head of the family and continuing with all the members of the family. The gender, age, regardless of the subjects' attending some form of education or being employed, were recorded for each household member, as well as their holding a driving license, together with the total number and type of vehicles the respective household has at its disposal. This was followed by a record of the movements, performed separately for each member of the household; normally, the travels that had been made the previous day. To carry out a representative survey, there was established a percentage of 1.5% relative to the population of Pitesti, i.e. 2700 valid forms [7]. This component of the study describes the current situation of movement in Pitesti and represents the basis for modelling transport demand in the forecast component. This resulted in a series of useful data for traffic modelling, grouped as follows:

a) Socio-economic data:

- household size: about 75% of households are made up of between 2 and 4 persons, the average household size is 2.48 members;
- *economically active members*: about 22.0% of households have no economically active members, these households, most often, being households consisting solely of pensioners, on average, households have 1.50 economically active people;
- availability of vehicles: 39% of households do not have access to a private vehicle, 53% of households have access to a single private vehicle, the average of vehicle availability per household is 0.69 vehicles/household or 276 cars per 1000 people;
- access to public transport: access to public transport is good, with an average travel time on foot to the nearest public transport station of 7.35 minutes, 25% of households can access public transport in less than five minutes, 60% of households can access public transport into 5 - 10 minutes;
- average household income: 33% of households have an average monthly household income under 368 EUR, 41% of households have an average monthly household income between 368 and 690 EUR.

b) Personal information. For each household member there were obtained data on personal characteristics (age and sex, driving license, employment status situation, industrial category, workplace or education institution).

c) Information on movements. Travel data provides a wealth of data on the behaviour and habits of traveling for residents of Pitesti.

The following information is presented as information about a classical modelling of the transport process in four steps:

- generating movements: data on the number of movements (there was estimated a daily average of 1.35 trips per capita) and movement time (for the first movement, there is a distinct peak in the morning between 07:30 and 8:30);
- attracting movements;

- area distribution;
- modes of transport distribution: the main modes of transport are walking (29%), by private car (35%) and by bus (23%) - this equates to 88% of all journeys.

2.1.4. Traffic censuses in intersections. Traffic censuses were performed in 40 intersections (figure 3). These were conducted 10 hours a day, in the following time intervals: 6:00 to 11:00 and 2:00 p.m. to 7:00 p.m.

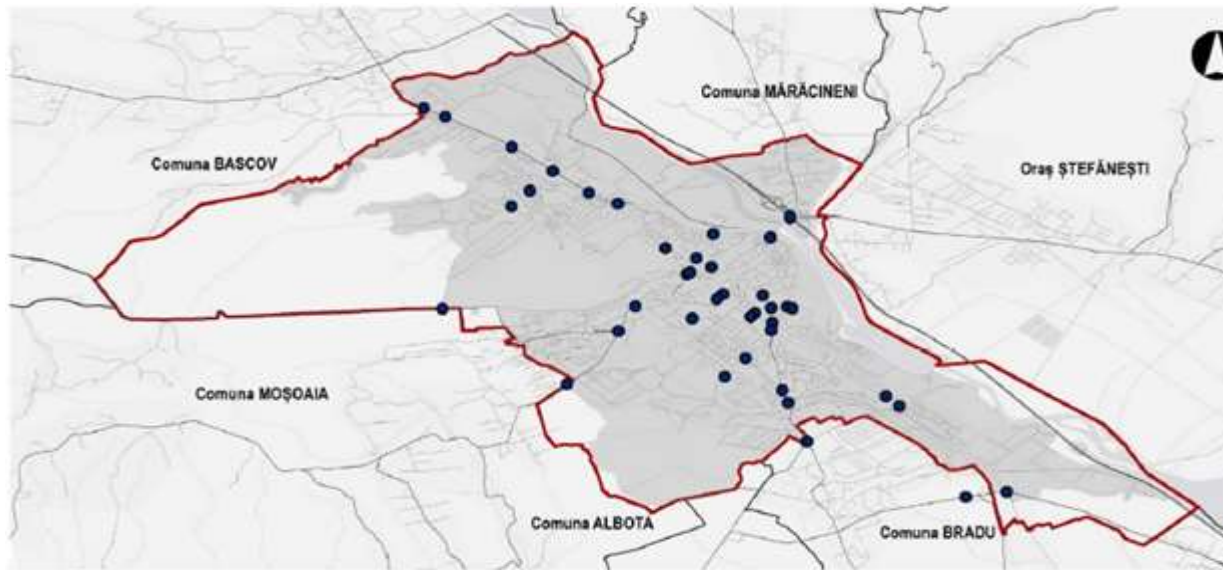


Figure 3. The 40 intersections in the municipality of Pitesti where traffic censuses were conducted.

The aggregated results for the 40 intersections reveal high levels of traffic flows measured in intervals of 15 minutes and two traffic peaks: a morning traffic peak (figure 4), between 07.30-08.30 a.m., and a second traffic peak in the afternoon, between 4.00 p.m. - 5.00 p.m. The figures below show the total traffic flows at the intersections that were the subject of the censuses.

2.1.5. Traffic censuses in section. The sections for which traffic censuses were conducted 24 hours a day are actually the most important intersections in the municipality of Pitesti, where cameras are located and the recorded images could be processed (DN65B - Bd. Petrochimistilor, Calea Craiovei - Basarabiei Str. - Vasile Parvan Str., Calea Dragasani - Bd. Libertatii, Bd. Nicolae Balcescu - Labusesti Str., Bd. Republicii - Bd. Eroilor, Armand Calinescu Str. - Bd. Eroilor - Egalitatii Str., Calea Bucuresti - Costache Negri Str. - Depozitelor Str.) [6]. The aggregated results for the seven sections where the traffic census was conducted show high levels of traffic flows measured in intervals of 15 minutes, and two traffic peaks (figure 5), just as in the case of the 40 intersections where traffic censuses were conducted manually by traffic observers.

2.1.6. Origin-Destination surveys in traffic. O-D surveys in traffic were conducted in seven locations outside the administrative boundaries of the city [7]. The reviewing and the interviews for the origin-destination surveys from the locations mentioned above were conducted between 06:00 a.m. - 9:00 p.m., i.e. for a period of about 15 hours. In this period there were counted about 50000 cars traveling to/from Pitesti. The main vehicle category was represented by the car, which counted for about 75% of all vehicles reviewed.

2.1.7. Reviewing public passenger transport. Studies of public transport were made to collect data on public buses in Pitesti during peak hours. There emerged certain characteristics of public transport

such as information on the loading degree and the working hours of the buses. Reviewing transport lines was performed between 7:00 to 10:00 a.m. and 1:00 p.m. to 5:30 p.m. on a normal working day. After analyzing the data obtained the usage degree of public transport stations was determined, being noted that the largest number of passengers is concentrated in the centre, on the Bd. Republicii and Armand Calinescu Str. arteries, both in the morning and in the afternoon.

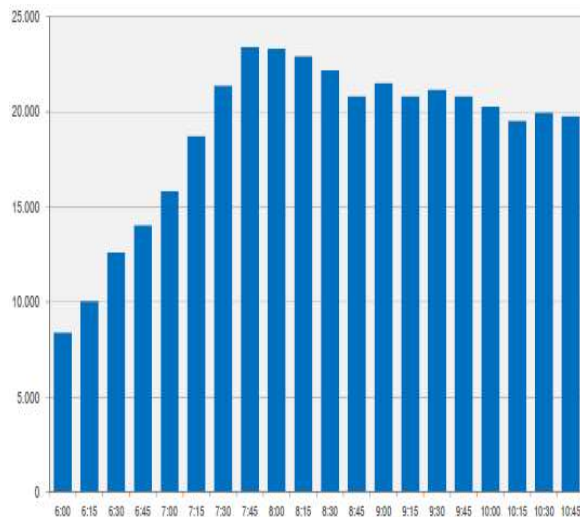


Figure 4. Traffic flows over intervals of 15 minutes, in the time interval of 06.00-11.00 a.m., cumulated for the 40 intersections.

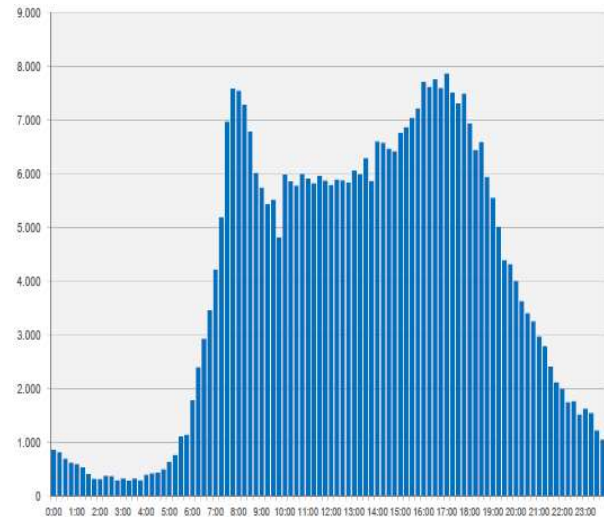


Figure 5. Traffic flows in intervals of 15 minutes, cumulative for the 7 sections monitored.

2.2. Evaluation of the transport demand

2.2.1. Definition of the zoning system. The zoning system needs to be defined so that the main daily models of inter-urban migration could be properly captured and modelled. This is especially important as cities begin to expand and the so-called satellite cities are developing towards their periphery.

The area specific to the transport model is an important element in the representation of demand for mobility, as movements are generated and attracted by the specific functions of each area. Thus, the zoning system is an integrated planning element, building at the same time an intrinsic link between urban features and mobility [4].

A condition for a transport model to be as close to reality as possible is to consider a large number of areas and the areas to be taken into account must be linked to the socio-economic data available and the purposes for which the model is developed.

The starting point in the zoning of the transport model was the delimitation of polling stations in view of organizing and conducting the 2016 elections, being later detailed in relation to their functional, socio-economic and demographic characteristics. The study area consists of 168 areas, of which 144 areas cover the municipality of Pitesti and 24 areas cover the territory of influence (figure 6).

The socio-economic data related to each area consist of the information regarding population (categories of age, occupation, income level, possession of a car or lack of possession of a car), the number of jobs by type of activity, places in education (educational establishments, number of places for students and pupils at the related educational establishments), income level and availability of using a car, economic activities (industry, services, trade, tourism, agriculture).

In the case of the large commercial or industrial centres, specific areas were considered within the transport model because of their specificity that leads to attracting significant flows of people and goods.

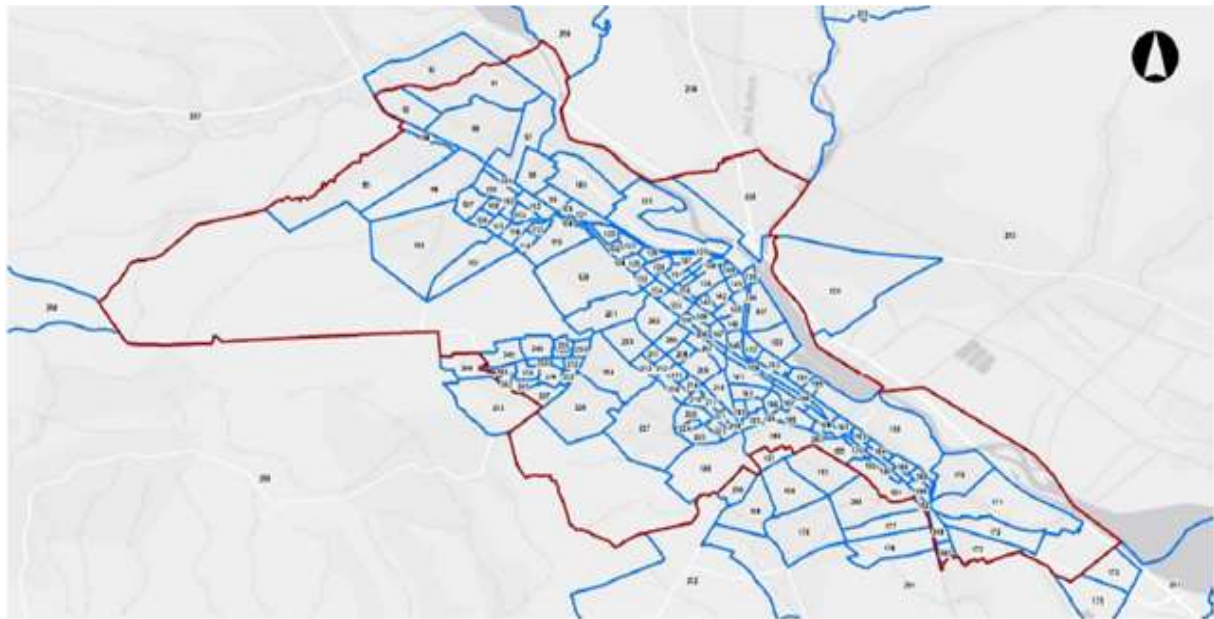


Figure 6. Zoning of the territory under study.

2.2.2. The a priori development of origin-destination matrices. The evaluation of the demand for passenger and freight transportation based on the data previously collected for morning peak hours (a.m.), afternoon peak hours (p.m.) and the daily annual average is an essential activity, the demand for passenger and freight transportation at the OD matrix level for the study area - a priori OD matrix, estimated directly based on home interviews, on the segments of mobility demand considered, is a major input for the calibration of the transport model. The informations taken into account for the development of the a priori matrices were information from home interviews and database of the 2012 General Transport Master Plan. The a priori OD matrices (observed) have been structured as a priori matrices for people movements and a priori O-D matrices for freight transport. The OD matrices for the base year 2017 were estimated based on a priori OD matrices, aggregated and converted into standard vehicles and based on the traffic census, the traffic flows being observed in equivalent standard vehicles and in vehicles related to public transport. There were taken into account techniques to estimate the matrices implemented in Visum. The information on the traffic flows observed was based on the traffic censuses carried out in the project, plus the automatic traffic counting conducted by CNAIR and the traffic censuses for national roads available for the project.

2.3. Data calibration and validation

2.3.1. Calibration of the urban transport model. Calibration is the iterative process whereby the model is revised repeatedly until it becomes stable and ensures the most faithful reproduction of the conditions of the reference year. The process involves refining (or finishing) in stages the network from the model in order to better display the existing conditions, such as the speed-flow relationships, the drive/steering constraints, the class in the network connection, the connectors, the traffic capacity, etc. After completion of the network model, the traffic volumes allocated are compared with the volumes observed or with the censuses conducted. The volumes of the application from the model are calibrated so that the flows modelled could be as close as possible to those reviewed either by manual manipulation of the matrix or automatically, by estimation of the matrix. The urban transport model calibration consists of calibrating the models specific to each of the stages in the process of modelling mobility [8].

An effective calibration of models is performed by estimating the parameters of the above equations for each individual model. The results of calibration within each model of generation and attraction of movements on travel purposes are evaluated by the statistical parameters of linear regression considered in the calibration process models. Thus, it is recommended that the standard deviation should be not less than 85% in most cases. The models of generating and attracting movements are important elements because they represent the link between the characteristics of the population and the functional characteristics of each area and the number of movements generated and attracted by it, being thus used for the forecast of movements generated and attracted by each area according to the new socio-economic and functional characteristics of the respective area. For the models of attracting and generating movements the following types of equations were considered:

$$G_i = a_i + b_i \cdot X_1 + c_i \cdot X_2 + d_i \cdot X_3 \quad (1)$$

$$A_j = a_j + b_j \cdot X_1 + c_j \cdot X_2 + d_j \cdot X_3 \quad (2)$$

where:

G_i – movements generated by the area „i”;

A_j - movements generated by the area „j”;

X_1, X_2, X_3 - socio-economic indicators for each area (population, active population, number of pupils, students, etc.);

$a, b, c, \dots$ - parameters to be calibrated.

Within the models of generation and attraction of movements there are two categories of users: those who have access to a car and those who do not. So, finally, there were calibrated 69 models for generating traffic, 8 different models of distribution, 8 different models for slow movements, 8 different models for the Modal Split and for the level of motorization.

Models of distribution between areas carries out the distribution of movements generated and attracted by each area, between each pair of O-D areas, on purposes of travel, at peak morning (a.m.) and afternoon (p.m.) hours. The models for each peak hour represent distinct models. The gravitational model was considered when modelling the distribution of movements [5]. The gravitational model is based on the theory of gravity in Newtonian physics and requires that the number of movements between areas be directly related to the number of movements generated by each area and inversely related to the difficulty of making the movement. Mathematically, the gravitational model is defined as follows:

$$T_{ij} = G_i \cdot \frac{A_j \cdot F_{ij} \cdot K_{ij}}{\sum_{k=1}^n A_j \cdot F_{ij} \cdot K_{ij}} \quad (3)$$

where:

T_{ij} – number of movements from Area i to j.

G_i - number of movements generated from Area i.

A_j - number of movements attracted by Area j.

F_{ij} - impedance factors related to the separation between Areas i and j.

K_{ij} – the adjustment factor of distribution of optional movements for interchanges between Areas i and j.

n = number of areas ($n = 136$).

The correct development and calibration of the model of modal distribution provides the functionality of the model, giving information on the use of transport modes depending on the services offered by each mode. The model is based on the relative attractiveness of each mode to the other. In addition, this facilitates testing the operational and/or infrastructure improvements to each mode and allows the quantifying of their impact on traffic generated and specific to a mode. The complexity of the model increases as choices grow and travel parameters change. The main objective is to assess the impact of improving public transport systems (accessibility, rates, new modes, etc.).

Home interviews make available information on the choice of transport mode depending on the fact of owning a car or not. With an increase of the income and of the availability of the car, its use

becomes more affordable to the members of the household, which leads to the performing of a larger number of movements by car. The choice of the transport modes considers the categories like slow modes, the choice of transport mode for those who do not have a car available, the choice of transport mode for those who have a car available. Most models based on choosing the model are based on formulation of the Logit model. Mathematically, the Logit model is defined by the formula [3]:

$$T_{ij,m} = T_{ij} \cdot \frac{e^{c \cdot U_{ij,m}}}{\sum_{k=1}^n e^{c \cdot U_{ij,k}}} = T_{ij} \cdot P_{ij,m} \quad (4)$$

where:

T_{ij} - Number of movements between the Areas i and j ;

$T_{ij,m}$ - the number of movements made by mode of transport m ;

c - the parameter of the procedure;

$U_{ij,m}$ - the generalized cost of the travel from i to j by mode m ;

$P_{ij,m}$ - the proportion of movements made by mode of transport m .

This approach calculates the share of demand among different modes of transport competing for travel, based on a number of inputs that influence the overall cost of the travel (generalized cost of the travel). A first step is that in which a distinction is made between the slow modes (walking and cycling) and the motorized ones. To do this, the following type of model was used:

$$P_{ij,w} = \frac{1}{1 + e^{a+b \cdot D_{ij}}} \quad (5)$$

where:

$P_{ij,w}$ - the share of movements performed by slow modes (walking and cycling), denoted by w from walk (go by foot);

$D_{ij,w}$ - distance between the Areas i and j

a, b - the parameters to be calibrated.

The model was calibrated using information from the interviews at home. In the second step the modal distribution model is calibrated. This module models the distribution between motorized modes of transport, between car and public transport. The model makes the difference between users who have a car and those who do not.

Allocation on the network constitutes the final stage of the 4-stage determination of the transport demand and the associated traffic flows on the street network and those taken over by public transport of passengers. Traffic allocation is the process after which the amount of traffic on each segment of the transport network and on turns in intersections is determined. Any version of traffic allocation on network based on the principle of balance uses such functions as volume - delay both for the links and for the turns, thus impedance changes depending on the traffic. Within a model of urban transport, the volume-delay functions related to turns are very important because intersections affect the transport network performance more than links. For the purposes of allocation on the road transport network the Allocation on the Network with an Intersection Capacity Analysis (ICA) was employed, which takes into account the impedance of the intersections in a detailed manner. This procedure of allocation on the network includes allocating lanes and traffic light times. Furthermore, the interdependence of directions allowed in each traffic hub within the network was also considered.

2.3.2. Validation of the model of transport demand. The validation of the model of transport demand represents the stage of analyzing the results for each stage of the model with the data observed, in order to determine the degree of representation of reality. The validation of the model of transport demand is the stage that follows after the calibration of the model and consists mainly of comparing the outputs of the model with an independent set of data not used in the process of development of the model, in order to make sure that the model reflects the travels volumes and velocities observed across the entire area of the model, not just in the locations used for the development of the movement matrices. A suitable model for the goal pursued meets the standards required for both calibration and

for validation. According to [9], for a model of transport to be considered valid four criteria should be met, by comparing the demand allocated, in more than 85% of cases in order to be considered accepted. The demand for private vehicles, passengers or freight should have a margin of 15% compared to the values observed. The flows on the windrows should have a margin of 5 % compared to the values observed. The GEH5 value (for individual flows $GEH < 5$, for total values for the windrow $GEH < 4$). The last criteria take into consideration was comparing travel times (times within a margin of error of 15% or of more than one minute).

Calibration of the transport model was satisfactory at this stage, the next step being to continue to examine in detail the transport network until the testing of scenarios. If certain aspects within the transport model are to be adjusted, this is done until the testing of scenarios.

2.4. Model results

The main results of the model are matrix on mode of transport and main OD relations, traffic flows on the network, network performance statistics. The figures below shows the flows for private and public transport traffic for the base year 2017 at peak a.m. hours (figure 7 and figure 8).

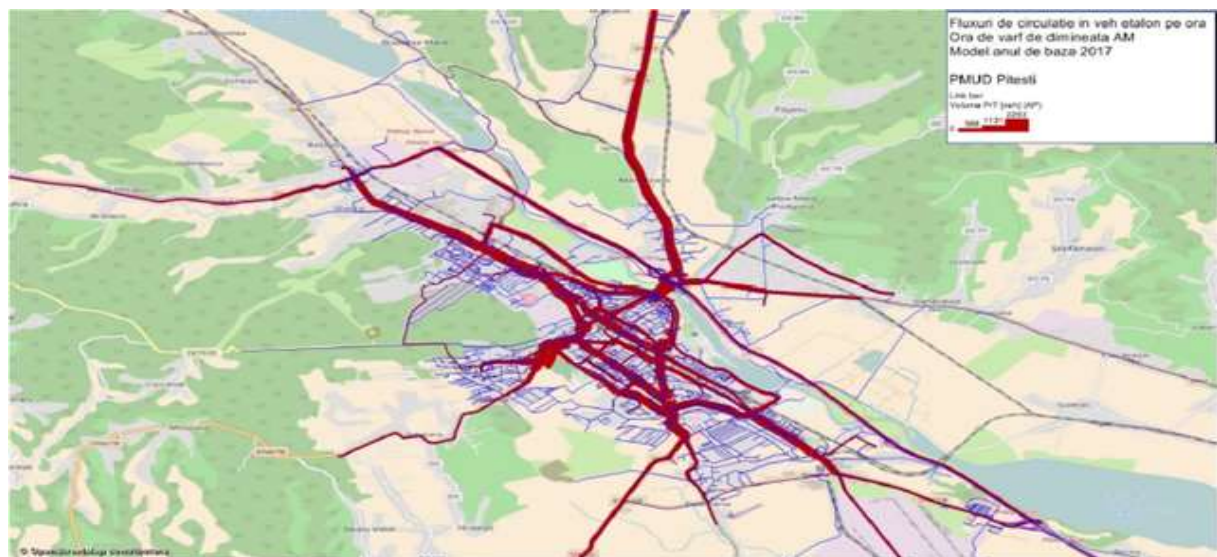


Figure 7. Hourly flows of road vehicles, in equivalent vehicles, for the morning peak.



Figure 8. Hourly flows of passengers (public transport traffic) for the morning peak.

3. Conclusions. Forecasts. Suggested remedies

The increase or decrease of the population, of the level of motorization, of incomes, of tourism, of the residential development and of the GDP are the key factors that directly influence the increase/decrease of the number of persons' movements within the municipality of Pitesti, locally and regionally, and these aspects were taken into account in the travel demand forecasts for the 2023 and 2030 timeframes.

After the base year model is validated, a synthetic base model is also developed for forecasting purposes. The synthetic model for the base year is calibrated based on the relations between transport supply, demand and socio-economic parameters. This allows the socio-economic factors to be incorporated in the forecast, such as population, income and the increase of the number of car owners.

Two scenarios were evaluated to test the sensitivity of the model:

- scenario 1: A 10% increase in the cost of fuel for cars;
- scenario 2: A 10% increase in the cost of public transport tickets.

The data obtained by traffic macrosimulation confirmed the overloading of the street network during peak traffic hours and the analyses made by the macrosimulation of road traffic for various road traffic organization scenarios have shown that there are sustainable solutions for urban mobility only if the road network is fundamentally reconfigured. So, there are sustainable solutions only if the street network is bounded by a belt outside the city, which will ensure that there are no transit traffic and a median ring that will allow travel between different districts in the city to be made without penetration in the central area. Thus, the necessity of realizing the road passage in the Prundu neighbourhood and the finishing of the city belt by realizing the „detour West” of the city is argued.

The importance of the work is that it brings scientific arguments for the realization of these road infrastructure projects, integrated in the urban mobility plan, which will base the development strategy of the Pitesti municipality.

4. References

- [1] Boroïu A 2009 *Transporturi de persoane* (Pitesti: University of Pitesti Publishing House)
- [2] Boroïu A, Nicolae V, Ilie S, Zaharia C and Soare C 2008 *Proiectarea strategiei de transport public de persoane in judetul Arges pentru perioada 2008-2013 si proiectarea programului de transport public de persoane in judetul Arges pentru perioada 2008-2011* Contract no 541/07.02.2008 Beneficiary Arges County Council.
- [3] Boroïu A A and Neagu E 2015 *Trafic rutier si siguranta circulatiei rutiere. Aplicatii* (Pitesti: University of Pitesti Publishing House)
- [4] Boroïu A A 2017 *Studii si cercetari privind reducerea poluarii fonice produse de autovehicule prin organizarea circulatiei rutiere*, PhD thesis, University of Pitesti
- [5] Florea D, Cofaru C and Soica A 2000 – *Managementul traficului rutier* (Brasov: University Transilvania of Brasov Publishing House)
- [6] Neagu E 2003 *Trafic rutier și siguranta circulatiei* (Pitesti: University of Pitesti Publishing House)
- [7] Nicolae V, Neagu E, Istrate M, Boroïu A, Vieru I, Badarau Suster H and Boroïu A A 2016 *Planul de Mobilitate Urbana Durabila al municipiului Pitesti. Culegerea și prelucrarea datelor de mobilitate*, Subcontracting agreement no. 10581/22.08.2016, Beneficiary S.C. SYNERGESTICS CORPORATION SRL Bucharest
- [8] Raicu S 2007 *Sisteme de transport* (Bucharest: AGIR Publishing House)
- [9] JASPERS (Joint Assistance to Support Projects in European Region) 2014 JASPERS Appraisal Guidance (Transport) *The Use of Transport Models in Transport Planning and Project Appraisal*
- [10] PTV Vision Software 2011 *VISUM User Manual* PTV AG Karlsruhe (Berlin: epubli GmbH)
- [11] <http://www.primariapitesti.ro> *The Plan of Sustainable Urban Mobility of the Municipality of Pitesti*, Project in public debates