Computing Programs for Determining Traffic Flows from Roundabouts

A A Boroiu[1], I Tabacu[1], A Ene[2], E Neagu[1] and A Boroiu[1]

[1] Automotive and Transports Department, University of Pitesti, 1, Targul din Vale Street, 110040, Pitesti, Romania
[2] Electronics, Computers and Electrical Engineering Department, University of Pitesti, 1, Targul din Vale Street, 110040, Pitesti, Romania

E-mail: boroiu_alexandru@yahoo.com

Abstract. For modelling road traffic at the level of a road network it is necessary to specify the flows of all traffic currents at each intersection. These data can be obtained by direct measurements at the traffic light intersections, but in the case of a roundabout this is not possible directly and the literature as well as the traffic modelling software doesn't offer ways to solve this issue. Two sets of formulas are proposed by which all traffic flows from the roundabouts with 3 or 4 arms are calculated based on the streams that can be measured. The objective of this paper is to develop computational programs to operate with these formulas. For each of the two sets of analytical relations, a computational program was developed in the Java operating language. The obtained results fully confirm the applicability of the calculation programs. The final stage for capitalizing these programs will be to make them web pages in HTML format, so that they can be accessed and used on the Internet. The achievements presented in this paper are an important step to provide a necessary tool for traffic modelling because these computational programs can be easily integrated into specialized software.

1. Objectives of the paper

In recent years, a phenomenon of roundabout proliferation has been remarked, being noted that this type of intersection brings forward a number of advantages, especially to the specifics of urban traffic. As a result, there is constant concern to improve the service level of these intersections [3,7-8].

The methodology for determining the level of service for the roundabout intersections is shown in [11], a reference work that was recently reviewed (2015). The main mathematical models that evaluate the capacity of each arm of the intersection are based on the volume of the conflict flow [6,9-10]. Thus, *the capacity of a roundabout intersection with a lane on the annular path* is determined with the relation:

$$c_a = \frac{3600}{\cdot t_f} \cdot \frac{V_c \cdot e^{\frac{-V_c \cdot t_c}{3600}}}{1 - e^{\frac{-V_c \cdot t_f}{3600}}} \tag{1}$$

where:
- c_a is the capacity of the arm (standard veh./hour);
- V_c is the conflict volume related to the arm (standard veh./hour);
- t_c is the critical access time from the arm to the intersection [sec];
- t_f is the time of tracking on the annular path [sec].

The conflict volume can be simply registered by a traffic operator (one operator for each arm of the intersection), but the methodology provides for a calculation algorithm by which this is established function of the current volumes of traffic at the intersection, as is the case, for example, of the conflict volume for arm b of a 4-arm roundabout intersection, presented below: adopting a trigonometrically increasing notation (b, b+1, b+2, b+3), this is given by the following analytical relation [1]:

$$V_c^b = V_{return}^{b+1} + (V_{left}^{b+2} + V_{return}^{b+2}) + (V_{forward}^{b+3} + V_{left}^{b+3} + V_{return}^{b+3}) \qquad (2)$$

Accordingly, in the software programs dedicated to traffic modelling, the determination of the levels of service for roundabout intersections is based on analytical models in which the first step is the introduction, as input data, of the output of each traffic stream in the intersection or the introduction of entry outputs and mentioning the proportions which the traffic streams are divided into [4]. It is to be noted that in both cases there is no requirement for the measurement of flows of conflict and their introduction as input data, but rather for specifying the size of the traffic streams. But determining these traffic streams can only be achieved by following the route of each vehicle, and this would require recording the entire crossroad and then identifying the route of each individual vehicle – a method that involves a large amount of time dedicated to the further processing of the recordings.

As a consequence, the following question arises: *is it possible that, for an intersection where the traffic is regulated as a roundabout on the basis of the measured values (with fixed observers) for the flows of entry, flows of exit and flows of conflict (circular), one could determine the volume of traffic streams (figure 1)? Exact values would emerge from this analytical method.* To find the answer to this question, road circulation in the roundabout was formalized by noting the volume of traffic flows (number of standard vehicles in a particular timeframe) as similar as possible to the notations in specialised literature (written in Romanian or in a foreign language), as follows[11].:
• ingoing flows volume: $V_{i,m}$;
• outgoing flows volume: $V_{e,n}$;
• conflict (circular) flows volume: $V_{c,m}$

The index m represents the sequential number of the ingoing arm (origin), m = 1, 2, 3, 4, ..., and n is the sequential number of the outgoing arm (destination), n = 1 2, 3, 4 ....
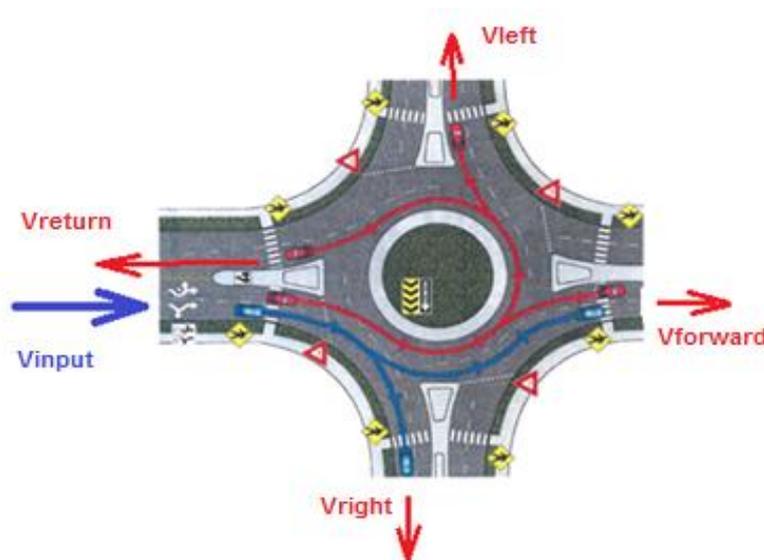
Figure 1. Traffic streams corresponding to an arm of the roundabout intersection [1].

The first three categories of flows are the flows that will be measured, so they represent the given data for the previously stated problem, and the last category of flows represents the values to be determined, therefore they constitute the unknown data of the problem. As a result, this issue will be analysed to discover if it can be solved, starting with the simplest roundabout intersection: the 3-arm roundabout. By cumulating the results derived from the theoretical research undertaken [1], carried out to discover whether it is possible to analytically determine traffic streams in roundabout intersections based on traffic measurements performed with fixed observers, the following results were obtained:

• In the case of the ***3-arm intersection***, one can formulate the analytical equations for the flows of return and flows of left turn as follows [2]:

$$V_{return} = V_{conflict}^{left\ arm} - (V_{entry}^{right\ arm.} - V_{right}^{right\ arm}) \tag{3}$$

$$V_{left} = V_{entry} - (V_{left} + V_{return}) \tag{4}$$

where:
- V_{entry}, $V_{right.}$, $V_{left.}$, V_{return} are the volumes of the flows related to the arm for which the calculation is performed (arm under analysis) – figure 2;
- $V_{conflict}^{left\ arm}$ is the conflict volume for the arm to the left of the arm under study;
- $V_{entry}^{right\ arm}$ is the entry volume for the arm to the right of the arm under study;
- $V_{right}^{right\ arm}$ is the volume of right-turn for the arm to the right of the arm under study.
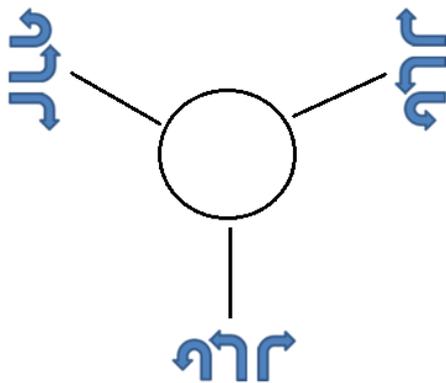
Figure 2. Traffic streams in a 3-arm roundabout intersection with return flows [1].
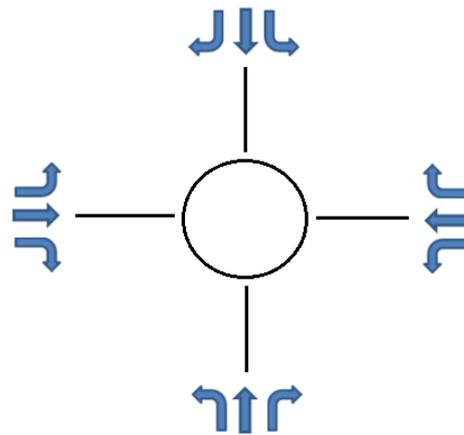
Figure 3. Traffic streams in a 4-arm roundabout intersection without return flows [1].

• In the case of the ***4-arm intersection***, it is possible to determine traffic streams only for the scenario „without return flows", the analytical relations for the flows forward and the left turn flows being [2]:

$$V_{left} = V_{conflict}^{forward\ arm} - (V_{entry}^{right\ arm} - V_{right}^{right\ arm}) \tag{5}$$

$$V_{forward} = V_{entry} - (V_{right} + V_{left}) \tag{6}$$

where:
• $V_{incoming}$, $V_{right.}$, $V_{left.}$, $V_{forward}$ are the volumes of the flows related to the arm for which the calculation is performed (arm under analysis) – figure 3;

- $V_{conflict}^{forward\ arm}$ is the conflict volume for the arm in front of the arm under analysis;
- $V_{entry}^{right\ arm}$ is the incoming volume for the arm to the left of the arm under analysis;
- $V_{right}^{right\ arm}$ is the right-turn volume for the arm to the right of the arm under analysis.

But a full capitalization of the analytical method discovered involves designing software programs in one of the dedicated programming languages, so the proposed analytical method could be used with ease – these representing ***the objectives of this paper***.

2. Development of computation programs for the analytical determination of traffic volumes at roundabout intersections

For each of the two cases that proved to be solvable by using data measured by fixed observers, a computation program was developed based on each set of analytical relations, a program that enables one to achieve, after introducing the data measured (volumes of entry, volumes of conflict and volumes of right turn), the values for the unknown flows on the annular path.

Thus, *two computation programs were developed in the Java programming language* (figure 4 and figure 5), with very user-friendly interfaces.

To meet any need, the programs also work when only partial results are necessary (a situation when only the necessary flows are to be measured).

If an analysis is required for all arms of the intersection, full measurement will be carried out.
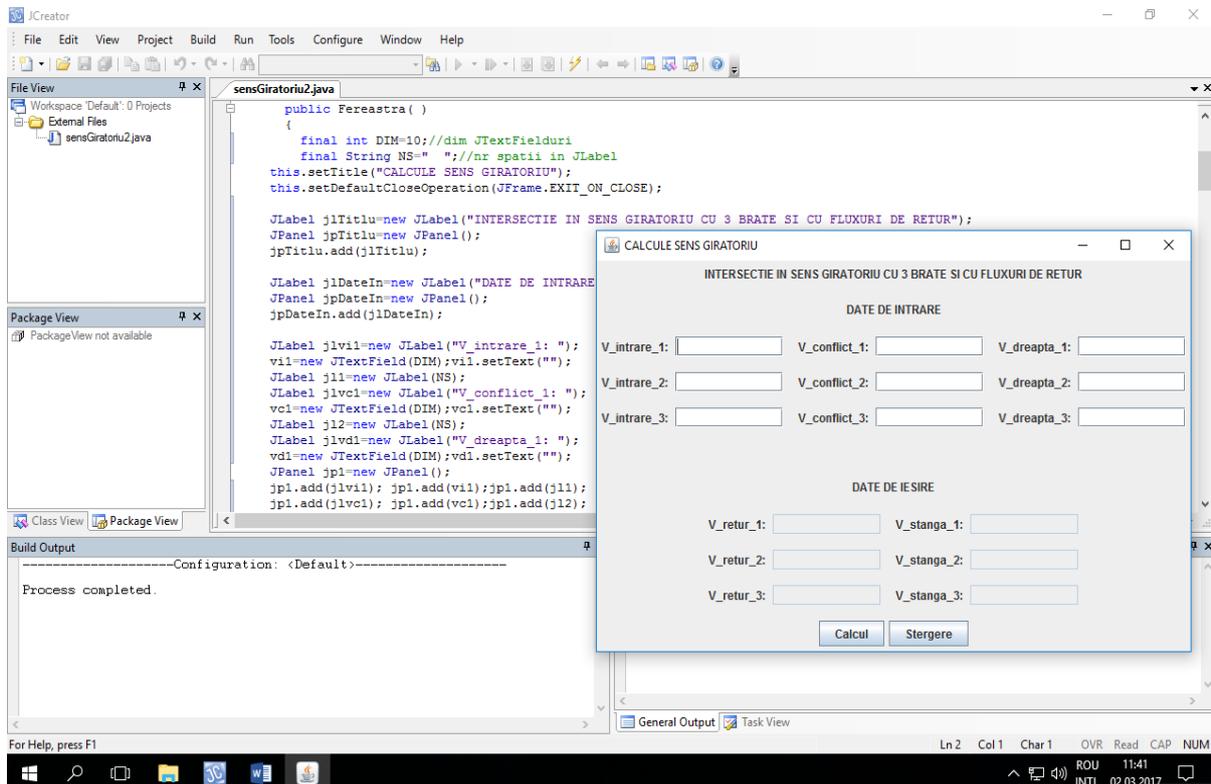
Figure 4. Developing the Java program for 3-arm roundabout intersections with return flows.
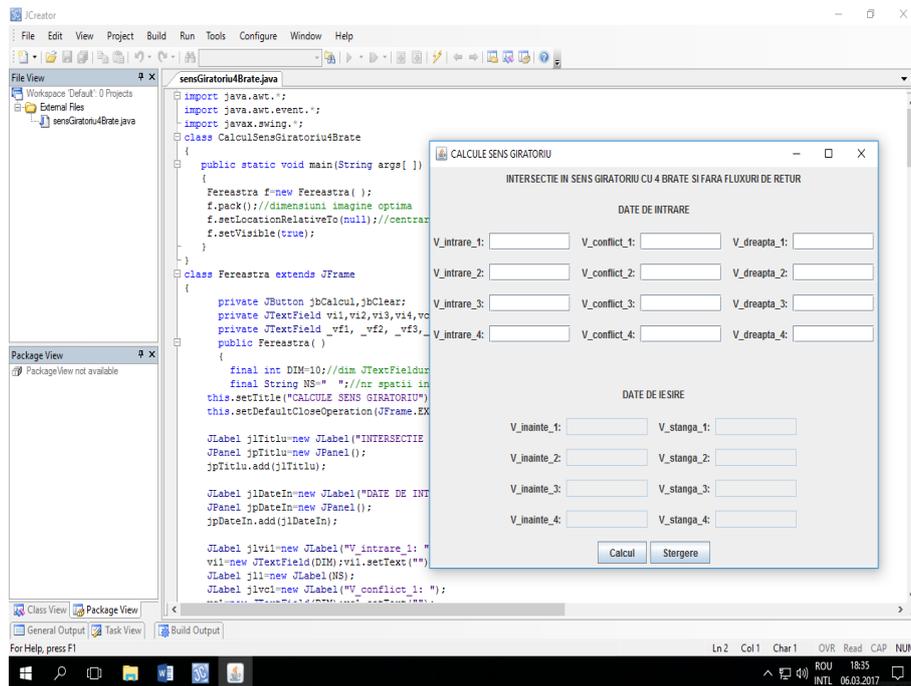
Figure 5. Developing the Java program for 4-arm roundabout intersections without return flows.

3. Results obtained by using the computation programs developed

With the help of the program developed for the 3-arm intersection, the data measured with fixed observers at the Podul Viilor roundabout intersection of Pitesti were processed - figure 6.
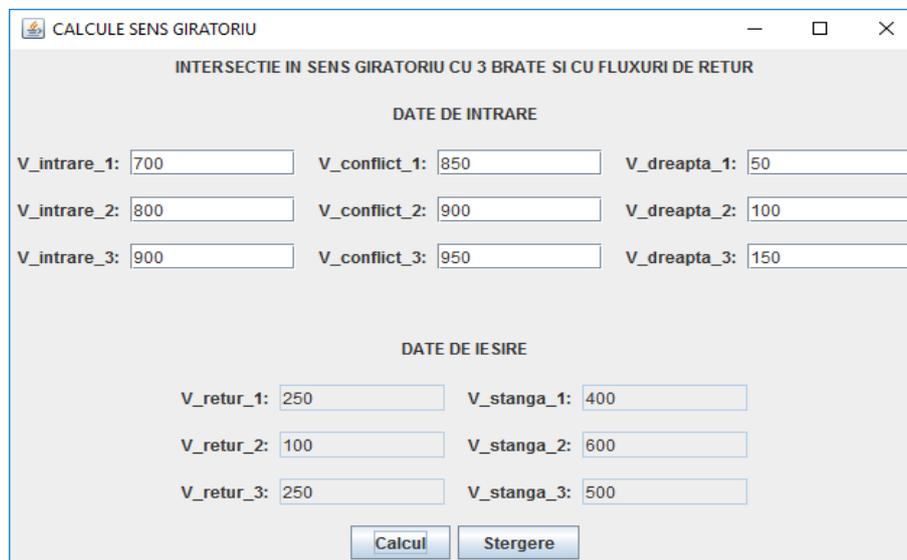
Figure 6. Traffic analysis for all arms with the Java program for the Podul Viilor 3-arm roundabout intersection with return flows.

Thus, it was noted that, on the Eastern arm, the return flow represents 70% of the incoming flow and it was possible to estimate that this flow, which increases the conflict flows for each of the other two arms, will be reduced substantially after the overpass artery road is put into service , so the traffic congestion reported in paper [1] will no longer take place.

The new measurements, made after the Calea Bucuresti overpass was put into service [12] confirmed the prediction.

4. Conclusions

It has been demonstrated that, for the 3-arm intersections with return flows and for the 4-arm intersections without return flows, the traffic streams may be fully known based on the traffic flows measured by fixed observers (measurement that are to mandatorily include the flows to the right) which is an absolutely unique and interesting achievement (the two sets of formulas represent personal contributions to traffic theory), because a knowledge of these traffic streams allows the reconsideration of traffic regulation in the area where the roundabout intersection is placed, for the purpose of traffic fluidization in the respective area, as well as in order to eliminate possible occurrences of congestion.

For each of the two cases that proved to be solvable with the help of the data measured by fixed observers, a computation program was developed based on each set of analytical relations, *in the Java programming language*, with very user-friendly interfaces.

To meet any need, the programs also work when only partial results are necessary (a situation when only the necessary flows are to be measured).

If an analysis is required for all arms of the intersection, full measurement will be carried out.

The use of these software programs allows formulating forecasts for road traffic in roundabout intersections.

The final step for the capitalization of these two programs will be to develop them as web pages [5], in HTML (HyperText Markup Language) format so that can be freely accessed and freely used on the Internet by any interested person.

5. References

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