The impact of a ring road in an urban road network. The case study of Guimarães, Portugal

Paulo J. G. Ribeiro and Luís A. P. J. Gonçalves

***Abstract*—** The high traffic volumes are a main source of the congestion in Cities, they are a big problem on urban road transportation systems. This congestion is the main cause of the increase of level of noise and air pollution in urban centers which directly affects the quality of life of the population. Also, contributing to the big number of vehicle conflicts that affects the performance of the urban road transportation systems and the quality of life of the population. These problems are the result of the high volumes of the through traffic. Therefore, to reduce the traffic volume in urban center of Guimarães, Portugal we studied a possible conclusion of the ring road, on the slope of the Penha hill for the peak hour of the morning. To carry out our study was estimated the Origin – Destination Matrix for peak hour from the data of traffic counts. Concluding the traffic volume in the section of the ring road already built there was a reduction. However, in the city center there were no major variations of the traffic volume.

***Keywords*—**Traffic congestion, Ring roads, Through traffic, Transport modelling, Urban transportation systems

I. Introduction

IN last years, it verified a high increase of number of trips [1]. Associated to this increase of the trips and the energy consumption, there are the congestion phenomena. This is related with the socioeconomic development, the fails in the infrastructure constructions, urban planning that having increased [2], being currently a big problem to the cities [3]. Also, the rapid trend of increase of the road traffic in cities, building a harmonious urban transportation system to ease traffic pressure is a common issue faced by many countries in urban development process [4]. The increase of road traffic volume is associated to the reduction of capacity of main roads and streets, being in the origin of the congestion phenomena. These phenomena are a problem for the cities where the resolution is not immediate and have serious consequences on many human activity domains (recreation, work, shopping, cultural activities, etc..). However, this problem is not of easy and quick resolution, so it is necessary to face these problems and it increase the quality of life of the population in the cities [5]. Other problems that usually are associated to congestion problems and affect the health and quality of life of the populations in the cities are the increase of noise and air pollution [6], [7].

In addition, it is necessary to avoid phenomena of urban congestion due to the existence and conflict of the crossing traffic in the cities [8], on high hierarchical importance streets, both at the road network level and, above all, in the performance of the function associated with issues of urban living in sensitive environmental urban areas [9]. This reduces congestion levels and increases the attractiveness of the suburbs, reducing the number of residents who need the private transport in urban centers [10]. One of the most commonly used techniques is the diversion of crossing traffic and, if possible, all heavy vehicles to new high-capacity and high-speed routes, called Rind Roads, and some cities may have more than one ring [11], [12].

However, this deviation of the traffic to the ring roads increases the noise levels in its surroundings, due to the increase of the practiced speed and increase of the volume of road traffic [12-14]. But in the design of this type of road, account must be taken of the characteristics of the infrastructure, as it plays a very important role in road safety, which is directly related to the quality of road network protection for the benefit of all road users [15]. Since there is a direct relationship between traffic speed [16] and access points [17] and road accident rates [18]. Consequently, from the point of view of the factors, it is important that the governmental entities that manage the road network and urban transportation systems carry out the development of transportation models and traffic forecasting that allow them to analyze the phenomena of lack of traffic flow, particularly in urban centers, historical areas and other noble urban areas.

Based on all referred factor, in this paper, it is intended to develop a calculation procedure for application in the PTV Visum software and its application to a case study to the city of Guimarães to demonstrate the applicability of this type of tool in urban planning, with the creation of the Matrix Origin - Destination from data of traffic counts. Also, it is intended to analyze the creation of a possible conclusion of the ring road of the City of Guimarães to effect a possible redistribution of

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the traffic to reduce volume of motorize road traffic in the central urban areas. This article is composed of 4 sections. Section 1 deals with the introduction, presenting a summary literature review about the subject under study, but also the objectives and structure of the paper. In section 2 is presents the methodology used. Section 3 presents the case study and analyzes the results. Finally, in section 4 the main conclusions are described.

II. Creation of a Transportation Model

In this section will be presented the methodology used in this work. Many points will be descripting about the creation of the model as the OD matrix estimation and validation and calibration process, using the transportation modelling software PTV Visum. The creation of the model is a complex process that involve a several steps (figure 1).

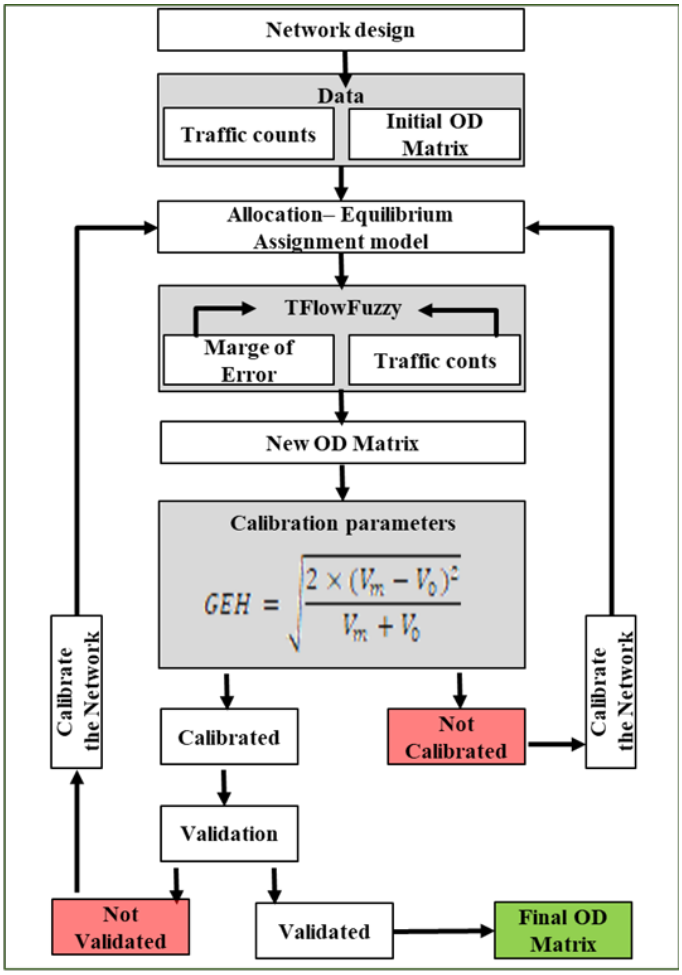


Fig. 1 - Transportation model

Initial it was design the network with all objects, nodes, links, Turns, Zones and connectors. In the design of the network it was applied the road hierarchy of [19]. The second step is the upload the data in the transportation model (traffic counts and Initial OD Matrix). The third step is the choice of the assignment model. The network in study is a congested network. Thus, it was used the Wardrop Equilibrium Model to make the allocation of the OD Matrix Data to the objects of the transportation network. This model is the most used for congested networks [20]. To calibrate the initial OD matrix, it was the TFlowFuzzy algorithm. This algorithm that possibility the utilization of traffic counts to correct and /or estimate the flows of OD matrix. [21]. Already the fourth step is the calibration the transportation model. To calibrate and validation the transportation model, it was the GEH (Geoffrey E. Havers) equation [22], where Vm is the Modelled traffic counts and V0 is the real traffic. After the calibration and validation of the model, the OD matrix estimated by the transportation model it is used to analyze the performance of transportation network, being used to generated traffic volumes in the turns, link and nodes of the transportation network.

III. Application to a Case Study of City of Guimarães

The case study is reference to transportation modelling of urban road transportation network of City of Guimarães, Portugal. This network focuses on the network of main distribution roads, covering the area of the historical center and its surroundings, bounded by an **Arterial Road and Mount of Penha**. The study area was divided into 27 zones (fig. 2), so that the internal zones ("colored") presented are 14, which aim to represent the operation and main flows that are generated in the interior of the city based on its land uses and the external zones ("white") presented are 13 and they characterized the points of entry and exit in the city. On the other hand, to the detriment of the non-existence of an initial OD matrix, the assignment will be made based on the estimation of the OD matrix from the traffic counts.

A. Input Data

The input data used in this study was an OD matrix and the Traffic counts. For the network of City of Guimarães wasn't possible obtain an OD matrix, since the studies of traffic and transportation carried out cover a much larger study area, adopting an initial OD matrix of value 10 with null diagonal and dimension (27X27).

The used traffic counts are referenced to peak hour in the morning (8:15 a.m. – 9:15 a.m), being subdivided into 4 subclasses, motorcycles (MC), light vehicles (LV), heavy vehicles (HV) and Bus (BUS). These data were posteriorly treated and inserted in the transportation model. It was used 8 count points (figure 2), totaling 57 directional movements (Turns) and 4 links were used. In the modelling process, the traffic was homogenized to the unit of vehicle equivalent (u.v.e.), based on the follow equivalence factors, 1 to motorcycles, 1 to light vehicles, 2 to heavy vehicle and 1,5 to

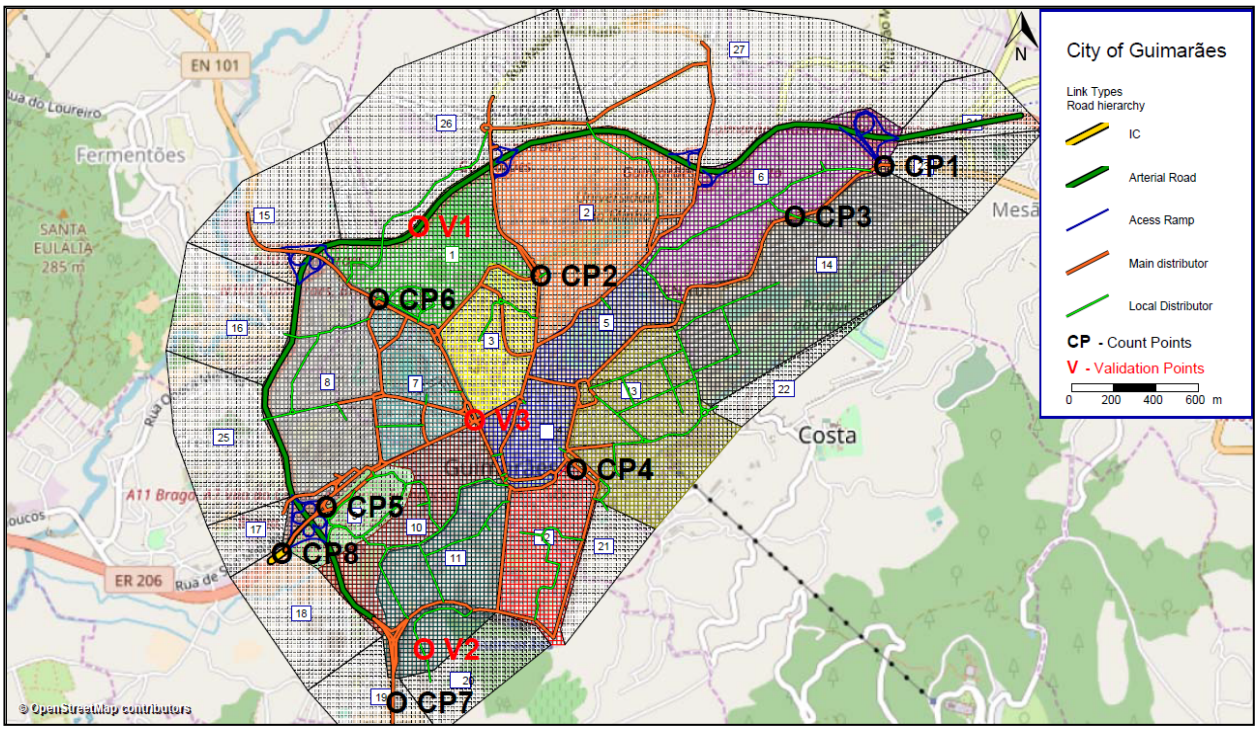


Fig. 2 - Map of network of city of Guimarães

bus [23].

B. Results of the calibration of the transportation model

Applying the calibration methodology presented in section 2, it is possible extract a several set of information, namely, the traffic volumes that are presented in the map of fig. 3. Based on the comparison between the counted and modeled traffic volumes calculated in the calculation of the parameter GEH (table 1) it is possible to conclude that the transportation model is calibrated.

Table 1 - Validation of the traffic counts values by parameter GEH to peak hour in the morning

GEH		
	Number of counts	**Percentage (%)**
GEH≤5	59	97 %
5<GEH≤10	2	3 %
GEH>10	0	0

Posteriorly, the transportation model was validated by carrying out traffic counts at three relevant points in the network - V1, V2 and V3 (Fig. 2) and the respective comparison with the traffic values modelled applying the validation criterion - GEH, the result of which is presented in table 2. It should be noted that, contrary to what happened with the other traffic counts, they did not enter the calibration process of the model. They were only used to validate the model.

Table 2 - Validation of the transportation model

Validation points				
Road (validation point)	**Direction**	**Counted traffic (u.v.e./h)**	**Modelled traffic (u.v.e./h)**	**GEH**
Variant (V1)	West > East	2398	2140	5
	East > West	1397	1344	1
António Costa Guimarães street (V2)	North > South	474	369	5
	South >North	714	798	3
Dr. Alfredo Pimenta Avenue (V3)	North > South	300	317	1
	South >North	362	400	2
S. Gonçalo street (V3)	East > West	72	88	2
	West > East	282	304	1
Conde Margaride Avenue (V3)	One way	493	500	1
Gil Vicente street (V3)	One way	75	112	4
Paio Galvão (V3)	One way	491	491	0

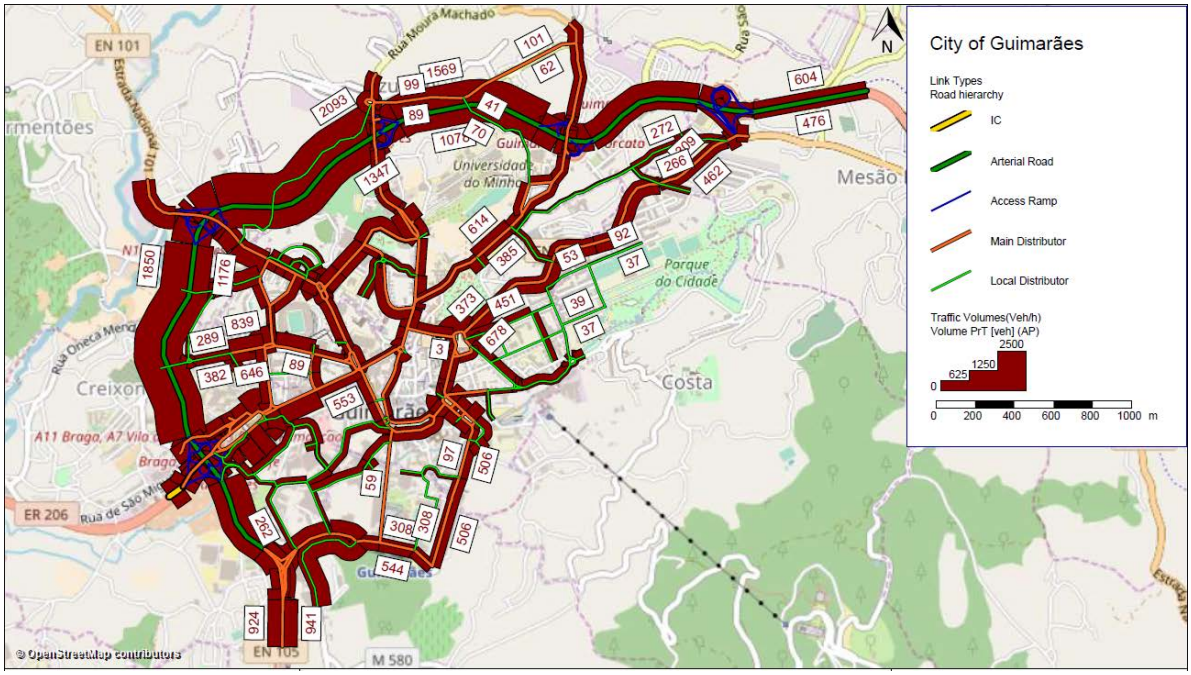
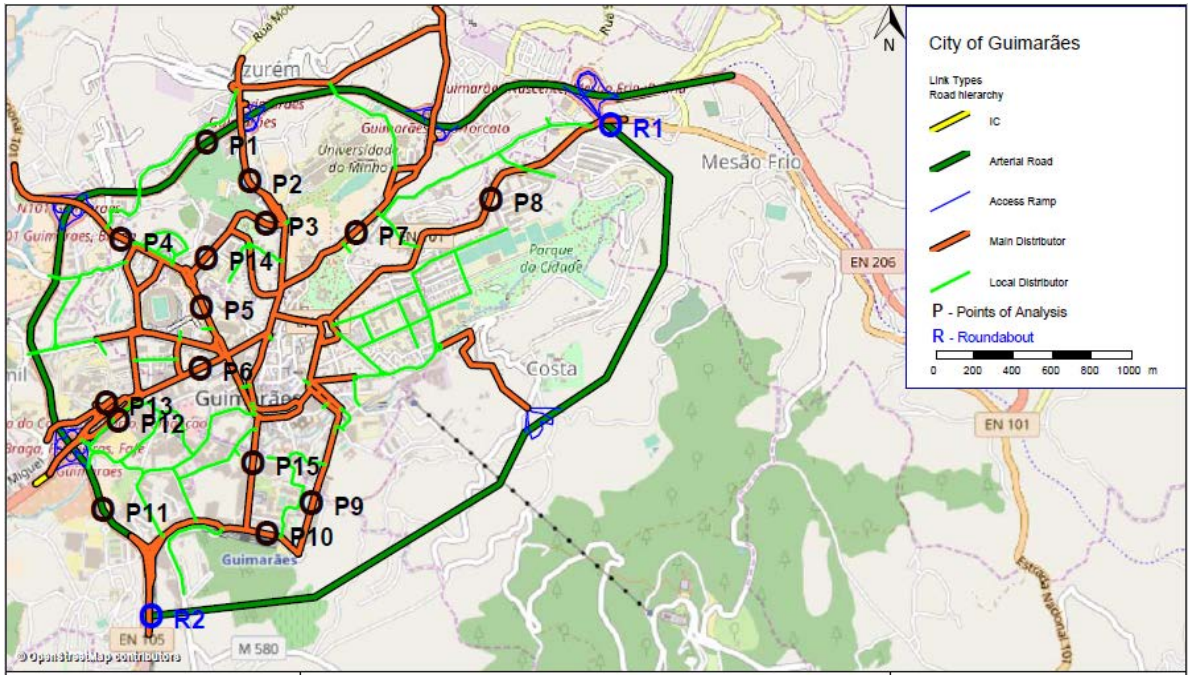


Fig. 3 - Traffic volumes of the model

C. Scenario development on the possible introduction of ring road around the city of Guimarães

In this subsection, it is presented the scenario and analysis of the conclusion of the ring road of the city of Guimarães, which surrounds half of the city, with the proposed



P 1 – EN 101 – Guimarães – Fafe connection	P 10 – Eduardo Manuel José de Almeida Street
P 2 – Universidade Avenue	P 11 – EN 105 – Vizela – Guimarães connection
P 3 – Cónego Dr. Manuel Faria Street	P 12 – Dr. Mariano Felgueiras Avenue (Direction A11 – Guimarães)
P 4 – EN 101 – Braga-Guimarães connection	P 13 – Dr. Mariano Felgueiras Avenue (Direction Guimarães – A11)
P 5 – Alfredo Pimenta Avenue	P 14 – Teixeira de Pascoais Street
P 6 – Conde de Margaride Avenue	P 15 – D. Afonso Henriques Avenue
P 7 – São Torcato Street	
P 8 – Padre António Caldas Street	
P 9 – D. João IV Avenue	

Fig. 4 - Road Network of the Alternative Scenario

construction of the remaining ring road on the slope of Mount

Penha. Consisting of the creation of a link between the southern entrance in the city, from Vizela to the northern entrance in City, from the Fafe (two cities from Portugal).

The realization of this new connection is established using two roundabouts (R1 and R2). Thus, it was constructed a new link branch to conclude the currently ring road of the City of Guimarães (fig. 4). With this new connection it is intended that users can travel from Vizela to Fafe and vice versa more quickly, avoiding congestion phenomena. In this way, an alternative connection to the City Center and Variant EN 101 is offered, which should guarantee the necessary conditions for good circulation as a ring road. To analyze the obtained results, the traffic volumes of the road network were compared between the base scenario and the alternative scenario, and the set of 15 counting points marked in fig. 4 were selected (P). Table 3 and fig. 5 show the variations of the traffic volumes for the peak hour in the morning between the two scenarios.

Present situation With the introduction of a new high-capacity road, it was found that the volume of traffic in the peripheral roads decreases, with further decreases in traffic on the selected points (road): P2, P8, P12 and P1, considering a static demand scenario, ie, the OD matrix remains constant and thus it is possible to evaluate a hypothetical readjustment of the demand in the road network, since no significant changes are expected in the overall demand of the transportation systems of the city of Guimarães. On the other hand, it was intended to simulate the creation of an alternative connection between Fafe and Vizela, also allowing a faster connection to the center of the city by the eastern zone, and thus to relieve pressure levels in certain sections of the current variant, namely along with important travel-generating poles such as the University of Minho and Hospital of Senhora da Oliveira, as can be seen in the results presented in Figure 6. Only one Point (road) suffered a significant growth rate, P14, maintaining a high ratio of volume/capacity and close to congestion of the road traffic. In this way it is possible to conclude that a small reduction of the traffic in the area of the center of the city and in the present variant (existent ring road), the closure of the remaining ring of the variant is foreseen, reason why the construction of such infrastructure is not justified.

	Volume (u.v.e./h)	volume (u.v.e./h)	**(u.v.e./h)**	
1	3484	2954	-530	-15%
2	1123	887	-236	-21%
3	864	906	42	5%
4	1451	1502	51	4%
5	513	446	-67	-13%
6	512	546	34	7%
7	899	809	-90	-10%
8	1220	697	-523	-43%
9	981	876	-105	-11%
10	1084	939	-145	-13%
11	2783	2475	-308	-11%
12	2131	1809	-322	-15%
13	963	982	19	2%
14	533	1063	530	99%
15	68	22	-46	-68%

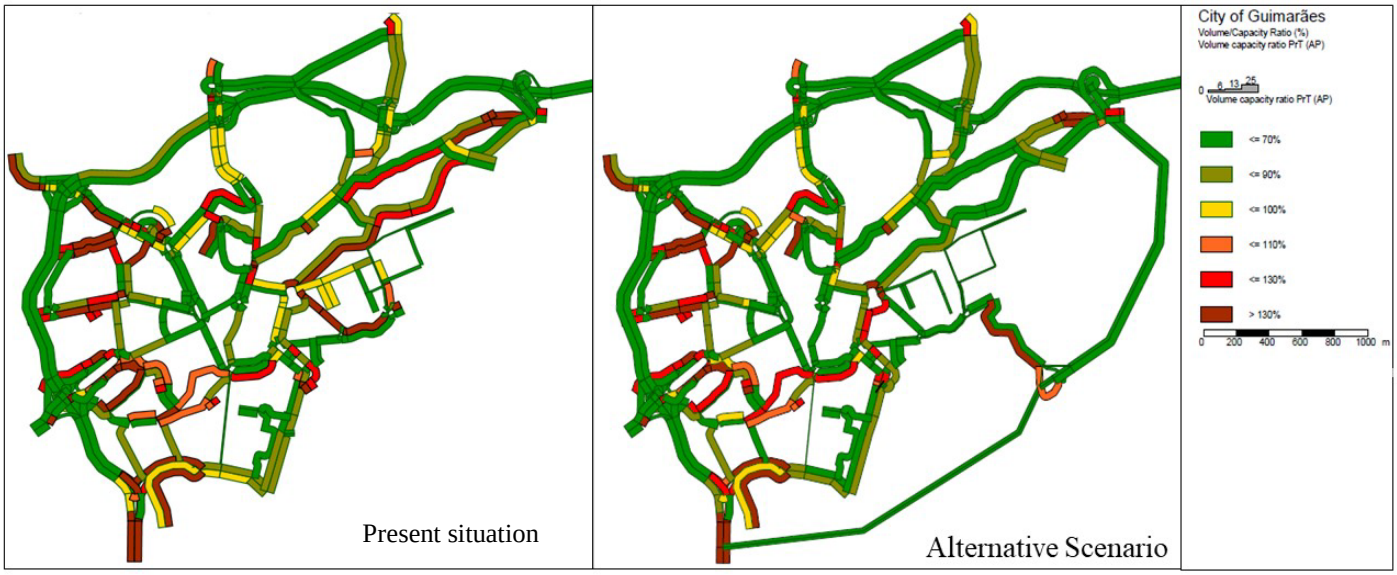


Fig. 5 - Map of the ratio of Volume/Capacity

Table 3 - Comparing of the volumes of the traffic to the peak hour in the morning

Points	**Peak hour in the morning**			
	Present situation	**Alternative Scenario**	**Traffic Volume variation**	**Growth (%)**
	Traffic	Traffic		

Although the analysis focuses on the optimization of routes taking account of travel times, it should be noted that the partial creation of the ring road on the northeast side of the city will bring considerable benefits from the point of view of

road safety and the concentration and emission of pollutants, namely PM10 and CO2, since Point P8 has a high average slope and is congested at rush hour in the morning. Thus, future work will be carried out cost-benefit analyzes that consider the different aspects of sustainability, namely the environmental, social and economic benefits in contrast to the direct and indirect costs associated with the creation of such infrastructure.

IV. Conclusion

In this work, a modelling and estimation methodology of the OD matrix for the city of Guimarães was applied based on traffic counts for peak hour in the morning, with its calibration and subsequent validation of the transportation model. On the other hand, it is important to highlight the possibility of validation of the OD matrix, since it was not possible to obtain an initial OD matrix. However, with a model it has been validated, being possible to do some tests and develop evolutionary scenarios about the road network of the city, namely to test the impact of some changes in the network operation that may allow to predict and identify the impact level of some proposals.

In the study of the scenario presented in this paper it was possible to verify a significant reduction of the volume of the road traffic in the section of the ring road (Arterial Road) already constructed, having been verified more descents in other ways of direct access to the city of Guimarães (P2 and P8), reducing traffic congestion problems. On the other hand, there is a high rise in other streets of the city (P15), not leaving this overloaded. It is concluded that the construction of the remaining ring of the ring road is not a task of great importance to contribute to the reduction of the traffic in the urban road transportation network of the city of the Guimarães.

This type of analysis becomes valuable for the managers of territory and mobility and the governmental entities responsible for the management of the transportation systems and networks and for the management of the cities. Thus, despite the limitations that the model has, namely, the absence of an initial OD matrix, it can be used for future city evaluations as a complement to transportation and urban mobility planning.

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