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COMPARATIVE STUDIES REGARDING TRAFFIC FLOW IMPROVEMENT SCENARIOS USING SOFTWARE MODELLING AND REAL MEASURED DATA

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Abstract

The purpose of this paper is to study and evaluate the effects of different road network changes on traffic conditions, based on measured stream characteristics and computer-based modelling. The studied perimeter is situated at the Western edge of the city of Cluj Napoca, Romania, on the borderline between urban and suburban areas. At the moment, the European E60 road is the only functional road link which connects the city to the Western suburb of Floreşti. Population increase and suburban expansion led to high traffic volumes, especially during the morning and afternoon commuting peak hours. As traffic is expected to further increase in the future, we conducted this comparative study to see which solution would have the best impact on traffic conditions in the studied area.

The traffic data we used was collected by a high-speed weigh-in-motion system, installed on the studied E60 road link. We used this real measured data to make a 15-years traffic forecast, based on Romanian regulations. After observing that road capacity has already started to be exceeded during peak hours, we studied two possible traffic flow improvement scenarios. In order to obtain a better look on the impact of the proposed measures, we studied a broader area, including parts of the adjacent neighbourhoods. The computer-based transport modelling and traffic assignment was done using Citilabs' Cube Voyager software. After setting up the road network and modelling the existing situation, we evaluated the impact of each scenario on the traffic volumes, route assignments and travel times. Results show the differences between the existing traffic conditions and the proposed possible future scenarios, which could be adopted to improve the level of service of the streets in the studied area. In the end, we reached a conclusion regarding the recommended solution.

Keywords: peak hours, weigh-in-motion, transport modelling, volume, travel time

1 Introduction

The development and evolution of human settlements have always been closely linked to the existence of a line of communication between them. As technology and transportation evolved, especially in the latest centuries, we have witnessed a rapidly changing and developing world [1]. Growth management and traffic congestion are relatively new, but difficult issues [2]. In the situation we approached, these are actually the main problems which this study aims to provide a solution for. The studied area is located in Romania, at the Western edge of the city of Cluj Napoca. The expansion and the rapidly increasing population of the Floreşti suburban area should have been backed up by sustainable urban development plans, traffic engineering measures and an efficient policy regarding public transportation [3]. The lack of these measures led to traffic congestion and increasing travel times. As traffic volume is expected to increase during the next years, we considered two possible solutions to improve traffic stream characteristics.

2 Traffic data

2.1 Location and traffic monitoring system

The studied perimeter, shown in Fig. 1, is situated at the Western edge of the city of Cluj Napoca, Romania. This city is a major cultural, industrial, academic and business centre in Romania. According to the 2011 population and housing census [4], around 325,000 people live in the city. The European E60 road (National road DN1) is the main road which connects it to the Hungarian border to the West, as well as to Central and Southern Romania. In the analysed section, the road has four lanes and an East-West layout.
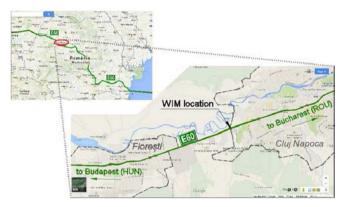

Figure 1   Study location

Approximately 4 km West of Cluj Napoca lies the suburban city of Florești. According to the 2011 census [4] and to Toșa et al. [3], the population of this settlement has known an increase of about 260% since 2007, from 8,600 to almost 23,000 inhabitants. This spectacular evolution led to the constant increase of traffic volumes on the only functional road link between the two cities, especially during the weekdays morning and afternoon commuting peak hours. Since April 2013, a high speed weigh-in-motion (WIM) system installed on the E60 road link (Fig. 1) has been functional. The system we installed has a piezo-loop-piezo configuration. Not only does it count and classify the passing vehicles, but it also uses piezo-electric sensors to weigh them [5].

2.2 Traffic stream parameters

All collected data was classified according to the direction of travel: Eastbound and Westbound. We extracted the traffic volumes from the WIM data and divided them into five vehicle categories, based on the Romanian standard for vehicles equivalation [6] and our knowledge of local traffic characteristics. We converted each of the five vehicle categories we considered into Passenger Car Equivalents (PCE), using the conversion factors provided by the Romanian standards for vehicles equivalation [6] (Table 1) and highway capacity evaluation [7]. As we also want to study traffic evolution over the next 15 years, we extracted the evolution coefficients provided by Romanian norms [8] (Table 1).
The current and estimated average weekday traffic [2] we obtained from the WIM data for the E60 link that we studied are shown in Fig. 2. We selected the 7.00–9.00 hrs and 17.00–19.00 hrs as peak intervals for traffic heading East and West, respectively.

Table 1 Vehicles data

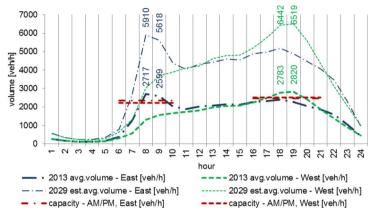| #	Vehicles	PCE conversion factor	Evolution coeff. (2014 – 2029)
1	motorcycles	0.50	0.64
2	automobiles	1.00	2.22
3	light commercial vehicles	1.20	2.10
4	other light vehicles	3.00	1.75
5	large goods vehicles (LGV), buses, coaches	3.50	1.95

Figure 2 Average weekday traffic

3 Traffic assignment

The modelling and analysis of the road transport system that we studied was done using Citilabs' Cube Voyager software. The computer–based transportation forecasting we carried out was based on the following main steps:
· setting up the existing road network;
· establishing the position of the origin and destination zones and connecting them to the network;
· building the trip matrices for the morning and afternoon peak hours;
· building the traffic assignment models for the existing situation;
· adjusting the model inputs so the results match the WIM measured average traffic volumes;
· setting up network improvement scenarios and forecasting their impact on the traffic volumes and route assignments.

3.1 Network model, path building parameters and existing situation

The first step of the traffic assignment process was generating the Cube Voyager network file, shown in Fig. 3. We focused on building a traffic simulation model with macroscopic characteristics, modelling only the main road links and considering five origin–destination zones (1-4, 11) to the West and six (5-10) to the East. The main link between the two areas is represented by the E60 road, where the WIM system is installed. The road network model was also detailed with turn penalties and signalised intersections data, including traffic signals phases, cycle times and delays.
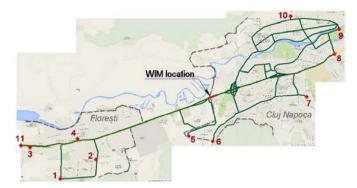
Figure 3 Model of the existing road network

We chose time as the cost of travelling on a certain path between two zones. We prepared the morning and afternoon trip matrices using data provided by traffic surveillance cameras, knowledge of local travel characteristics, data provided by Toşa et al. [3] and WIM data. One of the most popular optimisation algorithms to obtain network equilibrium and minimum–cost traffic paths, based on the Wardrop equilibrium principles [9], is the iterative Frank–Wolfe algorithm [10]. The general volume–delay function used to evaluate the travel time on a link is expressed by Eq. (1):

$$t(V) = t_0 \cdot \left[1 + 0.15 \cdot \left(\frac{V}{C} \right)^{\alpha} \right] \tag{1}$$

where:

$t(V)$	average link travel time;
t_0	free–flow link travel time;
V	traffic volume;
C	link capacity;
α	exponent.

Although the formula expressed by Eq. (1) is widely used, according to Spiess [11] it has a few disadvantages, especially in the case of roads with higher capacity, when α increases. Therefore, we chose to use the conical function proposed by Spiess [11] and described by Eq. (2):

$$t(V) = t_0 \cdot \left[\frac{2\alpha - 3}{2\alpha - 2} - \alpha \cdot \left(1 - \frac{V}{C} \right) + \sqrt{ \alpha^2 \cdot \left(1 - \frac{V}{C} \right)^2 + \left(\frac{2\alpha - 1}{2\alpha - 2} \right)^2 } \right] \tag{2}$$

with the same symbols as in Eq. (1). We adopted $\alpha=8$ for four-lane roads and $\alpha=4$ for one and two-lane roads.

3.2 Scenarios

After building the traffic assignment models and adjusting the model inputs so that the results match the WIM measured average traffic volumes, we obtained the current situation. Considering this situation and the evolution of traffic over the next 15 years, we carried out a traffic forecast using the Cube Voyager application, on two improvement scenarios. The first scenario we considered for the forecast, shown in Fig. 4, was the modernisation of an existing dirt road to the North of the E60 and the opening of a new road link, to the South. At the same time, we considered replacing a roundabout and a T intersection currently used in Floreşti

with two signalised intersections. The second improvement scenario, shown in Fig. 5, involves reversible lanes on the main East-West link, connecting zones #8 and #11, in addition to the changes considered in the first scenario. During the morning peak hours, we considered three lanes accommodating traffic heading East and one lane for the opposite direction, and vice versa for the afternoon peak hours. For the three-lane roads, we considered α=10 in Eq. (2).
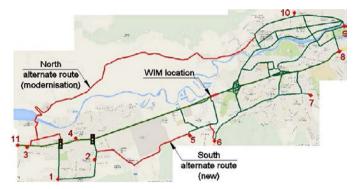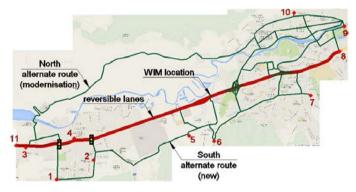

Figure 4   Scenario #1

Figure 5   Scenario #2

3.3 Results

We carried out the route assignment on the existing road network and on the two scenarios described, using traffic data collected in 2013 and estimated for the year 2029. A synthesis of the results we obtained is shown in Table 2, Table 3, Fig. 6 and Fig. 7.

Table 2   Peak hours average traffic volumes on E60 main road link – 2014

traffic heading	2014					
	AM (morning)			PM (afternoon)		
	existing	scen.#1	scen.#2	existing	scen.#1	scen.#2
	vol.[PCE/h]	change [%]		vol.[PCE/h]	change [%]	
E	2658	-27.8	-24.5	2332	-36.7	-45.2
W	1441	-40.2	-48.9	2801	-29.5	-16.4

Table 3   Peak hours average traffic volumes on E60 main road link – 2029

traffic heading	2029					
	AM (morning)	PM (afternoon)				
	existing	scen.#1	scen.#2	existing	scen.#1	scen.#2
	vol.[PCE/h]	change [%]	vol.[PCE/h]	change [%]		
E	5764	-18.8	-14.8	5038	-8.6	-10.8
W	3362	-28.3	-44.6	6480	-31.9	-23.9

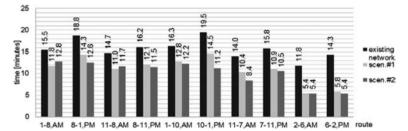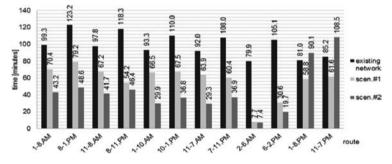**Figure 6**   Average travel times – busy routes, 2014 traffic volumes

Figure 7   Average travel times – busy routes, 2029 estimated traffic volumes

4   Conclusions

As we can see, maintaining the E60 road as the only road link between the zones we studied will lead to forced traffic flow and traffic congestion. If the evolution of traffic follows the pattern we estimated, in 15 years' time the travel times on the main routes we studied will be, on average, 6.6 times longer than now.

The two proposed scenarios would have a similar effect on the busy routes average travel times, reducing them with an average of 31.5% and 35.8%, respectively (Fig. 6). In the short term, we estimate that scenario #1 would have a better impact than scenario #2, reducing the traffic volume on the main link with approximately 30-40% (Table 2). However, in the long term, even though the peak hours average traffic volumes on the main link would be similarly reduced (Table 3), scenario #2 implies significantly shorter travel times. In 15 years' time, we estimate that the current travel times between main zones of interest would be reduced with 45.4% in scenario #1 and 67.6% in scenario #2 (Fig. 7). On the other hand, as shown in the last two clustered columns of Fig. 7, adopting reversible lanes has a negative impact on the travel times on some of the routes.

In conclusion, we estimate that scenario #1 would have a positive impact on traffic flow in the studied area, especially in the short term. The two alternate routes and the revised traffic signalisation would considerably reduce traffic congestion and average travel times. Reversible lanes would be a suitable solution in the long term, but adopting them should be reconsidered based on the traffic evolution up until that point. However, any route network improvement scenario should be sustained by further measures such as introducing an efficient public transport system and implementing a sustainable urban mobility plan.

Acknowledgements

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