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Comparative analysis of the performance of One-Way and Two-Way urban road networks

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Abstract. The fact that the number of vehicles is increasing year after year represents a challenge in road traffic management because it is necessary to adjust the road traffic, in order to prevent any incidents, using mostly the same road infrastructure.

At this moment one-way road network provides efficient traffic flow for vehicles but it is not ideal for pedestrians. Therefore, a proper solution must be found and applied when and where it is necessary. Replacing one-way road network with two-way road network may be a viable solution especially if in the area is high pedestrian traffic.

The paper aims to highlight the influence of both, one-way and two-way urban road networks through an experimental research which was performed by using traffic data collected in the field. Each of the two scenarios analyzed were based on the same traffic data, the same geometrical conditions of the road (lane width, total road segment width, road slopes, total length of the road network) and also the same signaling conditions(signalised intersection or roundabout).

The analysis which involves two-way scenario reveals changes in the performance parameters like delay average, stops average, delay stop average and vehicle speed average.

Based on the values obtained, it was possible to perform a comparative analysis between the real, one-way, scenario and the theoretical, two-way, scenario.

1. Introduction

If you plan cities for vehicles and traffic, you will get vehicles and traffic. If you plan it for people and places you will get people and places [1]. If we take a look in the past we can observe that traffic planners and engineers considered that with the continued development of road infrastructure they will keep up with increasing demand for transport. The way the streets are organized influences daily mobility.

If we refer only to the movement of vehicles we can say that one-way streets bring intersections with greater capacity, less conflict points and higher travel speeds but two-way streets are better for downtown areas because it provides higher accessibility and helps the driver to take the shortest route to destination.

There are three basic elements that constitute each long-term planning process:

1. Prognosis of requesting a system for different levels of endowment;

2. Describe the economic, social and environmental changes that accompany the development of the system at the same levels of plant endowment;

3. An evaluation of the system in terms of investment and benefit for the various options considered.

In general, forecasts of population and economic activities are obtained by specialists in demographic and economic statistics outside the scope of transport studies. Numerous models have been developed to report changes in land use for independent variables such as:

• accessibility to the job;
• the share of available vacant land;
• the degree of land use;
• the use of land surfaces in different situations;
• the degree of occupation with different types of land use;
• the maximum value of journey times and distances in the study area;

From the human factor (pedestrian - user and non-user of the urban road network) point of view, two-way streets are a better option than one-way streets because the two-way streets limit the travel speeds and also allows installation of median separators so the pedestrians can cross the street more safely. In the case of one-way streets, the tendency is to eliminate the cross-walk in order to eliminate the conflict points. When cross-walks are eliminated an alternative must be found for pedestrians to cross and then, underground or over ground passages are implemented. In the big city centers there are many underground passages but these are not always safe for pedestrians, especially if they are crossed at late hours, if they are not properly illuminated, monitored and effectively guarded.

From the point of view of the development of the downtown area two-way road network is also preferred to one-way road network because the local businesses have more visibility.

The present paper aims to highlight the impact one-way and two-way road networks have on the road traffic performance.

2. One-Way and Two-Way road networks particularities

One-Way road networks have a number of characteristics that can be used as advantages and disadvantages. They are used often in comparative analyzes in order to help design an overview and are static concepts, based on the descriptive parameters of an area, over a period of time. The characteristics represent what already exist.

2.1. Advantages and disadvantages of One-Way road networks [5]

Advantages of One-Way road networks:

- Travel speed increases
- On long arteries the travel time decreases
- Signalized intersections are easier to coordinate
- The conflict points with the pedestrians decrease
- Making a left turn is no longer difficult

Disadvantages of One-Way road networks:

- Decreased road safety because of the accidents caused by the high travel speed
- Increased number of conflict points between vehicles when changing lanes
- Increased travel distance from origin to destination
- Many cross-walks are removed because the risk of injuries is higher. Pedestrians are forced to walk a longer distance in order to cross the street

2.2. Advantages and disadvantages of Two-Way road networks [5]

Advantages of Two-Way road networks:

- Road safety is improved by the decrease of the travel speed
- Travel time is shorter which leads to a smaller level of chemical pollution generated by fuel consumption
- Local businesses grow easier because of the higher visibility

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- Travel distance from origin to destination is shorter
- There is a possibility to implement, for pedestrians, at cross-walks, refuges between the two ways
- The accessibility for vehicles is improved, allowing them to travel in both directions

Disadvantages of Two-Way road networks:

- Difficulties in coordinating intersections
- Travel speed is lower
- Many conflict points with pedestrians
- Many conflict points between vehicles when making a left turn

3. Performance measurement

For many years, traffic engineers were mandated to "move as much traffic as possible, as quickly as possible", often resulting in degradation of movement for other modes of travel. The unequivocal movement of the motor vehicle through a downtown network was of paramount concern; all other modes of travel took a back seat. Effectiveness of the network was measured by the amount of delay a motorist would encounter on a given street segment or intersection during either the morning or afternoon peak hours. [2].

Performance measurement focuses on identifying, tracking and communicating performance results with the help of performance indicators or parameters. It reveals, quantitatively, important aspects of the road traffic like: flow rate, speed, density.

3.1. Flow rate

Flow rate is a measure that quantify the amount of traffic passing a point on a lane during a giving time interval. As distinct from traffic volume which is the total number of vehicles that pass over a giving point during a given time interval, the flow rate is the equivalent hourly rate at which vehicles pass over a given point during a given time interval, but less than one hour. [3]

$$q = \frac{N}{t} \tag{1}$$

where,
q is the flow rate (veh/h)
n is the number of vehicles passing over a point
t is the time interval, usually one hour (h)

3.2. Average travel speed

Speed is defined as a rate of motion expressed as distance per unit of time. Average travel speed is computed by dividing the length of the street section or segment under consideration by the average travel time of the vehicles traversing it. [3]

$$s_a = \frac{L}{t_a} \tag{2}$$

where,
s_a is the average travel speed (km/h)
L is the length of the street (km)
t_a is the average travel time over L (h)

3.3. Density

Speed is defined as a rate of motion expressed as distance per unit of time. Average travel speed is computed by dividing the length of the street section or segment under consideration by the average travel time of the vehicles traversing it. [3]

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$$D = \frac{q}{s_a} \quad (3)$$

where,
D is the density (veh/km)
q is the flow rate (veh/h)
s_a is the average travel speed (km/h)

The relation between flow and density, density and speed, speed and flow, can be represented with the help of some curves. They are referred to as the fundamental diagrams of traffic flow presented in Fig. 1.

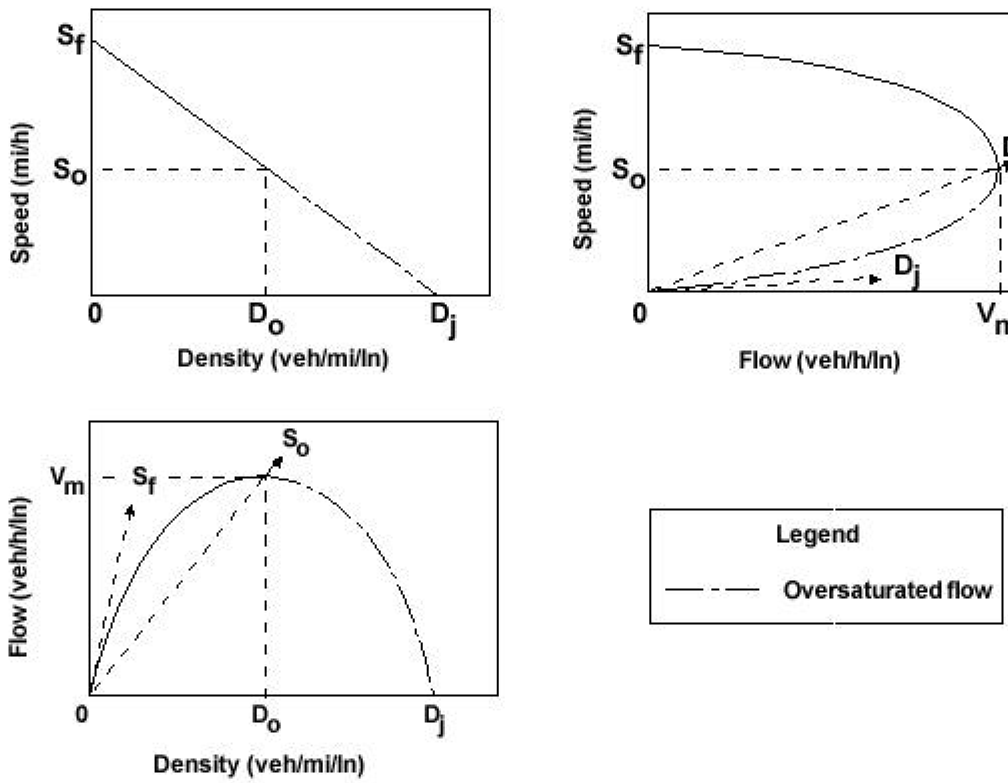

Fig. 1. Fundamental diagram of traffic flow [3]

On each of the diagrams above are presented traffic flow parameters as following: Sf is the free-flow speed, So is the optimum speed, Dj represents the jam density, Do is the optimum density and Vm represents the maximum flow.

The flow and density varies with time and location and similar to the flow-density relationship, speed will be maximum, referred to as the free flow speed, and when the density is maximum, the speed will be zero.

4. Analysis of the Civic Center Area of the Brasov City

The case study conducted on an area in the Civic Center of the Brasov City consists in comparing One-Way and Two-Way urban road networks. The first scenario consists in calculating the performance parameters for the real situation, Fig. 2, one-way road segments.

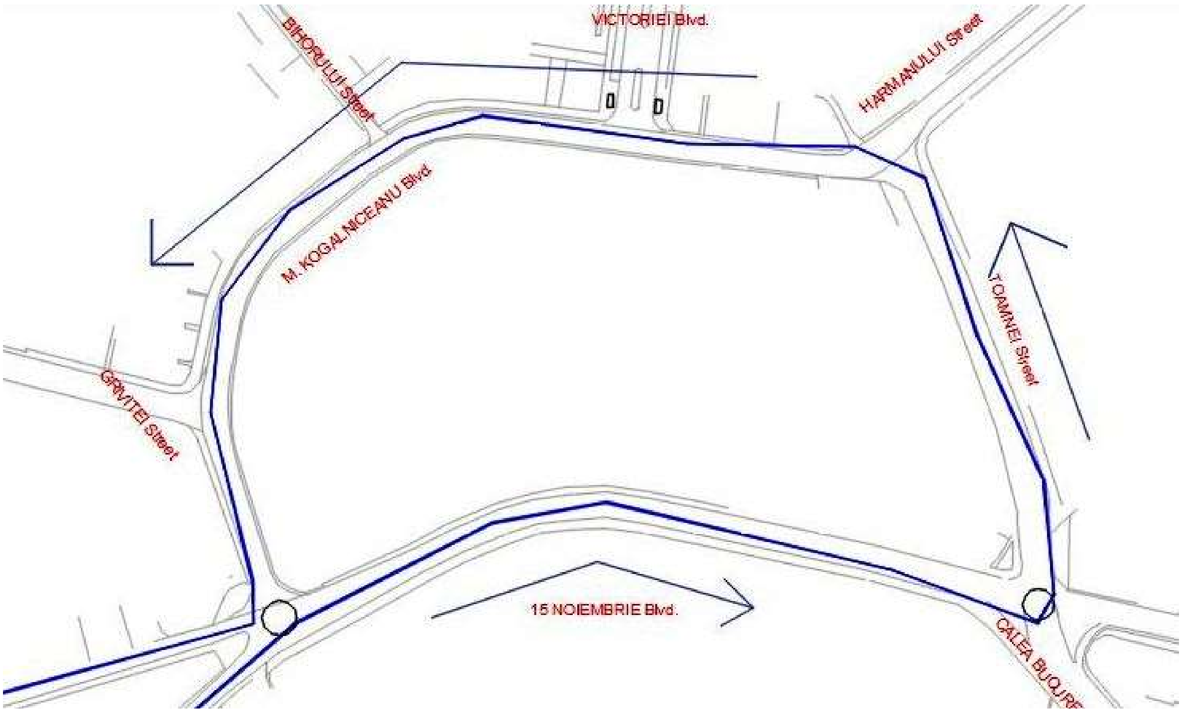

Fig. 2. Representation of the one-way road network in the Civic Center of Brasov City

The geometric and signaling conditions in the first scenario consist of two roundabouts and a traffic light coordinated intersection (Harman Street - Autumn Str.). Between the other intersections there is a continuous flow of traffic due to the six lanes used in one direction, only traffic signs being installed.

The second scenario, Fig. 3, consists in introducing two-way travel on all road segments.

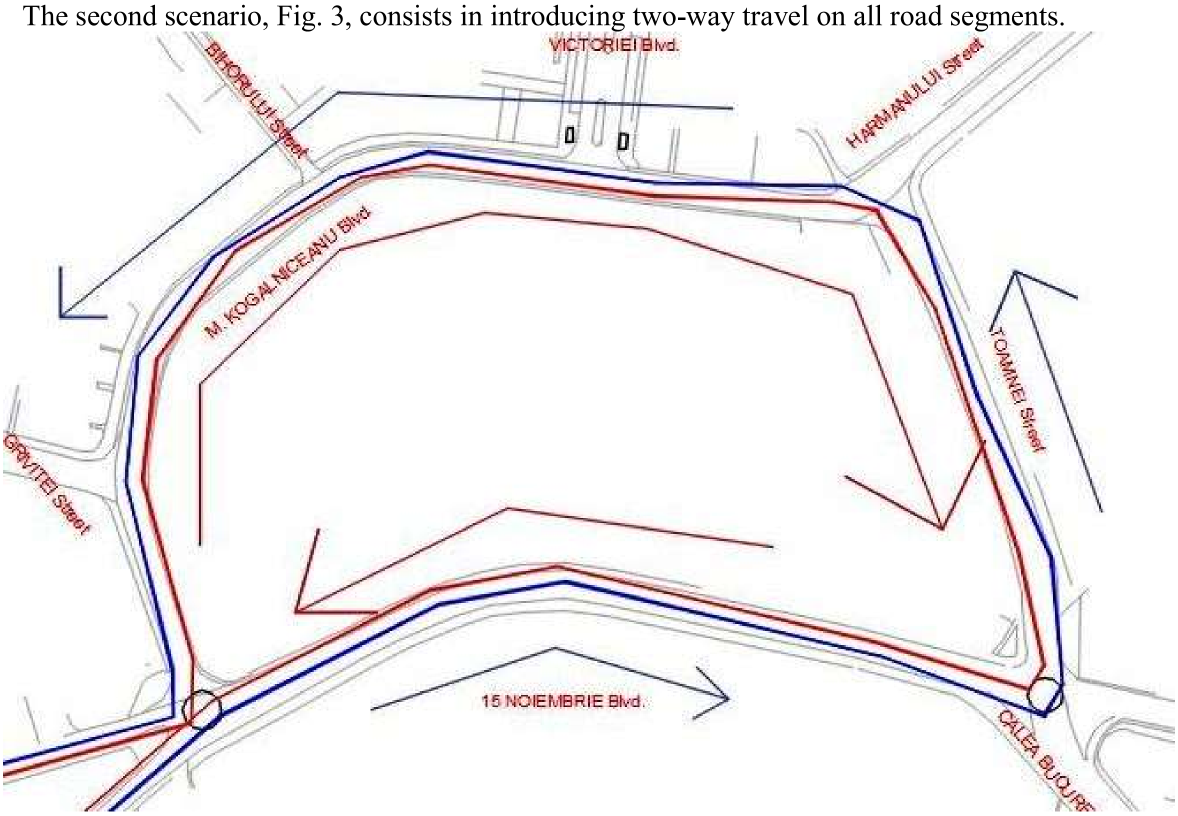

Fig. 3. Representation of the two-way road network in the Civic Center of Brasov City

In the second scenario the geometrical and signaling conditions were preserved, the only change being brought through systematization. Lanes 4, 5 and 6 were used for the opposite movement. However, it can be noted that, when introducing the two-way traffic, the signaling conditions for the following intersections:Kogalniceanu Blvd. - Victoriei Blvd., Bihor Str. and Grivitei Str. can not be preserved. It is necessary to introduce traffic light to improve traffic safety and to reduce points of conflict between vehicles. Also, a well-coordinated traffic light systemwould reduce to minimum the conflict points between vehicles and pedestrians, except for the Kogalniceanu Blvd. – Victoriei Blvd. intersection, where there is an underground passage for pedestrians.

4.1. The comparative analysis of the flow rate

In the analysis of the Civic Center area of Brasov City road network the traffic data were collected in 2014.[6] At the time of data collection, they were used for the elaboration of the bachelor project.

The first step consists in calculation of the flow rate, for each street that forms the Civic Center area, using equation 1. The number of vehicles used for the first way of circulation was collected in 2014 at the ingress of each intersection. For the second way of circulation the data used were estimated at 70% of each one-way lane.

The synthesis of results for the calculus of flow rates, for the two scenarios, is presented in Table 1.

Table 1. Results obtained for the flow rates calculation.

Segment name	Length (km)	*One-Way*	Two-Way
Toamnei Street	0,35 km	495 veh/h	421 veh/h
Kogălniceanu Blvd.	0,75 km	935 veh/h	795 veh/h
15 Noiembrie Blvd.	0,55 km	769 veh/h	653 veh/h

As can be seen in the table, in the second scenario, Two-Way, the flow rate is lower than in the first scenario and the explanation is that, in the Two-Way road network, the vehicles arrive at destination faster so the flow rate decreases. The destination is the place to which something is going and it could be a street, a place, a specific point.

4.2. The comparative analysis of the average travel speed

The second step consists in calculation of the average travel speed, for each street that forms the Civic Center area, using equation 2.

The synthesis of results for the calculus of average travel speed, for the two scenarios, is presented in Table 2.

Table 2. Results obtained for the average travel speed calculation

Segment name	One-Way	*Two-Way*
Toamnei Street	44 km/h	32 km/h
Kogălniceanu Blvd.	50 km/h	40 km/h
15 Noiembrie Blvd.	50 km/h	42 km/h

As can be seen in the table, in the second scenario, Two-Way, the average travel speed is lower than in the first scenario and the explanation is that the traffic flow is often interrupted, so when calculate the speed, the acceleration and deceleration at intersections are also introduced in the equation.

4.3. The comparative analysis of the density

The third step consists in calculation of the density, for each street that forms the Civic Center area, using equation 3.

The synthesis of results for the calculus of average travel speed, for the two scenarios, is presented in Table 3.

Table 3. Results obtained for the density calculation

Segment name	One-Way	*Two-Way*
Toamnei Street	11 veh/km	13 veh/km
Kogălniceanu Blvd.	19 veh/km	20 veh/km
15 Noiembrie Blvd.	15 veh/km	16 veh/km

It is worth pointing out that all densities presented in Table 3 are the number of vehicles in one lane per km and as can be seen the number is slightly higher in two-way road segments especially due to the lower speed. Even if the flow rate is lower in the second scenario, the lower average travel speed makes the density grow.

5. Conclusions

This paper was aimed to establish the influence of road network performance parameters. Based on the calculations and the results presented above, it is noted that two-way road networks are more efficient than one-way ones only if there is an effective signalling system so as to minimize the conflict points.

Speed, flow, and density are all related to each other. The relationships between speed and density are not difficult to observe in the field, while the effects of speed and density on flow are not quite as apparent and that is because the flow rate is measured as an hourly rate.

As the maximum density accepted is 100 vehicles per kilometre, if we report density to the measured length of the segment then it can be said that, in two-wayscenario the segments will have an optimum occupancy degree.

Even if the benefits of one-way road networks are evident, in this case study, due to the central position of the area and because the accessibility function has priority over the mobility function, the second scenario (two-way road network) is more appropriate.

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