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COMPARATIVE ANALYSIS OF THE MOVING OBSERVER KINEMATICS IN THE URBAN ROAD NETWORK

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Abstract: *The parameters that describe the urban road traffic are related to the speed evolution on certain routes. In order to make a good quality analysis is mandatory to have good quality data. That means one of the most important activity is the data acquisition, which involve the selection of the appropriate methods and devices. Using a database build in years, it was possible to compare the distribution of speed frequency for a moving observer in our city, before and after some major changes in the road network architecture.*

Keywords: moving observer, kinematic, speed, road network, statistical analysis

Introduction

During the last three years (2010 – 2012) many changes were made in the road network of the Brasov city and these lead to changes in the traffic parameters. Part of these changes consists in converting signalized intersections into roundabouts, also the speed limit was increased from 50 km/h to 60 km/h, so it is expected to obtain reduced stop times and higher values for mean speed. Starting from 2008, in the Department of Automotive and Transport Engineering of Transilvania University it was build a database with kinematic data collected using the Moving Car Observer method. This paper is based on a study conducted using the data collected during these years.

The goal of the study was to highlight the changes in the travel speed of individual vehicles. Such information may be useful for estimating the level of noise or chemical pollution caused by the road traffic [4], or for estimating the effect of the traffic on the vehicle itself. This study was made from a "microscopic" point of view, and this means that it was analysed the movement of the vehicle as entity, not the traffic flow. However, since the individual vehicle is driven in the same conditions as all the other vehicles in the flow, it can be assumed that the average values determined for a vehicle travelling many times on a certain routes are valid also for other vehicle on the same routes.

The concepts used in the traffic flows theory [3] were extended to the microscopic analysis of the driving, for an extended urban network instead of the analysis of a particular road segment. The statistic indicators used to describe the spot speed distributions are used to describe also the distribution of the moving observer speed.

Theoretical aspects

The key statistics used in the traffic theory to describe the speed distributions are [6]:

- *Average speed* (time mean speed);
- *Standard deviation* – the average difference between the measured speed and the mean speed;
- *85^{th} percentile speed V85* – the speed below which 85% of the vehicles are travelled;
- *Median speed V50* (*50^{th} percentile speed*) – the speed that equally divides the distribution of the spot speeds;
- *Pace* - a 20 km/h increment in speeds that encompasses the highest proportion of observed speeds.

The literature [6] recommends a 10 miles/hour increment and we converted this value into 20 km/hour; an increment of 16 km/h looks more closed to the recommended value, however the experimental results revealed similar values and the same conclusions with both values of the *pace* intervals.

The mean speed, the median speed and the pace are all measures of the central tendency, describing the approximate middle or center of the distribution. The standard deviation is a measure of dispersion, describing the extent to which data spreads around the center of the distribution.

Formulas used for calculation of the above indicators are as follows:

Average speed: $$\bar{v} = \frac{\sum_i f_i v_i}{N} \qquad (1)$$

where $\bar{v}$ is the average speed, f_i is the frequency of observations in the speed group i, v_i is the middle value of speed in the group i and N is the total number of observations;

Standard deviation: $$s = \sqrt{\frac{\sum (v_i - \bar{v})^2}{N - 1}} \qquad (2)$$

where s is the standard deviation, v_i is the value of the speed i, $\bar{v}$ is the average speed, and N is the number of observations.

The median speed, as well as the 85th percentile and 15th percentile speeds (V85 and V50) are determined graphically, using the diagram of the cumulative frequency distribution. The pace can be found also from diagram, moving a horizontal line of the established length along the left side of the curve, on the diagram of frequency distribution, until the right end of the line meet the right side of the curve. A measure of both central tendency and dispersion is the percentage of vehicles travelling within the pace speeds. This can be found also graphically using both the frequency distribution and cumulative frequency distribution curves.

Data acquisition and processing techniques

The data were collected using GPS receivers with a sampling rate of 1 Hz. This means that one record is saved at every second. Each record includes information about time and the vehicle position (longitude, latitude and altitude). The method was described in previous work [1, 4] and it was extensively used in traffic studies in the last years. Basically, it is the moving car observer method, where the car is equipped with GPS receiver as data acquisition device. One of the great advantages of using GPS devices is the easy of installation and use.

Each record is stored sequentially in a text file, or in an XML field in a GPX file, depending by the device used [2]. Each record corresponds to a speed observation, according to the theory presented above. The sampling rate of 1 Hz is accurate enough for statistical analysis of the travel speed. The output file from the GPS receiver is downloaded on a PC using a custom CAD application written for AutoCAD and described in detail in the book [2], where are given also more information on the accuracy of the devices and methods that can be used for GPS data acquisition.

The routes used as reference in this study are presented in Fig. 1 using dedicated map viewing software and in Fig. 2 as AutoCAD drawing. On these routes, three intersections previously signalized with traffic lights were converted into roundabouts. The data collected are grouped in two categories: before and after changes of the road network. The length of the routes is between 4.2 and 5.3 km.

The first phase of processing data consists in importing the text file in the CAD environment, draw the track(s) and generate the diagrams of speed and/or acceleration as function of time and space (example in Fig. 3).

Fig. 1 – The reference routes shown using a map software (MapSource)

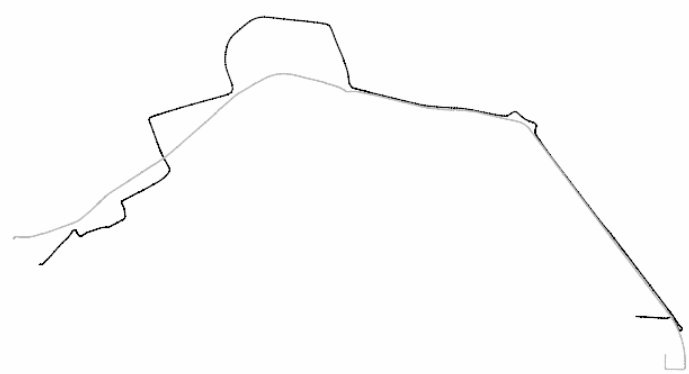

Fig. 2 – The reference routes represented in AutoCAD

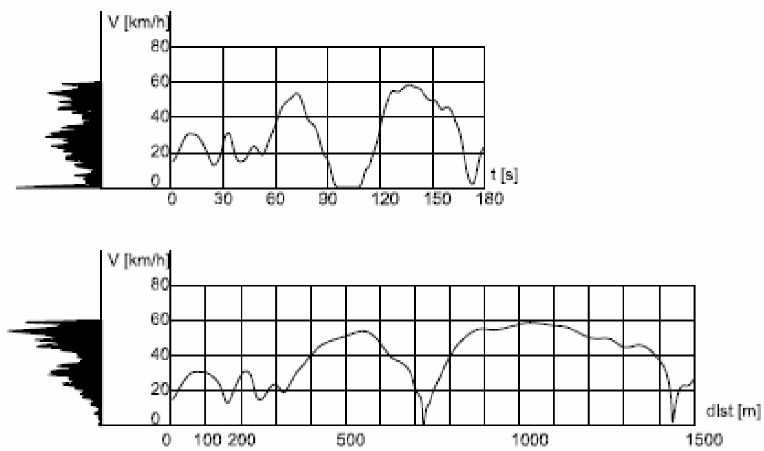

Fig. 3 – Example of speed versus time (top) and speed versus space (bottom) diagrams for a track

In Fig. 3 the side diagrams represents the frequency distribution of speed. These diagrams are presented here for one single track. When the all the tracks are added together on the same diagram, the frequency distribution looks like in Fig. 4.

The next action is to generate the diagram of cumulative frequency distribution, starting from the diagram shown in Fig. 4. It is used a custom function written in Lisp, which browse through the curve reading the coordinates of each vertex, then calculate the percentage of each speed group. Each speed group in this analysis has a 2 km/h range. The result of this action is the curve shown in the bottom part of Fig. 5 and Fig. 6. The horizontal axis is for the speed values, the vertical axis is for the speed percentage.

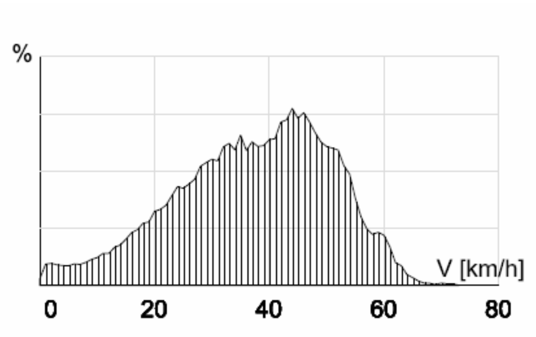

Fig. 4 – Frequency distribution for speed/space diagram

The 85th percentile, 50th percentile and 15th percentile speeds can be easily extracted from the curve: a horizontal line starts from the percentile value on the vertical axis, and then the line is extended until it intersects the curve. From the intersection point a new line is created down to the horizontal axis. The distance from the origin of the diagram to the last intersection point is the value of the percentile speed.

The pace is more difficult to be obtained graphically, even using the CAD environment. A good solution is to calculate the pace interval analytically, comparing the number of observations for all the possible pace intervals. The input values are the vertices of the curve representing the frequency distribution (top diagram in Fig. 5 and Fig. 6).

Results

The data collected before implementing the changes in the road network were used to generate the diagrams in Fig. 5. It can be observed that the value of V85 is 50.49 km/h. Since V85 is recommended to be the value of the speed limit, it can be stated that the limit of 50 km/h was a good choice at that time. The median speed V50 was found at 37.58 km/h.

After upgrading the road network, the same routes were traveled in order to collect new data, which are summarized in the diagrams in Fig. 6. The new value of V85 is 52.69 km/h, not far from the previous V85, even if the speed limit is now 60 km/h. This means that a higher speed limit don't lead automatically to higher travel speeds inside the urban network. V50 is now 37.51, practically the same value as before.

The general aspect of the frequency distribution curve is not changed dramatically (Fig. 7); it is mainly flattened, having a lower mode (modal speed: the single value of speed that is most likely to occur) and little higher values on both sides of the curve. The area inside the curve is almost the same, since the traffic volumes are similar.

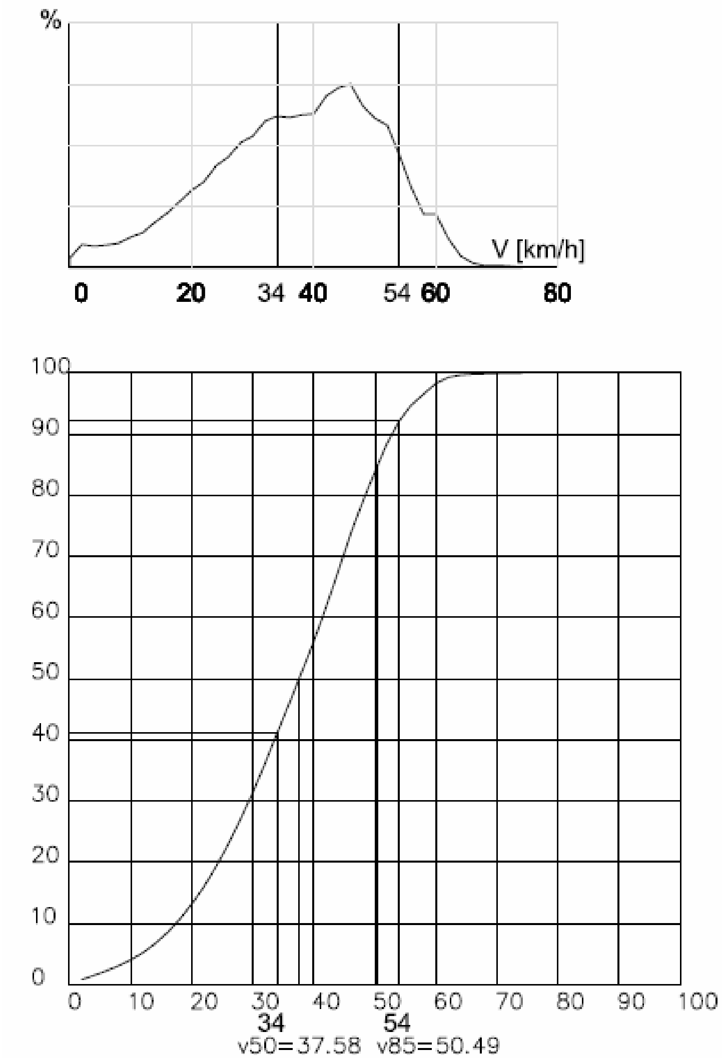

Fig. 5 – Frequency distribution and cumulative frequency distribution
(before changes in the road network)

The pace interval was found to be the same in both cases: between 34 and 54 km/h, but with different percents of measured speed values. The percent vehicles within the pace can be ascertained from the cumulative frequency diagram, by measuring the vertical distance between the intersection of curve with the two pace limits. This means that 51% and 45% respectively of the measured speeds are in the interval of 34 – 54 km/h, with a standard deviation of approximately 10 km/h.

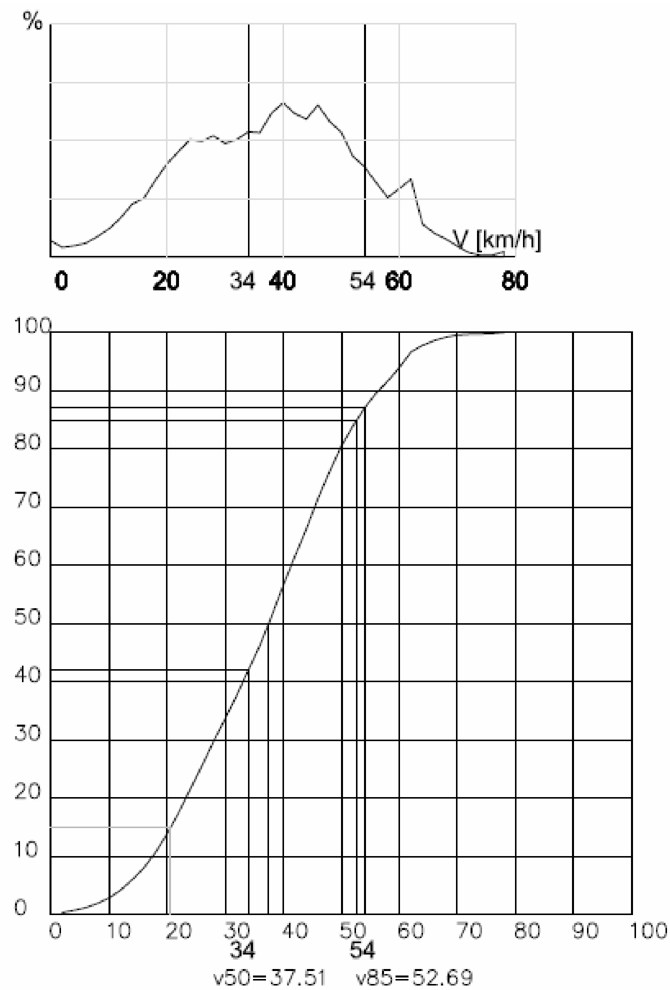

Fig. 6 – Frequency distribution and cumulative frequency distribution
(after changes in the road network)

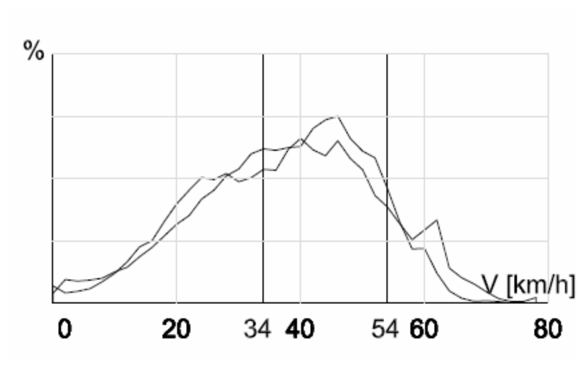

Fig. 7 – Frequency distribution before and after changing the road network

The 85th and the 15th percentile speeds can be used to roughly estimate the standard deviation of the distribution [6]. The formula for this estimation is:

$$s_{est} = \frac{V85 - V15}{2} \qquad (3)$$

resulting a value for the standard deviation of 16.52 km/h for measurements taken before changes in the road network and 16.02 km/h after.

Table 1 – Summary of results

	Before	After
Average speed (km/h)	37.14	37.71
V15 (km/h)	17.45	20.65
V50 (median speed) (km/h)	37.58	37.51
V85 (km/h)	50.49	52.69
Modal speed (mode) (km/h)	46	40 and 46
Pace interval (from-to, km/h)	34 - 54	34 - 54
Percent vehicles within the pace	51	45
Standard deviation (km/h)	13.7	14.86

The results are summarized in Table 1. It can be noted that there are two values for modal speed – two speed values are most likely to occur, equally – 40 km/h and 46 km/h. As the number of observations will be increased, most probably the modal speed will be somewhere between these two values.

The average speed here is the space mean speed, as the observations are extracted from the diagram of speed as function of distance travelled.

The values for standard deviation of the measured speeds calculated from the precise experimental determinations (values given in Table 1) are close to the values estimated above using formula (2).

Conclusions

The study on which this paper is based was made from the point of view of the individual vehicles moving through an urban road network. Having a database built in time, about five years with tens of tracks recorded per year, with different vehicles on few routes (but not just a single route), the results can be extended to all individual vehicles in the network.

The goal was to make a comparative analysis of driving parameters before and after some major changes in the road network. The main changes were the conversion of three intersections that were initially signalized with traffic lights into roundabouts, and the increase of the speed limit from 50 km/h to 60 km/h.

It was expected that these changes will cause an increase of the average speed and an increase of the number of vehicles moving with higher speeds – a higher value of V85. The 85th percentile speed was increased indeed, but with a small difference from the previous value. Before changes the V85 value was close to the speed limit, but after the changes were implemented the new value is less than the new speed limit (see Table 1). This led us to the conclusion that the changes in the speed limit do not affect the traffic fluency too much.

The space mean speed, the median speed (V50) and the pace are almost the same. The most important increase is of the 15th percentile speed, and this means that there are less road segments where the vehicles move with low speeds – like in the queues at intersections.

In this study it was not taken into account the time to destination, or the distance travelled to destination, neither the duration while the vehicles are stationary.

References

1. Covaciu, Dinu; Florea, Daniela; Preda, Ion; Timar, Janos; *Using GPS Devices For Collecting Traffic Data*; SMAT2008 International Conference, Craiova, 2008.
2. Covaciu, Dinu; *Use of GPS and CAD in Vehicle Dynamics Study*; VDM Verlag, Saarbruecken, ISBN: 978-3-639-35589-5, 2011.
3. Florea, Daniela; *Managementul traficului rutier, Ediţia a II-a (Road Traffic Management, Second Edition)*, Editura Universităţii Transilvania din Braşov, ISBN 973 –9474-55-1, 2000.
4. Florea, Daniela; Cofaru, Corneliu; Covaciu, Dinu; Timar, Janos; *Data Acquisition Methods for Estimate the Noise Generated by the Road Traffic*; 3rd WSEAS Conference on Urban Planning and Transportation UPT 2010, Corfu (Kerkyra), Greece, 2010.
5. Hobbs, F.D.; *Traffic Planning & Engineering – Second Edition;* Pergamon Press, 1979.
6. Roess, Roger P.; Prassas, Elena S.; McShane, William R.; *Traffic Engineering, 3rd Edition*, Pearson Prentice Hall, ISBN 0-13-142471-8, 2004.

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