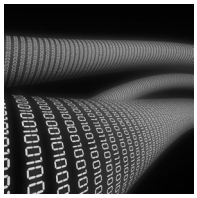

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GPS use to determine accurate speed

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ABSTRACT

The paper presents the importance of measurements and research in the road traffic as well as the most often used methods of speed measuring. Possibilities of GPS system use for speed measurements are described. Possibilities created by this method usage to determine the speed in the road traffic are shown.

KEYWORDS: mobility, road traffic measurements, speed, methods of speed measurement in road traffic, GPS

1. Introduction

In the Middle Ages a European tramped about 200 meters per day. At the end of the 19th century he tramped already 500 meters. Nowadays an average distance which is passed during day by a European is equal to 50 kilometres. Big part of that distance a human covers by participation in the road traffic.

Participants of the road traffic are pedestrians and different type vehicles driven by humans. Pedestrian and vehicle traffic depends on many factors, determined as "road conditions" [3,4,7]. "Road conditions" is a group of factors which are directly or indirectly related to the road, which influence efficiency, economics and traffic safety [7,9]. Road conditions meant in such way are characterized by road features and also by traffic parameters, which are a function of, among others, road features. Traffic parameters are connected with roads' features. The traffic speed and its density are the parameters especially important from the road traffic description point of view [5,6].

2. Measurements of and studies on the road traffic

Measurements of and studies on the road traffic are one of basic traffic engineering sections. They are the basis for analyses and decisions connected with road solutions planning and designing and they are helpful at solving problems related to the traffic management and organization [5,6,7,9]. The first road traffic measurements were conducted in France in the year 1844 [7]. They were repeated every few years with the purpose of establishing relations between the traffic volume and roads construction and maintenance.

The date of the first road traffic measurements in Poland is unknown. It is only known that at the end of 19th century vehicles were counted on main high roads in some cities of Poland, which appeared in those administrative sections during conferences, markets and church fairs.

From the beginning of seventies, as a result of increase in transport problems caused by the growth of vehicles number and by the increase in society mobility, different type of measurements have been made. The range of measurements and studies performed, especially in relation to urbanized areas, changes with motorization development. Directions of conducting measurements and studies on the road traffic have been devised, thanks to what it is possible to compare results of measurements made by different entities in different places [5,6]. Generally we can claim that traffic studies are conducted for very different ad hoc and long-term goals, and needs and requirements in that field are very diverse in different countries [3,8].

The range of research and analyses conducted now in

Poland and their usage depends on goals of their performance. Basic purposes of traffic research include [4,5,7]:

- getting to know and describing rules of traffic,
- providing data for analyses of traffic needs and of changing tendencies for areas of transport research,
- providing data to design and operate elements and equipment of transport system,
- analyses of traffic as a sociological phenomenon.

So the basic aim of measurements and traffic research is getting the information about transport system operation and behaviour, which can be put down to transport system elements. Another practical use of measurements and research is the implementation of task connected with town planning and different types of economic analyses.

The most frequent measurements and road traffic research include: traffic intensity measurements, speed measurements, measurements of time loss and measurements of parking [4].

3. Speed measurement methods

Speed is the most essential attribute of road traffic [5,6]. It can be a determinant of road traffic quality and its consequences with reference to participants and in the social dimension [7]. It decides about comfort, economics and road traffic safety. The following speed types are mainly studied [5,10]:

- temporary speed, that is a speed in a determined road section,
- speed of driving or walking, that is an average speed of an object (e.g. vehicle) movement on a road section without the time of stops,
- journey speed, that is an average speed of an object (e.g. vehicle) covering a road section, taking into account the time of stops.

Drive and journey speed is marked out in an indirect way, on the basis of drive (walk) speed.

Speed measurements are made by different methods with external and internal equipment, stationary and non-stationary [3,5]. The choice of equipment is made depending on the type of speed measured. We have also to determine if we are interested in a single vehicle or in the entire vehicle stream.

In the case of temporary speed measurements we need to distinguish two situations [5,9]:

- when the speed of a single vehicle is measured on the same determined profile during a determined time,
- when the speed of a single vehicle is measured on many profiles of the section what is related to current vehicles arrangement at the observation moment.

The following ways of measurement can be used to perform measurements in the first case:

- measurement of time needed to cover a short part of the road (on the assumption that this speed does not change) with the use of stopwatches, detectors (pneumatic, induction, magnetic, optical, radar) or video-detectors; measurements with drive detectors usage need their installation before,
- direct speed measurement by a radar meter or by its reading from a speedometer in the moving vehicle on the measured section.

Measurements of the drive speed and journey are most often taken at the same time and determine time of vehicles movements and stops. The measurement depends on multiple drives on the studied section by a test vehicle at a speed close to the speed of other participants of road traffic [3,7]. Any type of vehicles which appear in the stream of vehicles on the analyzed section can be the test vehicle.

An observer in the vehicle has measuring equipment which assures identification and data registration, enabling to ascribe those values to proper points in space. The information about the time of driving (time of starting and stopping) and of stops is registered, reasons of stops caused by the traffic organization and other reasons disturbing fluent driving.

The values of time of driving and of stops in individual parts of the measurement section can be counted for that section and its parts, journey speeds. If we make many drives it will be possible to determine average values of measured speeds. The values obtained can be shown in a road vs. time graph, thanks to what we can estimate traffic conditions on the section.

Speed measurements are also performed to determine the speed profile and speed line. Those measurements are made by multiple drives on the analyzed section in a test vehicle [6,7]. The test vehicle should have proper equipment allowing a temporary speed registration of the moving test vehicle. The data obtained can be shown as a speed dependence on time in the form of a graph [7]. Because of simultaneous graphic recording of driven road length this dependence can be converted to a speed profile. It allows making analyses of traffic conditions of vehicles streams.

An alternative method of speed measurements is the use of video cameras with a scanner, which allows speed measurements and classification [3,7]. The advantage of video detectors is the possibility of serving many traffic ways by one measuring device, the disadvantage – lower efficiency at night and in bad weather conditions. Because of that the video detectors are more often used in cities [9].

Methods of speed measurements mentioned above require special equipment which is installed in vehicles,

adapting means of transport to speed measurements, using special measuring vehicles with proper equipment installed during vehicles fitting out or building proper measure systems in the transport infrastructure. In the case of measuring vehicles it is required to buy a properly equipped vehicle or to adapt a vehicle to speed measurements. Such measurements cannot be made without previous preparation.

4. Speed measurements using GPS

GPS that is the Global Positioning System is a satellite system which assures precise determination of the position, speed and time. Twenty four satellites NAVSTAR (they are on 6 levels at a height of 20180 km, at 55° angle of inclination) which run around the Earth and transmit a radio signal which allows determining the actual position. The signal is available worldwide and the usage is free. Measurements accuracy fluctuates from a centimetre (geodetic receiver, differential GPS) to several dozen meters (simple navigation receiver without a differential correction) [2,8].

The minimisation of the equipment, higher precision and the reliability of operation cause that the GPS becomes a precise global system, commonly used by different users and for different objectives. Nowadays at the world there are more than 4 million GPS users.

The GPS - Global Positioning System – is a system which uses methods of navigation parameters measuring. The method is based on the distance measurement to at least three known points – satellites, which position is known by the user at any time. The straightforwardness of radio waves propagation and their steady speed of propagation provide conditions for the distance measurements method. Navigation parameters are measured directly by the measurement of propagation time of radio signals of known structure transmitted by a navigation satellite and received by the user's receiver. The condition for proper operation of a navigation system using the distance method is [2]:

- elimination of time scale fault in the receiver;
- proper synchronization of user's receiver time scale with the time scale of GPS system.

The measurement of distance between a navigation satellite and user's receiver is made by transmission of known structure signal by the satellite transmitter and next comparing the signal received with its replica in the receiver. As a result of that we obtain the propagation time of electromagnetic wave, which multiplied by the speed of electromagnetic wave propagation gives the distance between the object and satellite [2].

GPS receivers calculate also the object's speed on the basis of relative speeds of the receiver and satellite measurements. Usually receivers update data of pseudo-distance and relative speeds on a second. The purpose of navigation is to calculate the receiver position, speed and time in the GPS scale. The time passing between the moments of signal transmitting and receiving is directly proportional to the distance between the satellite and receiver, so it is necessary that both the satellite and receiver use the same time as a reference. The receiver uses a reconstructed GPS time scale to measurement data received from the satellite. Receivers have no high-stability model as for example an atomic model, which is on satellites. Instead, receivers have quartz oscillators. The lack of time scale generated by this oscillator conformity with the GPS scale is corrected on the basis of measurement results of four pseudo-distances. This allows solving a system of four equations with four unknown: three receiver coordinates and the correction of receiver time scale. The counted speed is similar, but with the use of relative speeds instead of pseudo-distances.

The system fixes the receiver speeds:

- on the basis of its position change,
- using the Doppler effect – that is on the basis of electromagnetic wave frequency change caused by object's movement.

To improve the positioning by GPS so-called Differential GPS is added, a system of referential ground bases, which allows determining the position with higher accuracy. More advanced space specifications are also used which take into account:

- Sagnac effect ,
- real Earth shape, which is not an ideal sphere,
- Earth gravitation and magnetic dynamics which is a result of its rotary movement in relation to the north-south axis.

Differential systems work using both methods:

- In real time – conducting corrections to the receiver by radio waves; they are conducted by a working base receiver of known antenna coordinates,
- Remembering results of measurements made by a moving receiver and a base receiver and later computing the correction data for the moving receiver.

Using this method in real time a precision of 0.2 – 0.5 m is obtained [1]. Its use requires: base receivers, moving receivers and a contact canal to corrections transmission [2]. The measurements precision can be additionally increased using a GPS receiver with an external antenna, which allows eliminating more disturbances.

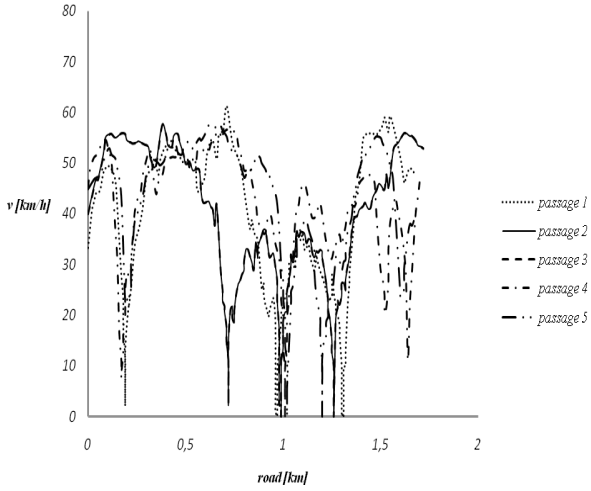

Fig. 1. Distribution of velocity (Radom, 25 Czerwca street)
Source: [own work]

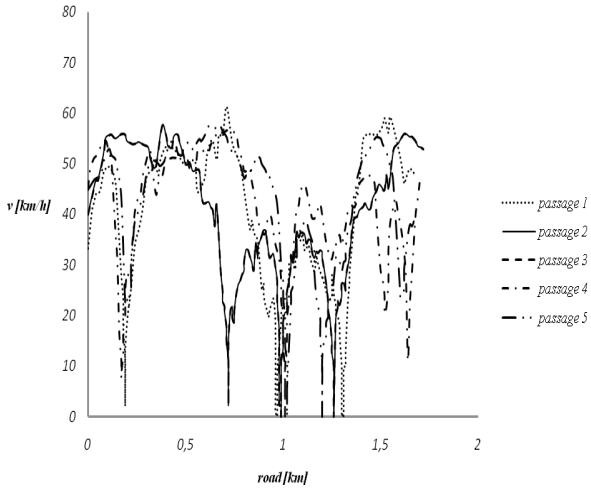

Fig. 2. Distribution of acceleration (Radom, 25 Czerwca street)
Source: [own work]

Using the available, GPS referenced, navigation systems on a portable computer it is possible to perform measurements in one vehicle.

After making the measurements and saving the data on a portable computer it is possible to get the following data:

referenced to entire data:

- time of measurement start and finish,
- length of way,
- average and maximum speed,
- minimum and maximum height above sea level,
- information about lay of the land;

referenced to unit measurement:

- real time,
- distance from the beginning of measurement,
- geographical data,
- speed,
- value of measurement quality.

After measurements the data obtained can be transformed using e.g. EXCEL. The scope of analysis depends on the objective of the measurements and of studies on the road traffic. Examples of data and results are shown in Figures 1-6.

An additional advantage of this measurement method is the possibility to illustrate changes of speeds and interesting road traffic parameters in reference to longer measured sections. Because of data collection and registration it is possible to perform different analyzes of basic road traffic parameters.

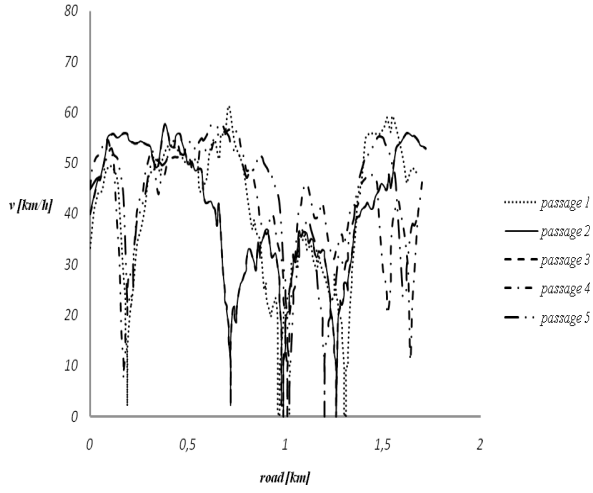

Fig. 3. Distribution of "acceleration noise δ_a" (Radom, 25 Czerwca street)
Source: [own work]

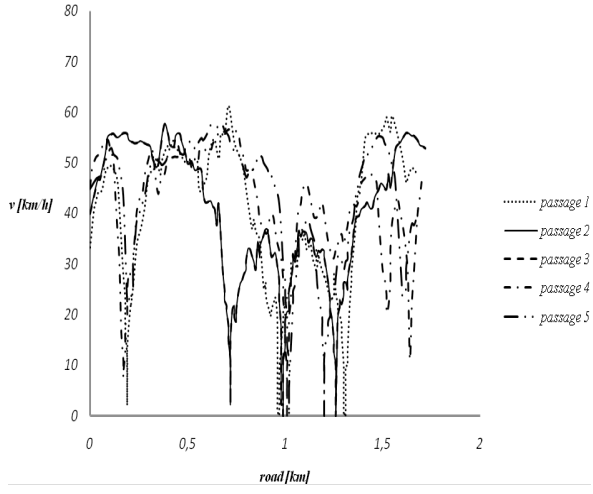

Fig. 4. Distribution of velocity (Radom, Malczewskiego street)
Source: [own work]

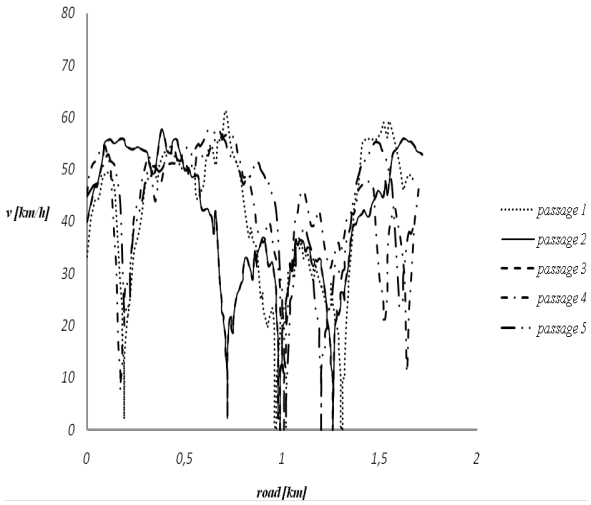

Fig. 5. Distribution of acceleration (Radom, Malczewskiego street)
Source: [own work]

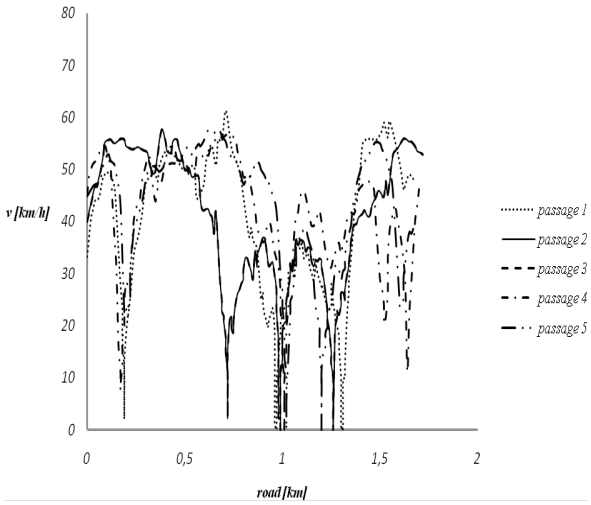

Fig. 6. Distribution of "acceleration noise δ_a" (Radom, Malczewskiego street)
Source: [own work]

5. The References Section

The GPS use allows making speed measurements without modification of a vehicle collecting the information about road traffic parameters. At every moment it is possible to make such observations without the necessity to buy special equipment or special test vehicle. Only a standard means of transport, proper GPS receiver with an external antenna and a portable computer, where measurements data will be registered, are needed. Thanks to measurements made in such a way it is possible to obtain different data with a satisfying precision. Then it is possible to interpret the results properly in reference to e.g. time or road profile. This data working out depends on the purpose which decides about the measurements necessity.

Bibliography

[1] CHALKO T., High accuracy speed measurement using GPS. http://nujournal.net/HighAccuracy-Speed.pdf 2007.
[2] CHRZAN M., JACKOWSKI S., Contemporary telecommunications systems. Part I, II, Monograph, Technical University of Radom 2008 (in Polish).
[3] DATKA S., SUCHORZEWSKI W., TRACZ M., Traffic engineering, WKiŁ, Warszawa 1999 (in Polish).
[4] DĘBOWSKA-MRÓZ M., Program of the liquidation of dangerous places on roads on the example of the Radom region. Unpublished work, Technical University of Radom, Radom 2006÷ 2009 (in Polish).
[5] DĘBOWSKA-MRÓZ M., ROGOWSKI A., Measurement and importance of research on the identification of road safety. Logistics no 6/2009, XIII International Conference-Transcomp 2009, Computer Systems Aided Science, Industry And Transport, Zakopane 2009 (in Polish).
[6] DĘBOWSKA-MRÓZ M., ROGOWSKI A., Meaning of measurement of speed in road traffic. Logistics no 2/2010, VII Conference Of Science And Technology -Logitrans 2010, Logistics, Transport Systems, Safety In The Transport Szczyrk 2010 (in Polish).
[7] GACA S., SUCHORZEWSKI W., TRACZ M., Engineering of the road traffic. The theory and the practice, WKiŁ, Warszawa 2008 (in Polish).
[8] SUDA J., The accuracy of satellite location, public transport vehicles. IV International Scientific-Technical Conference EXPLO-SHIP, Scientific Papers No11(83), Maritime Academy Szczecin 2006 (in Polish).
[9] SZCZURASZEK T. & TEAM: Safety of the urban traffic. WKiŁ, Warszawa 2005 (in Polish).
[10] TAYLOR M.: The speed of vehicles which are involved in fatal accidents. Traffic Engineering end Control No 2 (2001)