Research Article

Ján Ondruš*, Marián Gogola, Kristián Čulík, Rudolf Kampf and Ladislav Bartuška

Speedometer reliability in regard to road traffic sustainability

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Abstract: The speedometer with radar head is a device displaying the instantaneous speed of vehicles in both the directions of the traffic lane. Interactive with the video, it collects and effectively interprets particular statistic data, such as the number of passed vehicles, classification of vehicles, exceeded speed, drivers' behavior – speed change right before the measuring device, etc. The video is synchronized with the radar. In the areas where speedometer is installed, it is predicted that about 30% of the drivers slow down in front of the measuring device and about 60–90% of vehicles slow down after passing the device. The speedometer also serves as a light decelerator with respect to safe and sustainable traffic. The aim of the research was to carry out and subsequently to evaluate the three profile reviews executed on the selected road section under specific light and traffic conditions. After that, the evaluated data was compared with the real data gained by the respective reviews. The result of such comparison showed the measure of reliability and accuracy of the speedometer.

Keywords: speedometer, reliability, traffic intensity, traffic survey, speed, classification

1 Introduction of the speedometers

The speedometer is a device which shows an actual vehicle speed and collects the individual statistics (Figure 1). It is equipped with an automatic wireless data transfer through the selected network [1]. The software is equipped with attractive accessory functions such as online automatic warning in the areas where the speed is often overpassed [2].

The singular statistics (vehicles density, vehicles ranking, and license plates recognition) can be applied for establishing the roads utilization. Time and day when the speed is being overpassed most often can also be set. The operation of the instrument requires no service during the first few years [3].

The measuring instrument is mounted on a supporting construction on the trolley line pillar, at a height of 3 m (Figure 1). It is fixed in a standard technique, with the constricting tape Bandimex. The pillar is located approximately 1.5 m from the roadside. Should the pillar be too far from the road, the device accuracy and the display readability would worsen [4].

The device is aimed at informational vehicles velocity measuring. It contains a monitor with radar and shows the spot velocity of the coming vehicles, and a recording device for the predefined recording with an automatic wireless data transfer (general packet radio service) to the client [2,5]. Measured velocity data, place, and time are shown in the image. The record contains a series of images with a detailed record of the vehicle exceeding the permitted velocity. The measuring instrument is synchronized with the radar-head [6,7].

The main tasks of the device are the following:

- to show the driver the spot velocity of the vehicle,
- to record the traffic data which can be statistically evaluated,
- to provide the recorded images,
- to record the traffic violations,

* **Corresponding author: Ján Ondruš**, Department of Road and Urban Transport, Faculty of Operation and Economics of Transport and Communications, University of Žilina, Univerzitná 8215/1, Žilina, Slovak Republic, e-mail: jan.ondrus@fpedas.uniza.sk

Marián Gogola: Department of Road and Urban Transport, Faculty of Operation and Economics of Transport and Communications, University of Žilina, Univerzitná 8215/1, Žilina, Slovak Republic, e-mail: marian.gogola@fpedas.uniza.sk

Kristián Čulík: Department of Road and Urban Transport, Faculty of Operation and Economics of Transport and Communications, University of Žilina, Univerzitná 8215/1, Žilina, Slovak Republic, e-mail: kristian.culik@fpedas.uniza.sk

Rudolf Kampf: Department of Transport and Logistics, Faculty of Technology, Institute of Technology and Business in České Budějovice, Okružní 10, České Budějovice, Czech Republic, e-mail: Kampf@mail.vstecb.cz

Ladislav Bartuška: Department of Transport and Logistics, Faculty of Technology, Institute of Technology and Business in České Budějovice, Okružní 10, České Budějovice, Czech Republic, e-mail: bartuska@mail.vstecb.cz

Figure 1: The speedometer and its location.

- to share the data with the other measuring instruments, etc., [8,9].

The main function of the radar speedometer (hidden in the board) is to measure the speed. The speedometer uses the effect of the frequency change in the electromagnetic radiance during the relative movement of the radiance source, or the observer. This phenomenon was discovered by Christian Doppler [5]. The point of the Doppler's phenomenon is that the oscillation frequency defined by the measuring device is different than the oscillation frequency of the source (vehicle), if the distance of the source changes with time. This happens for instance if the vehicle drives closer to, or further from, the measuring device [10].

In praxis, this phenomenon is being used as follows: The speedometer sends a permanent unmodulated carrier frequency signal in such a way that it illuminates the measured vehicle. This signal is echoed back from the measured vehicle and is received by the speedometer. The difference between the oscillation frequency of the signal echoed back from the moving vehicle and the oscillation frequency of the sent signal is the Doppler's offset, and is in due proportion to the speed of the measured vehicle [7,11]. Mathematically, this relationship can be expressed as follows:

$$f_d = f_r - f_s = \frac{2 \cdot v \cdot f_s}{c} \cdot \cos \alpha, \quad (1)$$

where f_d – Doppler's frequency (the difference of the echoed and sent signal), v – speed of the measured vehicle (m s^{-1}), f_r – frequency of the echoed signal (GHz), f_s – frequency of the sent signal (GHz), c – light speed ($2,9979 \times 10^8 \text{ m s}^{-1}$), and α – the angle between the axes of the antenna of the speedometer and the axes of the direction of the measured vehicle [7].

It is obvious that the speed of the measured vehicle is directly proportional to the specified Doppler's frequency. Out of the above stated formula we can extract the speed.

$$v = \frac{c \cdot f_d}{2 \cdot f_s \cdot \cos \alpha}. \quad (2)$$

The system is to be most effectively used in the areas with restricted permitted speed or in the areas with higher occurrence of traffic accidents [13,34]. It increases safety in the areas with high pedestrian's appearance, such as crossings in front of the hospitals or schools.

The device shows the current velocity to the driver in real time or shows other drivers the speed of the preceding vehicles up to 80 m in front of the radar [12,14].

2 Materials and methods

2.1 The processing of the statistical data

The speedometer possesses a SYDO Traffic Tiny software which collects and statistically interprets the particular data [15]. The software shows the speed indicators with the most important information. The individual data are to be transferred into the backup source, where the SYDO Traffic Tiny software is installed, due to limited memory of the device. The data can be statistically shown as graphs or images and can also be exported to other programmes, such as Microsoft Excel [16]. The device possesses an automatic wireless data transfer to the client through the modem or an alternative feature. The entry consists of a series of images showing in detail the overpassing vehicle.

Due to the accuracy of the collected data, it is very important to correctly set the SW SYDO Traffic Tiny. Mostly the vehicles classification requires a very precise set up through the default settings. The system automatically puts the vehicle into one of the categories (passenger cars, vans, freight vehicles [FV], and combination vehicles [CV]), and saves the respective image of the vehicle into the memory [13,17].

The vehicles are categorized through the so called “virtual passing gateways,” which interpret the vehicle type based on its height, width, and length (Figure 2). The gateway automatically evaluates the vehicles category based on the measured percentage occupancy and transfers the file into the operating entity. If the gateways are not appropriately installed, the data shall be biased. Consequently the device can mistake the passenger vehicle for a lorry or a truck [3,18].

2.2 Performing the traffic survey

The traffic survey was performed to specify the traffic intensity and to carry out the vehicles classification on the respective profile. The results were compared with the results obtained from the speedometer for the same time period. Based on the result, we were able to specify the accuracy of the speedometer itself [19].

Three surveys were performed. Due to the fact, that the speedometer evaluates the statistics (traffic data) based on a videoanalysis using the “virtual drive-through gates,” the most significant problem create the vehicles driving at a very low speed. Typical problem is the traffic congestion. Taking this into account, the aim of the survey was to point out the main traffic problem – the morning and afternoon peak hours [20].

Figure 2: Virtual passing gateways [11].

The first survey was carried out on Friday, March 17, 2017 from 02:30 pm to 06:30 pm. During the survey, we aimed to catch the congestions arising during the afternoon peak hour. These congestions lasted for about 1.5 h, then the intensity started to ease.

The second survey was carried out on Thursday, March 23, 2017 from 05:00 am to 08:00 am. During the survey, we aimed to catch the morning darkness followed by the dusk (Figure 3). We also aimed to catch the morning traffic peak hour, which was at its intensity peak at about 06:00 am, then eased, and then raised again at about 07:00 am.

The third survey was carried out on Thursday, March 23, 2017 from 07:00 to 09:00 pm. During this third survey, we aimed to catch the dusk and the following dark. The vehicles intensity during this survey was very low.

The traffic research was performed at the junction of Dolné Rudiny and Závodská road, close to the downtown. The respective junction is objectionable mainly during rush hours because of a traffic density of all passenger cars, trucks, and public mass transport. The trucks density is due to a nearby industrial zone and also a public transport depot is situated nearby. The junction is also used by the trolleys heading from/to the Hájik residential area [6,21].

3 Results

The goal of this article was to evaluate the traffic intensity of the three surveys on the selected road section in Zilina. Consequently, we processed and evaluated data obtained from the speedometer, which we then compared with our data gained from the executed surveys. Based on the data comparison, we were able to define the speedometer reliability and accuracy [22,23].

Figure 3: Catching the dusk.

The vehicles were classed into three categories as follows: “passenger vehicles” (PV) (passenger cars up to 3.5 t and vans), “FV” (vehicles over 3.5 t, trolley, and busses) and “CV” (semitrailer trucks, trailer trucks, and articulated busses or trolley).

The number of vehicles and traffic classification was divided to the traffic intensity for the vehicles driving toward the device, for the vehicles driving in the opposite direction, and the total traffic intensity in both the directions [24].

3.1 Evaluation and comparison of the first survey

Table 1 shows that the total traffic intensity in both the directions for our first survey was at the level of 7,029 motor vehicles, out of which 3,395 are the incoming vehicles (48.3%) and 3,634 are the outgoing vehicles (51.7%) of the total traffic intensity in the respective section.

The total vehicles number in both the directions, based on the data obtained from the speedometer, was 6,719, out of which 3,253 are the incoming vehicles (48.4%) and 3,466 are the outgoing vehicles (51.6%) of the total traffic intensity in the respective section.

In the first category (PV + V), data obtained from our survey, compared to data obtained from the measuring device, are higher by 220 vehicles (in the direction towards the device), which presents a device deflection of 6.73%. In the direction opposite to the device, the difference was 233 vehicles, which presents a deflection of 6.6%.

In the second category (FV) and the third category (CV), data obtained from our survey are lower than those obtained from the measuring device [25]. This is due to congestions, when the measuring device evaluates the vehicles moving close to each other as trucks or CV. Also, in the evaluation there were less personal vehicles and more trucks and CV recorded by the evaluation device compared to the survey carried out by us [26]. The highest deviation (125.53%) was recorded for CV in the incoming direction; however, they created only 1.3% out of the total number of vehicles.

If we compare the traffic intensity in both the directions during our first survey with the result obtained from the measuring device we come to a conclusion that the measuring device during the first survey evaluated the statistics (traffic data) obtained from the video-analysis with the deflection of 4.41% (a difference of 310 vehicles) [27].

Table 1: Traffic intensity and traffic classification – 1st survey

Category	Survey (respective direction)		Survey (opposite direction)		Speedometer (respective direction)		Speedometer (opposite direction)		Speedometer deviation (opposite direction)	
	No.	No.	No.	No.	No.	%	No.	%	No.	%
Passenger vehicles + vans (PV + V)	3,267	3,529	3,047	3,296	–220	6.73	–233	6.6		
FV	81	60	100	102	19	23.46	42	70.0		
CV	47	45	106	68	59	125.53	23	51.11		
Total	3,395	3,634	3,253	3,466	142	4.18	409	11.25		
Grand total	7,029		6,719			4.41%				

Source: Authors.

Figure 4: Speedometer deviation for the individual vehicle categories (1st survey).

Figure 4 shows the percentage deviation of the speedometer from the survey of the individual vehicles categories [28]. The highest deviation was reached in the category “CV.”

Table 1 also specifies the number of vehicles in individual categories. During the first survey, 6,796 PV + vans (96.7%), 141 FV (2.0%), and 92 CV (1.3%) passed the respective road section (Figure 5).

Figure 5: The ratio of the individual vehicles categories (1st survey).

3.2 Evaluation and comparison of the second survey

Table 2 shows that the total traffic intensity in both the directions for our first survey was at the level of 4,248 motor vehicles, out of which 2,098 are the incoming vehicles (49.4%) and 2,150 are the outgoing vehicles (50.6%) of the total traffic intensity in the respective section.

Table 2: Traffic intensity and traffic classification – 2nd survey

Category	Survey (respective direction)		Survey (opposite direction)		Speedometer (respective direction)		Speedometer (opposite direction)	
	No.	No.	No.	No.	No.	%	No.	%
Passenger vehicles + vans (PV + V)	1,994	2,015	1,903	1,869	-91	4.56	-146	7.25
FV	73	94	100	75	27	36.99	-19	20.21
CV	31	41	70	72	39	125.8	31	75.6
Total	2,098	2,150	2,073	2,016	25	1.19	134	6.23
Grand total	4,248		4,089			3.74%		

Source: Authors.

The total vehicles number in both the directions was, based on the data obtained from the speedometer, 4,089, out of which 2,073 are the incoming vehicles (50.7%) and 2,016 are the outgoing vehicles (49.3%) of the total traffic intensity in the respective section.

In the first category, (PV + V) data obtained from our survey, compared to data obtained from the measuring device, are higher by 91 vehicles (in the direction towards the device), which presents a device deflection of 4.56%. In the direction opposite to the device, the difference was 146 vehicles, which presents a deflection of 7.25%.

In the second and the third categories (FV and CV, respectively), the data obtained from our survey are lower than those obtained from the measuring device. This is due to congestions, when the measuring device evaluates the vehicles moving close to each other as trucks or CV.

The other reason can represent a certain inaccuracy in the virtual drive through gate settings, which are used for the vehicles categorization [29]. Also, in the evaluation there were less personal vehicles and more trucks and CV recorded by the evaluation device compared to the survey carried out by us. The only exception is the FV intensity in the opposite direction, where the measuring device had registered 19 trucks lesser than that registered during the survey. The highest deviation (125.8%) was again recorded for CV in the incoming direction; however, they created only 1.7% of the total number of vehicles.

If we compare the traffic intensity in both the directions during our second survey with the result obtained from the measuring device, we come to a conclusion that the measuring device during the second survey evaluated the statistics (traffic data) obtained from the video-analysis with the deflection of 3.74% (a difference of 159 vehicles) [30].

Figure 6: Speedometer deviation for the individual vehicle categories (2nd survey).

Figure 7: The ratio of the individual vehicles categories (2nd survey).

Figure 6 shows the percentage deviation of the speedometer from the survey of the individual vehicles categories. The highest deviation was again reached in the category “CV.”

Table 2 also specifies the number of vehicles in individual categories. During the second survey 4,009 PV + vans (94.4%), 167 FV (3.9%), and 72 CV (1.7%) passed the respective road section (Figure 7).

3.3 Evaluation and comparison of the third survey

Table 3 shows that during our third survey the total traffic intensity in both directions was at the level of 1,457 motor vehicles, out of which 858 are the incoming vehicles (58.9%) and 599 are the outgoing vehicles (41.1%) of the total traffic intensity in the respective section.

The total vehicles number in both the directions, based on the data obtained from the speedometer, was 1,402, out of which 834 are the incoming vehicles (59.5%) and 568 are the outgoing vehicles (40.5%) of the total traffic intensity in the respective section.

In the first category (PV + V), the data obtained from our survey, compared to data obtained from the measuring device, are higher by 13 vehicles only (in the direction towards the device), which presents a device deflection of 1.55%. In the direction opposite to the device, the difference was 28 vehicles, which presents a deflection of 4.78%.

In the second (FV) category, the measuring device did not catch any freight vehicle (from the non-specified reason), therefore the deflections are as high as 100%. In the third category (CV), the data from the survey are similar to the data from the measuring device. This is probably due to the low vehicles intensity, when the device functions properly and precisely [31].

Table 3: Traffic intensity and traffic classification – 3rd survey

Category	Survey (respective direction)		Survey (opposite direction)		Speedometer (respective direction)		Speedometer (opposite direction)		Speedometer deviation (respective direction)		Speedometer deviation (opposite direction)	
	No.	No.	No.	No.	No.	No.	No.	No.	%	%	No.	%
Passenger vehicles + vans (PV + V)	841	586	586	828	558	828	558	-13	1.55	4.78	-28	4.78
FV	9	5	5	0	0	0	0	9	100	100	5	100
CV	8	8	8	6	10	6	10	2	25	25	2	25
Total	858	599	599	834	568	834	568	24	3.00	5.18	31	5.18
Grand total	1,457			1,402					3.77%			

Source: Authors.

Figure 8: Speedometer deviation for the individual vehicle categories (3rd survey).

If we compare the motor vehicles traffic intensity in both the directions during our third survey with the result obtained from the measuring device, we come to a conclusion that the measuring device during the third survey evaluated the statistics (traffic data) obtained from the videoanalysis with the deflection of 3.77% (a difference of 55 vehicles).

Figure 8 shows the percentage deviation of the speedometer from the survey of the individual vehicle categories. The highest deviation was reached in the category “FV.”

Table 3 also specifies the number of vehicles in the individual categories. During the third survey 1,427 PV + vans (97.9%), 14 FV (1.0%), and 16 CV (1.1%) passed the respective road section (Figure 9).

Figure 9: The ratio of the individual vehicles categories (3rd survey).

3.4 Total evaluation of the speedometer reliability

On the respective road where the measuring instrument is located, we investigated its accuracy based on the three surveys performed by us. Figure 10 shows that the

Figure 10: The reliability of the speedometer.

speedometer is rather accurate and reliable. During the first survey, it evaluated the total vehicle intensity with the accuracy of 95.59%, during the second survey with the accuracy of 96.26%, and during the third survey with the accuracy of 96.23%.

As we already mentioned, the speedometer is not able to class the vehicles correctly if there are excessive congestions in front of the virtual gate. Such a situation is shown in the Figures 11 and 12, when during the personal vehicles congestion, the measuring instrument evaluates a personal vehicle as a truck [32]. Despite this defect, we can consider the instrument as a relatively inexpensive device, very helpful for the traffic situation analysis [33].

4 Conclusion

Traffic survey is a set of activities designed to get traffic information. Traffic surveys mainly serve as a basis for solving and assessing suitability and quality of transport, for solving and designing an optimum outlook arrangement in traffic, for analyzing the current traffic situation

Figure 11: Incorrect vehicle classification [15].

Figure 12: Incorrect passenger car classification [15].

and actually solving each engineering work. Traffic surveys aim to capture data that accurately reflect the real-world traffic situation in the area. It may be counting the number of vehicles on a road, their classification, or collecting journey time information for example, but there are many other types of data that traffic surveys collect. In recent years, the manual approach has been largely replaced by new modern types of data collecting (speedometers, automatic traffic counters, etc.).

The aim of this contribution was to verify the speedometer reliability for the purposes of traffic analysis and traffic flow. The speedometer collects traffic data, such as the density, traffic intensity, velocity, etc.

We had to perform and evaluate the direction surveys of the traffic intensity on the selected road section. Consequently, we processed and evaluated data obtained from the speedometer, which we then compared with our data gained from the executed surveys. As previously mentioned we could define the accuracy and reliability with which the speedometer works.

The most objective data are gained under the ideal conditions (ideal light conditions, low traffic intensity, good wind conditions, etc.). The speedometer is rather precise (approx. 96% reliability), but in the high traffic density, in the congestions, or during the dusk, the measured data can be deformed.

The higher speedometer accuracy deviations were noticed mainly during the traffic jams during the morning peak hour. During the longer traffic research (for instance 12 h as per the Technical conditions 102), the abovementioned short-time higher deviation does not significantly influence the total device accuracy. It goes without mentioning, that the virtual passing gateways must be set properly.

The speedometer works more precisely in the incoming direction – deviation of 1.19–4.18%. In the opposite direction, the deviation is within the range of 5.18–11.25%. From the vehicles classification point of view, the highest

reliability is for the PV and vans, and the lowest reliability is for the CV.

When comparing the other studies, the authors [35] state that two traffic surveys were carried out with the deviation of 9.2% (reliability of 94.3%) and 5.7% (reliability of 94.3%). They further declare that the average difference in traffic count at two-lane road was approx. 5.0% and the average difference in traffic counts at one-lane road was approx. 6.1%.

Another device, Miovision Scout, is a video traffic counter working in different regimes. It contains a light-weight and compact, portable pole with low payload. Miovision ensures 95% + data accuracy on all traffic data collection studies using a three-step-process [36].

The main advantage of speedometer or vehicle counter is their easy installation and data collection. The system is aimed to improve the state of the traffic in the towns and villages, increase the traffic safety in certain areas, improve the traffic fluency, decrease the number of traffic accidents, decrease the number of fatalities on the roads, decrease the amount of the emissions, and improve the living standard in towns and villages. According to authors' opinion, this device is suitable for informative traffic counting, for long-term traffic counting, and for obtaining additional traffic data for traffic modeling; e.g., vehicle's speed is very important parameter for traffic model calibration [37,38].

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