Increasing the Hand Radar Efficiency in Low Cost Conditions

Prof. PhD. eng. **FILIP NICOLAE**
Department of Automotive and Transport Engineering
Technical University of Cluj – Napoca,
Cluj-Napoca, 400641, România,

Ph.D. eng. **CRISTEA FLORIN GABRIEL**
Department of Automotive and Transport Engineering
Technical University of Cluj – Napoca,
Cluj-Napoca, 400641, România,

PhD. student eng. **GROZA MARIUS**
Department of Automotive and Transport Engineering
Technical University of Cluj – Napoca,
Cluj-Napoca, 400641, România,

Ph.D. student eng. **CRIȘAN HOREA GEORGE**
Department of Automotive and Transport Engineering
Technical University of Cluj – Napoca,
Cluj-Napoca, 400641, România,

Abstract: **Mobile radars, known as hand radars become standard road patrol and are an effective way to control the vehicles speed by traffic safety point of view. Price reduced in comparison with radars mounted on the patrol cars or fixed detection systems, make these more accessible.**

We developed a complete detection and speed registration system starting from basic hand radar, finding at the same time a main low cost solution.

Our solution combines the radar system with a video camera, both linked with a portable PC, for capture the picture of the detected vehicles. For make the connection between both devices, we developed a soft for record traffic values (speed and vehicle flow together with the image capture of the target vehicle). We proposed an upgrade of vehicles detection which assure plus information recorded: vehicles flow and time delay between two vehicles which run on the same direction. Supplementary a data base is automatic created and it contains vehicle capture image in sated speed detection limit conditions.

We test the developed system in laboratory conditions (testing center) and in real conditions (national road). The results showed the viability of the proposed upgrade developed for the hand radar equipment, based on the video and statistic information acquired as a low cost solution.

Keywords: hand radar, vehicle flow, video capture, speed, database.

I. INTRODUCTION

Vehicle detection represents a continuous demand for traffic safety survey. There are two major considerations for the speed detection of the vehicles in traffic [1] .

- in terms of ongoing traffic conditions, it represents one of the input data used for developed traffic optimization algorithms;
- in term of the vehicle platoons` safe movement on public roads, the speed represents the parameter to which legislative measures, with direct effect on drivers behavior, have been associated.

For speed detection, there are equipments that correspond to the metrological rules, called kinetic speed meter. Currently, however, radars are used. The calibration and the speed detection conditions represent a discussion point for most traffic operators [2] .

The radars are equipments consisting of a signal generator connected to an emitter (antenna) and a receiver (processor) connected to a data displaying device. The radar detection principle is based on the Doppler effects. It consists of generating (acoustic, electromagnetic, laser) waves at an imposed frequency and comparing these with the received wave [3] .

Depending on the relative position of the target object encountered by the wave (moving towards, moving away or resting), the frequency of the received wave will be modified in ways that can be translated in the vehicle's speed relative to the emitter, according to the Doppler effect [4] .

In Europe, the frequencies in which both mobile and stationary radars operate are established too: X low band – 9.20 – 10.00 GHz; X band – 10.50 – 10.60 GHz; Ku band – 13.40 – 14.00 GHz; K band – 24.05 – 24.25 GHz; Ka band – 33.40 – 35.20 GHz [5] .

In order to be used for speed detection in Romania, the radar equipment has to be approved by the Romanian Office of Legal Metrology according to the norms of legal metrology NML021-05 considering the following operation regulations in accordance with international legislation [6] .

- OIML R 91/1990 – "Radar equipments for measuring vehicle speeds" ;
- OIML D 11/2004 – "General requirements for electronic measuring devices" ;

- Legal metrology requirements NML [7] .

The radar equipments used by the traffic patrols in our country have been researched and analyzed. A statistic of the radar equipments approved to be used in Romania from 1994 to 2016 is shown in Table 1.1 [3] .

TABLE. 1.1 CHRONOLOGICAL LIST OF HOMOLOGATED RADARS IN ROMANIA

Authoriza-tion docu-ment	*Homologa tion date*	*Item name*	*Manufacturer*	*Term of valid-ity*
AM 231/94	18.01.1994	Traffipax-speedophot-m	Trafiipax-vertieb	31.03.1995
AM 090/95	31.03.1995	Traffipax-speedophot-m	Trafiipax-vertieb	31.03.2005
AM 333/99	16.07.1999	JAI Pro Vida 2000/Stalker Dual	JAI A-S	16.07.2004
AM 535/99	20.12.1999	AMVT 01	S.C. FEA S.A.	20.12.2003
AM 185/01	27.07.2001	Autovision Compact PY-THON II	Traffic Safety Systems Limited Anglia	27.07.2006
AM 242/05	22.11.2005	Gatso GTC-D	Gasto Meter BV Olanda	22.11.2010
AM 271/05	21.12.2005	Gatso DRCS	Gasto Meter BV Olanda	21.12.2010
AM 168/06	27.10.2006	Multiradar S580	Robot Visual Systems Germa-nia	27.10.2011
AM190/06	18.12.2006	Codec C01	SC CODES SRL Cluj-Napoca	18.12.2011
AM 290/07	06.12.2007	PoliScan Speed	Vitronic Germania	06.12.2012
AM 301/07	20.12.2007	Trafficam TCS-1	Intellicam ltd Israel	20.12.2012
AM 059/08	10.10.2008	Scout Stalker Dual DSR	Sintel Italia	10.10.2013
AM 012/09	13.03.2009	Radar AUTOVISION	Traffic Safety Systems ltd. GB	13.03.2014
AM 032/09	01.06.2009	CODEC C02M	SC CODEC SRL	01.06.2014
AM076/09	12.10.2009	Redflex Radarcam	Redflec traffic system Austra-lia	12.10.l2014
AM 089/09	18.12.2009	Redflex Red-speed	Redflec traffic system Austra-lia	18.12.2014
AM 022/10	07.06.2011	Velored Base	SCAE SPA Italia	07.06.2015
AM 002/11	23.03.2012	LTI 20/20 TruCam	Laser Technology USA	23.03.2016

Increasing the radars efficiency represents a continuous demand. J. Sánchez - Oro and all, proposed a system which detects tracks and computes the speed of vehicles and also generates alerts when vehicles exceed the predefined road speed limit [8] . The radar detection efficiency, including Doppler radars, are tested in the urban traffic real conditions. Soledad proposed an speedometer which boarded in the target vehicle, estimates its speed from the Doppler variation of the GPS satellites signals, and transmits it via radio to the police vehicle, where the radar can verify where is located [9] .

The radar efficiency verification was detailed in few research articles, in order to reduce the detection errors. Lei Due & all, investigated the speed measurement error of ATR (Across-The-Road) radar, related to antenna horizontal beamwidth, and theoretically calculated in various combinations of installation angles and horizontal beamwidths [10] .

Increasing the hand radar efficiency by attaching a video recorder device, was tested too. Greg C. & all, evaluate the speed and traffic safety effects of the photo radar program. The study employed a number of analytical frameworks, including simple before and after comparison, time-series cross-sectional analysis, and interrupted time series analysis [11] .

Arunesh R. & all, analyzed Continuous Wave (CW) Doppler radar speed measurement systems lack the ability to distinguish multiple targets, using the video 3D processing capture. The 3D tracking information obtained from the calibrated video camera, was used with more accurate information from the Doppler radar, in order to produce a position and velocity track of the targets, within the surveillance region [12] .

We proposed a device attached to the usually digital hand radar, for collect more informations regarding to the speed detection. We consider the fact that it will be useful to attach at the speed enforcement, a capture of the vehicle. By the other side, the data collection on a databased, design in this purpose, represent an opportunity for count the traffic on the surveyed road. We developed a soft application which offer few options as: to set the speed limit for video capture alert, in accordance with the each road requirements. Using the recorded information's, we improve a calculation method for identify some details regarding to the traffic flow and the type of data storage in the database.

II. MATERIALS AND METHOD

A. Design elements for acquiring data from mobile radar

The mobile radar has a high degree of flexibility and it is successfully used in traffic surveys. It is recommended to place this type of radar on a tripod, in order to decrease the possibility of operational errors occurred. For research, we used in the laboratory conditions, commercial Genesis Decatur mobile radar. It is a speed mobile detection equipment, with optimized features and ability to communicate real-time data. It is presented in fig. 2.1 [13] .

Main technical characteristics of Genesis Decatur hand radar are: work frequency *K* band (24.150 GHz); Stationary Accuracy: +/- 1 MPH; Target Speed Range: 12-210 MPH; Speed Sampling Rate: 100 Samples / Sec.; Beam Width: 12^0; Power Output: 10 mW; Supply Voltage: 8.5 - 16.5 VDC; connection option to a computer or a printer by using a serial communication port.

Figure. 2.1 Genesis Decatur mobile radar

Considering the operability and the flexibility of the Genesis Decatur mobile radar, several upgrade possibilities we analyze. From the radar's communication options through the serial port, the ones usable for saving the data in a database on a PC were identified, so the recording's results can be used in traffic calculations. In order to optimize the recordings with this radar, a series of objectives we take into consideration, objectives that meet the needs of both the traffic safety patrols and the traffic operators [14] .

For capture the image we used a low cost HD webcam, easy assembled on the car patrol [15] . The main characteristics of the HD camera are: 720p HD video calling (up to 1280 x 720 pixels); Carl Zeiss lens with 20-step auto focus; automatic low-light correction; photo capture up to 15 megapixels [16] .

We select the connection between the radar, web cam and PC according with the diagram from fig. 2.2. The PC makes the link between the radar device and the webcam. Both two are considered offering input data for the proposed system. The output dates storage in a database are: the traffic parameters obtained during the traffic survey, mean speed resulted from timer observation and pictures with the detected vehicles.

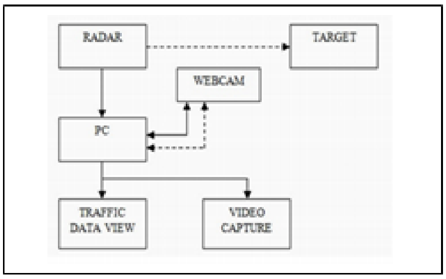


Figure 2.2 The radar, PC and webcam connection diagram

Our proposal respects the technical demands and the on day target, to offer low cost and precisely measurement solutions [8] .

In this context, appeared the need to distribute the recordings in a database, so they would be available to traffic operators. The possibility to attach a photo of the target object, in the moment of detection, represents an option proposed by the police patrol users. The photo must contain identification characters as: the car sped, date and time of the operating work.

For this reason we consider necessary to develop a software application that satisfies the aforementioned needs of the operators. In order to connect the radar to the PC, the jack output of the serial port RS 232 was used.

By means of 2 pins, the mobile radar Genesis Decatur sends to the PC a sequence of characters as the sample shows in fig. 2.3. The couple of characters representing the speed recorded by the radar, is the second one, so only 5 characters are taken into consideration, starting with the 7th position.

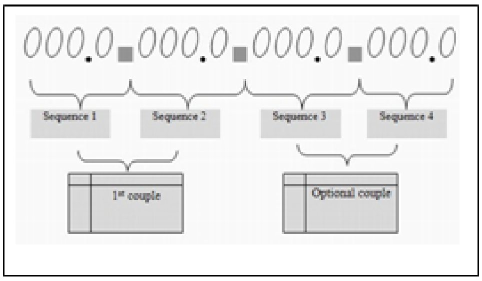


Figure. 2.3 The character string generated by the communication connection of Genesis Decatur mobile radar

For establish the main connection between the selected hand radar and a PC, we analyze the communication port offered by the manufacturer. For that we began basically analyzing the communication port of the device and its accessibility.

B. The database application developed

The analysis of the data required accompanying the speed detection correlated with the vehicle flow and the requirement to identify the targeted vehicle, led us to identify the demands by traffic safety and traffic engineering point of view presented in the following Table 2.1 [4, 5 , 17, 18] .

TABLE 2.1 ANALYSIS OF DATA ACCOMPANYING THE DETECTION

Specification	Relevance Level			
	1	2	3	4
Date and time detection				
Recorded speed				
Vehicle Image				
Vehicle Flow				
Vehicle speed				
Weather conditions				
Interval between vehicles				
Average traffic speed				
Where:				
1	*Priority demand*			
2	*Very necessary*			
3	*Useful*			
4	*Informative*			

By taking into account the ranking from Table 2.1, we have identified the parameters that can be correlated by upgrading the hand radar. Because the print-screen is a very necessary parameter, we reached/developed the option to connect the web-cam to the radar.

For record the measured speeds and to have a database with the images of the target vehicles, a Visual Basic algorithm was developed according with the considered requirements presented in table 2.1. That allows the users to record the measurements using the following options [19, 20, 21, 22] .

- ***Option 1:*** *Save all with photo* – enables the user to record in the database all the measurements made, also saving the photo taken of the target vehicle;
- ***Option 2:*** *Save all without photo* – enables the recording in the database of the speed values, without saving the photo;
- ***Option 3:*** *Save with photo, but only if the vehicle's speed exceeds the speed limit* – allows the possibility of entering a speed limit, above which the recording is made. It also saves the photo taken of the target vehicle;
- ***Option 4:*** *Save without photo, but only if the vehicle's speed exceeds the speed limit* – allows the possibility of saving in the database only those recordings made of vehicles exceeding the speed limit. It doesn't save the photo;
- ***Option 5****: Save with photo, if the vehicle's speed exceeds the speed limit and without photo otherwise* – allows the possibility of saving the recording with photo, if the speed limit is exceeded and saving the recording without a photo if the vehicle is moving below the speed limit.

The webcam is always on stand-by and it becomes active when the radar information meets a condition given by an *if* decision block. The software interface designed in this purpose allows us to operate the webcam with the radar.

It starts by preparing the reading and data-storing environment (it opens the database, it opens the radar communication port, it opens the webcam communication port) and then, the speed recordings begin. Any detected speed greater than 0 is saved in the database, according to the options selected by the operator (fig. 2.4). If the measured value does not fit any of the categories, it is deleted and the equipment moves on to measuring new values.

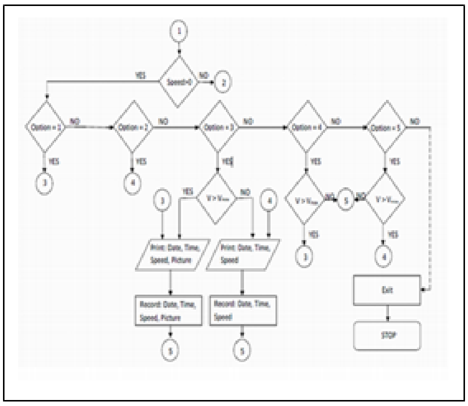


Figure. 2.4 The algorithm of the application developed for acquisitioned parameters

In order to record the information in the database, the developed software uses as an input parameter, the real-time radar recordings. From the decision blocks the software operating procedures are selected, according to the requirements described above.

The software was developed considering the imposed requirement to have the option to access the menu in both Romanian and English. Recording the information in the database is done using an algorithm. Accessing the database and filtering the information is the first decision level for the developed software. In order to record the information in the database, the developed software uses as an input parameter the real-time radar recordings. From the decision blocks the software operating procedures are selected, according to the requirements described above (fig. 2.5).

The traffic safety requirements considered during the software's design were [23, 24, 25] .

- Identifying the traffic participants who exceed the speed limit on the monitored road sectors: this data is saved by registering the time and date as well as the speed with which the vehicle was running at the time and an image capture of the vehicle on which the aforementioned data is written;
- Identifying the vehicles` speed:

  The data collected in the database can, if necessary, be transferred to an Excel file in order to facilitate spreadsheet calculation, subsequently used to develop traffic analysis by:
- Calculating the hourly flux density;
- Calculating the average traffic value in the DEN (Day, Evening, Night) time period;
- Calculating the average speed;
- Identifying (0.85 and 0.15) of mean speed deviation.

The software allows the user to operate with the databases in order to identify the required data through successive queries, so there is no need to manually search for a record or a specific set of records.

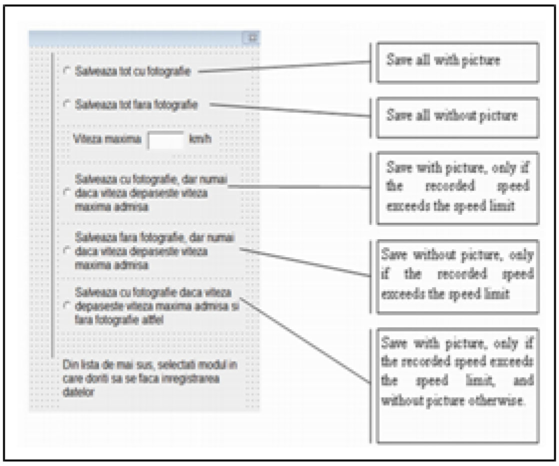


Figure. 2.5 Saving options interface, in native language and English translation

III. REZULTS AND DISCUSSIONS

After having checked the system's compatibility in the laboratory, two stages tests we proposed in order to evaluate the upgrade availability.

First tests consist of proposed system evaluation by synchronize point of view between the radar detection and webcam capture availability. On this stage, the database recordings were evaluate and verified regarding to the time recognition and data allocation, according with the assigned sign.

In the second part of tests, the system was used in real traffic condition on a national road E 60, assisted by the police patrol operators. The feedback of the measurements results consist of:

- How easy the equipment was to use;
- The impact of the information it gave;
- The mean traffic values calculation with the proposed soft options.

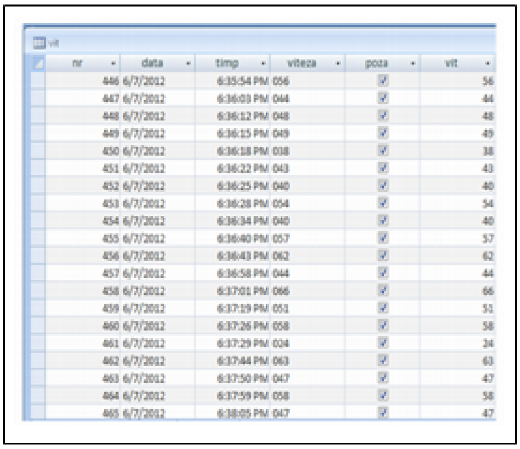
We store on the PC more than 1120 registrations for two hour speed detection on the same observation location. The results stored in database for the tests carried out, are presented in fig. 3.1.

The tests on road were conducted only by day time and at the measurements participate patrol officers too. Analyzing the results of the measurement session led to the following basic conclusions:

- The synchronization remained stable;
- The image-quality had improved, but not enough to clearly identify particular features of the target vehicle.

Furthermore, several requests suggested by the radar's users (traffic safety patrols) were taken into consideration, such as: Printing on the image capture the movement speed while mentioning the time variable as well as in fig. 3.2.

On the PC display we have the possibility to manage the measurements procedure and also the real time speed detection is available. First of all was necessary to increase the video resolution because due to synchronize time between the video – radar and PC, the first capture was not so clear.



vit

nr	data	timp	viteza	poza	vit
446	6/7/2012	6:35:54 PM	056	☑	56
447	6/7/2012	6:36:03 PM	044	☑	44
448	6/7/2012	6:36:12 PM	048	☑	48
449	6/7/2012	6:36:15 PM	049	☑	49
450	6/7/2012	6:36:18 PM	038	☑	38
451	6/7/2012	6:36:22 PM	043	☑	43
452	6/7/2012	6:36:25 PM	040	☑	40
453	6/7/2012	6:36:28 PM	054	☑	54
454	6/7/2012	6:36:34 PM	040	☑	40
455	6/7/2012	6:36:40 PM	057	☑	57
456	6/7/2012	6:36:43 PM	062	☑	62
457	6/7/2012	6:36:58 PM	044	☑	44
458	6/7/2012	6:37:01 PM	066	☑	66
459	6/7/2012	6:37:19 PM	051	☑	51
460	6/7/2012	6:37:26 PM	058	☑	58
461	6/7/2012	6:37:29 PM	034	☑	34
462	6/7/2012	6:37:44 PM	063	☑	63
463	6/7/2012	6:37:50 PM	047	☑	47
464	6/7/2012	6:37:59 PM	058	☑	58
465	6/7/2012	6:38:05 PM	047	☑	47

Figure 3.1 Speed recorded exemplification of database access

Processing the traffic results, allowed us to create a traffic statistic detailed in:

- Distribution of speed's frequency;
- The variation of the traffic flow;
- The relative frequency of speeding detailed in 10 km/h intervals.

In order to validate the radar's upgrade, successive stages of experimental trials were needed.

Going through these stages, led to adjustments to the software, so both the data and the image/video recordings were improved.

For the video capture, in order to prove the speeding, is necessary to accurately identify the targeted vehicles. The accuracy depends on the delay with which the print-screen is generated, which in turn depends on the signal the PC receives from the radar.

The collected parameter types, allow us to determine through simple operations, the traffic indicators and so by recording the passing vehicles, we can determine the traffic flows, using the relation 3.1 .

$$\theta = \frac{6}{n} \cdot \sum_{i=1}^{n} K_i \quad [veh/hour] \qquad (3.1);$$

Where:

K_i - vehicle's order number;

n - the number of recorded vehicles on 10 minutes interval.

In order to determine the succession interval between vehicles, was used the relation 3.2 .

$$\Delta = t_i - t_{i-1} \quad [s] \qquad (3.2);$$

Where: t_i - the moment when the order i vehicle has passed;

The hourly succession interval has been determined by using the relation 3.3 .

$$\Delta_m = \frac{6}{n} \cdot \sum_{j=1}^{n-1} \Delta_j \quad [s] \qquad (3.3);$$

Where: Δ_j - the succession interval between vehicles;

Average recorded speed for each hour has been calculated through relation 3.4 .

$$V_m = \frac{6}{n} \cdot \sum_{i=1}^{n} v_i \quad [km/s] \qquad (3.4);$$

Where: v_i - measured velocities of vehicles;

The values can be updated every 10 minutes, throughout one hour, using the soft options.

An example with regard to the calculated traffic parameters, using above statistic relations, is shown in fig. 3.2 .

Figure 3.2 Capture of detected vehicles and basic information on PC display registered in the data-base

IV. CONCLUSIONS

Improving the existing radar equipments by upgrading them is a viable solution for maintaining thereof in use, if we consider the costs of purchasing new equipments. The requirement regarding proving the speeding driver's guilt, is subject to the procedural demand to prove the finding.

By upgrading the Decatur radar, several opportunities were created; opportunities that should be taken into consideration because they regard to obtaining statistical data concerning the actual ongoing traffic conditions, during the monitoring period.

By taking into account the users (both the traffic operators and the traffic safety patrols) requests, the common radar, available at a medium price, was upgraded.

Attaching the image capture as well as the software designed to develop the database and the recording option, proved to be viable throughout the conducted tests.

An analysis in a time reference system, showed that delay is not constant, varying between 25 ms and 600 ms for each registered speed value.

The speed of the image processing, directly depends on the characteristics of the PC's processor and this constitutes a limitation of the detection equipment which leads to maximum delay values when a speeding vehicle was detected.

The developed database highlights a less explored feature of this type of radar.

By processing the records exported in XLS format, several traffic parameters can be calculated.

The proposed system represents a low cost solution for increase the efficiency of the common radars in use.

V. REFERENCES

[1] Weil, R., J. Wootton, J., García-Ortiz, A., Traffic incident detection: Sensors and algorithms. Mathematical and Computer Modelling, 1998, Volume 27, Issues 9–11, 257–291.

[2] Jendzurski, J and Paulter, N.G., Calibration of Speed Enforcement Down-The-Road Radars. J. Res. Natl. Inst. Stand. Technol., No. 114, 137-148, 2008.

[3] * * * Radar equipment for the measurement of the speed of vehicles. International Recommendation OIML R 91, 1990.

[4] Filip N., Ingineria Traficului Rutier, Cluj-Napoca, Ed. Mediamira, 2010.

[5] Holland, C.A., Conner, M. T., Exceeding the speed limit: An evaluation of the effectiveness of a police intervention. Accident Analysis & Prevention Journal, 2008, Vol. 28, Issue 5, 587–597. http://dx.doi.org/10.1016/0001-4575(96)00031-0.

[6] * * * http://www.brml.ro/download NML/NML.

[7] * * * Legal metrology requirements NML 001-05. www.untrr.ro.

[8] Sánchez-Oro, J., Fernández-López, D. Cabido, R., Montemayor R.S., Radar-based road-traffic monitoring in urban environments. Digital Signal Processing, 2013, Volume 23, Issue 1, 364–374. http://dx.doi.org/10.1016/j.dsp.2012.09.012.

[9] Soledad T. G.,Esteban V. F., Miguel S., J. Alfonso M. A traffic radar verification system based on GPS–Doppler technology. Measurement Journal, 2010, Volume 43, Issue 10, 1355–1362. http://dx.doi.org/10.1016/j.measurement.2010.07.

[10] Lei D., Qiao S., Changqing C., Yue Z., Hongbo H., Verification methods and antenna horizontal beamwidth of across-the-road radar for traffic speed enforcement in China. Measurement, 2013, Volume 46, Issue 4, 1512–1520. http://dx.doi.org/10.1016/j.measurement.2012.11.023\.

[11] Greg C., Jean W., Wayne M., Peter C., Evaluation of photo radar program in British Columbia. Accident Analysis & Prevention, 2000, Volume 32, Issue 4, 517–526. http://dx.doi.org/10.1016/S0001-4575(99)00071-8.

[12] Arunesh R., .Gale, N., Lang H., Automated traffic surveillance using fusion of Doppler radar and video information. Mathematical and Computer Modeling, 2011, Volume 54, Issues 1–2, 531–543. http://dx.doi.org/ 10.1016/j.mcm.2011.02.043.

[13] * * * http://decaturelectronics.com/ content/genesis-handheld-directional.

[14] Samuel, N., Police technology in cities: changes and challenges. Technology in Society, 2011, Volume 23, Issue 1, 2001, 11–27. http://dx.doi.org/10.1016/S0160-791X(00)00033-6.

[15] Huaguo Z., Fatih P., Peter H., A new roadway lighting measurement system. Transportation Research Part C., 2009, Volume 17 , 274–284. doi:10.1016/j.trc.2008.11.001.

[16] * * * Logitech HD Pro Webcam C920, technical specifications.

[17] Bar-Gera, H., Evaluation of a cellular phone-based system for measurements of

traffic speeds and travel times: A case study from Israel. Transportation Research Part C., 2007, Volume 15, Issue 6, 380-391.

[18] D'Ariano, A. Pacciarelli, D. Pranzo, M., Assessment of flexible timetables in real-time traffic management of a railway bottle-neck. Transportation Research Part C., 2008, Volume 16, Issue 2, 232-245.

[19] Clarck J.C., Webb J., Visual Basic 6.0 Developer's Workshop, Microsoft Press, 1998.

[20] Finaru L., Brava I., Visula Basic primii pasi … si urmatorii, Editura Polirom, 2001.

[21] Tylee, L., Learn Visual Basic 6.0. KIDware 15600 NE 8th, Suite B1-314, Bellevue, 1998.

[22] Bolderdijk, J.W., Knockaert, J., Steg, E.M. Verhoef. E.T., Effects of Pay-As-You-Drive vehicle insurance on young drivers' speed choice: Results of a Dutch field experiment. Accident Analysis and Prevention Journal, 2011, 43, 1181–1186.

[23] Bogaert. M., Video-based solution for data collection and incident detection. Traffic Technology International '96, UK & International Press, 150–156, 1996.

[24] Lebre, T., Advanced video-based incident detection. Traffic Technology International '96, UK & International Press,. 147–148, 1996.

[25] Liu, A. & al., Traffic flow prediction by radial basis function networks. Proceedings of the Neural Network Applications in Highway and Vehicle Engineering, Washington, DC, 1996.

