RADAR SPEED DISPLAYS AND THEIR EFFECTS ON SPEED BEHAVOIR OF DRIVERS

Klavdija Krznarič, Peter Dernič
JP LPT d.o.o., Ljubljana, Slovenia
Andreja Jarc, Klemen Perko
Sipronika d.o.o, Ljubljana, Slovenia
Marko. I. Valič
Faculty of Maritime Studies and Transport, University of Ljubljana, Portorož, Slovenia
klavdija.krznaric@lpt.si, andreja.jarc@sipronika.si, marko.valic@fpp.uni-lj.si

ABSTRACT

In the contribution a brief review of radar speed detection, radar speed displays and their presumed effects on traffic calming is presented. In the wider area of Ljubljana quite a few of these systems are model MHP50 produced by Sipronika d.o.o. In this study an attempt was made to evaluate the effectiveness of these installations by using only the data a standard commercial unit provides. To achieve the goal, several week-long measurements were made on two locations with different traffic flow characteristics and speed limits imposed. The measurements were carried out with speed displays operating (visible, ON) and speed displays non-operating (covered, OFF). From a limited choice of available measured and stored parameters, a detailed analysis of the data available lead to some positive conclusions regarding the effectiveness of these devices for speed calming in urban traffic. The work is a partial results of the research project 'REMSIS' co-founded by EU incentive EUREKA and supported by the Ministry of Science and Technology of R Slovenia.

KEYWORDS: speed indicator display, speed control, speed calming

INTRODUCTION

Radar speed displays have become the technology of choice for a growing number of law enforcement professionals looking to slow traffic. In surveys of police officers, traffic engineers and traffic safety officials, the displays were identified as the single most effective traffic calming solution near schools, playgrounds and neighborhood streets. More than speed bumps, stop signs or even police with radar or laser guns, radar speed displays were ranked as the preferred means of slowing speeders and keeping average driving speeds down in the long run. There are numerous studies made in various locations under different conditions using other auxiliary measuring techniques to evaluate the effectiveness of these systems [1,2]. In Slovenia a considerable increase of radar speed display installations started in the year 2000. In the wider area of Ljubljana quite a few of these are model MHP50 produced by Sipronika d.o.o. In this study an attempt is made to see whether the effectiveness of these devices can be determined by using only the data a standard commercial unit provides, i.e., without any internal modification, other external interventions or auxiliary instruments for the purpose of this evaluation.

EXPERIMENTAL

The measurements were conducted on two locations where permanent Sipronika radar speed displays, model MHP50 are installed. The first of the two, under jurisdiction of JP LPT d.o.o., is located within the city of Ljubljana in the southern part on the 'Jurčkova' road. In Figure 1 an ortho photo snapshot of part of 'Jurčkova' on which the location of the radar speed display, by the side of a pedestrian crossing, is indicated (red line). The radar with speed display visible (left) and display covered (right) is shown in Figure 2. The second system, on the state road R3-742 Podpeč-Brezovica and under the jurisdiction of DRSC, has been installed very recently (17/2/2010) on the 30 km/h speed zone section of the road. In Figure 3 an orto photo view of the Podpeč-Brezovica road is shown with the location of the radar display indicated. The installation is in the immediate vicinity of a school (lower left corner in Figure 3). A close-up view of the display and speed limit sign is shown in Figure 4. Personal vehicles are predominant in the traffic flow at this site with inter-city type daily time variations during working days. The radar speed display in this case is configured in the following way. When a car drives within posted speed (30 km/h) on the display, apart from speed an accompanied message 'HVALA' (eng. 'THANK YOU') is written out. In the case of speeds in the 30 to 35 km/h range, the display begins to blink with no accompanied text. For speed > 35 km/h (17 % over the limit) on the display, apart from the speed value, an accompanied warning 'POZOR ŠOLA' (eng. 'CAUTION SCHOOL') shows up.

The MHP50 radar speed meter and display system has been described in an earlier reference [3]. Its Doppler radar operates at a frequency of 24 GHz. The minimum speed detected was set to 8 km/h at Jurčkova and 20 km/h at Brezovica site. The primary function of the system is to measure and to display the speed of a vehicle once it enters the radar speed detection zone.

Figure 1: Ortho photo view of 'Jurčkova' road

Figure 2: View of the radar speed display visible (left) and display hidden (right)

Figure 3: Ortho photo view of 'Podpeč-Brezovica' road

Figure 4: View of the radar speed display and speed limit sign on Brezovica site

It is important to know that MHP50 in these particular applications is configured to measure and display speeds. It stores only four parameters:

- speeds of individual vehicle V_i ;
- number of speed measurements (vehicle speeds recorded) N_k^V in each 15 min interval (in accumulated mode);
- dates;
- interval times;

that are available for the analysis. Further, the speed V_i of each vehicle is recorded several times depending on its actual speed, when driving through the radar detection zone D (the length of radar beam in the lane direction). The number of speed values N_i recorded for each vehicle is

$$N_i = \frac{D}{V_i\, T_r} \qquad (1)$$

where T_r is a predetermined time (1.5 s) between two successive speed measurements. The radar detection zone D can be determined from the radar range R (100 and 125 m for Jurčkova and Brezovica-Podpeč roads, respectively), radar's height position H and beam divergence (Figure 5). Due to a very small ratio H/R, the cos α correction to the measured speeds is negligible, meaning that N_i -times measured speeds V_i are equal. Eq. 1 is valid when car-to-car spacing is $\leq D$. This is certainly true during the late evening and early morning hours (low traffic) but not necessarily in conditions of denser traffic. Therefore all V_i and N_i values cannot be determined from the data available. All other data, e.g., average interval speed $\bar{V}_k$, maximum interval speed $\bar{V}_{\max,k}$, percentile interval speeds (e.g., $\bar{V}_{85,k}$), interval number of vehicles N_k (volume $Q_{15\min,k}$) etc., are derived from stored data. Thus, the average interval speed here is calculated as an average of all speed recorded $\bar{V}_k^V$ (eq. 2, left) and not as an average of speed $\bar{V}_k$ of N_k vehicles (eq. 2, right):

$$\bar{V}_k^V = \frac{1}{N_k^V}\sum_1^{N_k^V} V_i \quad ; \quad \bar{V}_k = \frac{1}{N_k}\sum_1^{N_k} V_j \qquad (2)$$

where N_k is the number of vehicles in each interval. In a similar manner the volume $Q_{15\min,k}$ is calculated using equation

$$Q_{15\min,k} = \frac{N_k^V}{\bar{N}_k^1} = \frac{N_k^V}{\bar{V}_k^V}\, f \qquad (3)$$

where $\bar{N}_k^1$ is an average number of speeds per vehicle and f a factor taking into account radar range R and T_r. Important here is that

$$\bar{V}_k^V < \bar{V}_k \ , \qquad (4)$$

the measured values $\bar{V}_k^V$ are smaller than $\bar{V}_k$ by several percents.

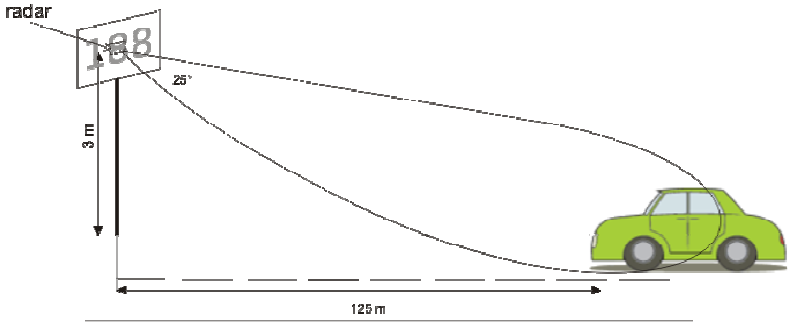

Figure 5: Geometrical data of MHP50 device schematically

RESULTS

All measurements, eight in total, were taken for week long periods. The start/end of periods, locations and state of display are summarized in table 1. There is a great body of results to be analyzed but only the most relevant are presented here.

In table 2 the speed class shares, week average interval speed $\overline{V}_{week}$, maximum interval speed $V_{week,max}$, total number of vehicles N_{week} and percentage of recorded speeds over speed limit for each measurement on the two locations, are presented. On 'Jurčkova' the posted speed limit is 50 km/h, on Brezovica 30 km/h. It is important to emphasize that the values given are week average (large sample with over 10^5 recorded speeds).

The week average speeds $\overline{V}_{week}$ (measurements 1, 2, 5) on Jurčkova are 48,6 km/h with the display operating (visible) and 49,0 km/h with display covered (hidden). The difference is hardly noticeable but indicative of a small increase of $\overline{V}_{week}$ in favor of covered display. Such a result is expected for the following main reasons: very large sample (averaging!), 'old' installation (in the sense that the majority of drivers have become aware of non-penalizing function of the installation) and a narrowed roadway due to piles of accumulated snow (Figure 2). In fact, lower values of $\overline{V}_{week}$ in measurements 3 and 4 are due to the days of heavy snowing. On the contrary, the difference in $\overline{V}_{week}$ on Brezovica site (measurements 7, 8) of 2,6 km/h/) is very pronounced for display visible or hidden. It should be pointed out that during measurement 7 there were two days (Feb 10 and 12) with relatively heavy snowing, meaning that the difference should be, by comparison with results on Jurčkova, much larger (about doubled).

Table 1: Start/end periods, locations and state of display of data collections

	start		**end**		**location**	**display**
No.	**day/hour**	**date**	**day/hour**	**date**		
1		02.12.2009		09.12.2009	Jurckova	visible
2	Wen 10:00	09.12.2009	Wen 10:00	16.12.2009	Jurckova	visible
3		16.12.2009		23.12.2009	''	visible
4		06.01.2010		13.01.2010	''	visible
5		13.01.2010		20.01.2010		hidden
6		20.01.2010		27.01.2010	Jurckova	visible
7		10.02.2010		17.02.2010	Brezovica	hidden
8		17.02.2010		24.02.2010	Brezovica	visible

DISCUSSION

In Figure 6 the vehicle volume $Q_{15\min,k}$ for each day of the week for measurement 4 (Jan 6 ÷13) is presented. For working days the shape of the shapes of the curves are typical for the city traffic, very low in the early morning hours up to 6:30 (on Sun up to 8:00), increasing sharply from then on up to 8:30. From there on the flow is slowly and steadily increasing up to 17:00 and after that strongly decreasing to the low value at around midnight. A very different behavior is seen on Friday (exception due to heavy snowing) and expectedly on the two non-working days (Sat and Sun).

In Figure 7 a comparison of daily interval average speed, maximum speed and flow $Q_{15\min,k}$ is shown separately for two consecutive measurements (5 and 6), for the same day of the week (Thu Jan 14 and 21), with display hidden and visible, respectively for measurements 5 (Fig. 7 above) and 6 (Fig. 7 bellow). The general shapes of the three curves on each diagram are much the same. Higher $Q_{15\min,k}$ (reaching above 80, i.e., 6 vehicles per minute) occur from about 8:00 to 18:00. During these hours the flow is more or less forced. This is depicted in Figure 7 with average interval speeds close to speed limit and with less scatter. In the late evening and early morning hours the flow is nearly free permitting higher average interval speeds with larger scatter. Some differences between curves showing the data with the display visible or hidden are also noticeable.

Table 2: Speed class distribution from all measurements on the two locations

Speed (km/h)	Speed class share in individual measurements (%)							
Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
< 30	7,8	8,5	10,0	11,5	7,5	7,7	1,5	4,1
≥ 30 ÷ < 40	10,9	11,9	15,9	15,9	9,7	10,1	10,7	19,7
≥ 40 ÷ < 50	36,5	36,4	39,6	38,2	34,1	35,1	38,6	40,6
≥ 50 ÷ < 60	36,6	35,5	29,1	28,7	39,1	37,7	38,0	28,1
≥ 60 ÷ < 70	7,0	6,5	4,7	4,9	8,3	8,1	9,4	6,3
≥ 70 ÷ < 80	1,0	0,9	0,7	0,7	1,1	1,1	1,4	1
≥ 80 ÷ < 90	0,1	0,2	0,1	0,1	0,1	0,2	0,3	0,2
> 90	0,1	0,1	0,1	0,02	0,1	0,1		
$\overline{V}_{week}$	48,9	48,5	46,5	44,9	49	48,4	50.9	48,3
$V_{week,max}$	131	127	125	140	118	131	121	120
N_{week}	31.338	31.651	30.620	25.473	29.545	27.915	25.502	27.156
speed > limit (%)	44,8	43,2	34,7	34,4	48,7	47,2	98,5 (49,1)	95,9 (35,6)

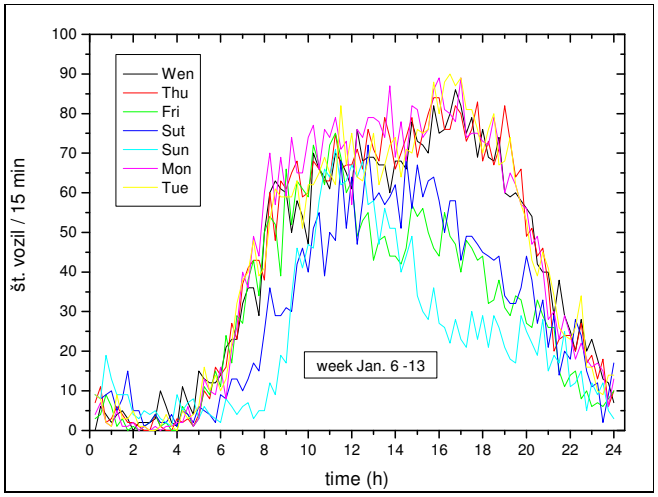

Figure 6: Volume $Q_{15\min,k}$ for each day of the week (Jan 6 to 13)

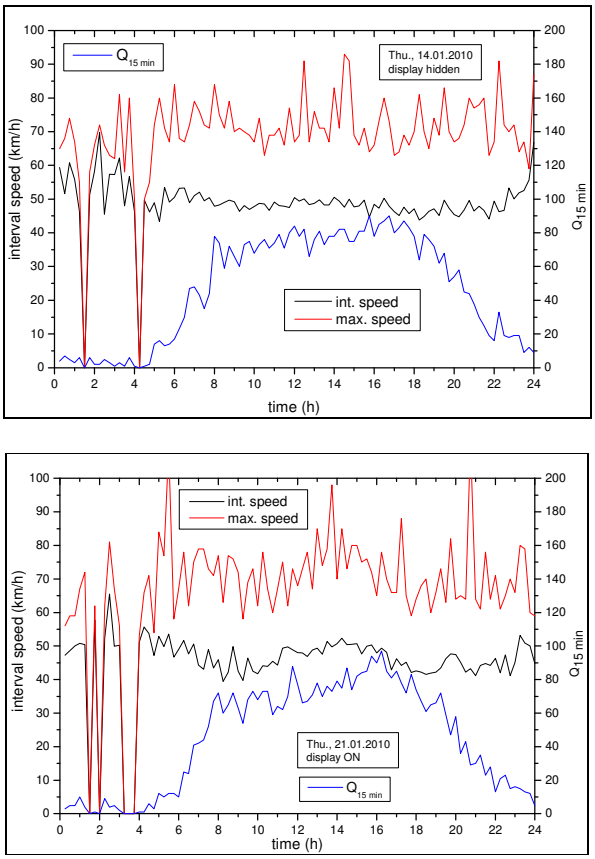

Figure 7: Average interval speed, max. speed and volume $Q_{15\min,k}$ for Thu 14/1, display hidden (above) and Thu 21/1, display ON (below)

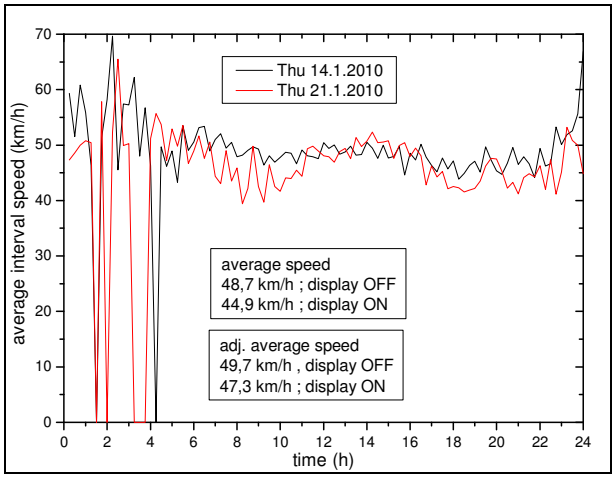

Figure 8: Comparison of interval speeds for the same day of two consecutive weeks with display OFF and ON

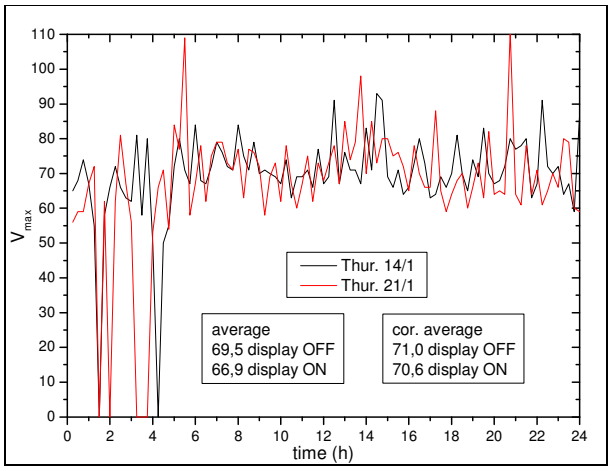

Figure 9: Comparison of maximum interval speeds for the same day of two consecutive weeks with display OFF and ON

For the purpose of a better comparison of differences, the average interval speeds and maximum interval speeds for the two days are redrawn in Figures 8 and 9. The daily average interval speeds $\overline{V}_{day}$ are found to be (48,7 and 44,9) km/h (Fig. 8). There is a significant difference of 3.8 km/h, which was hardly noticeable in $\overline{V}_{week}$ result (influence of averaging!). The daily average maximum interval speeds $\overline{V}_{\max,day}$ are (69,5 and 66,9) km/h (Fig. 9 bellow) with display OFF and ON, respectively. There are differences of 3.0 km/h but at speeds 20 km/h over the speed limit. It is seen in Figures 8 and 9 that there are no vehicles (speeds 0 km/h) in some early morning time intervals. By correcting the above values for $\overline{V}_{day}$ and $\overline{V}_{\max,day}$, adjusted values are (49,7 and 47,3) km/h for the former and (71,0 and 70,6 km/h) for the later. The result says that there is a reduction of the average daily speed for more then 2,4 km/h with display ON and, at the same time, the speediest drivers are ignorant to the posted speed limit sign and radar speed warnings at this location.

From the results given in Table 2 effectiveness of MHP50 on the Brezovica location is apparent. First, without MHP50 installed the drivers, to a large extent do not observe (ignore) the 30 km/h speed limit sign. Very few are driving bellow this limit. In Figure 9 a comparison of accumulated number (normalized) of vehicles for week long measurements vs. speed at Brezovica site with display OFF and ON is presented. The OFF values represent also the state of driver's habits at this site before the warning radar was installed. From Figure 9 it seen that V_{50} is 50 km/h, i.e., almost half of drivers travel with speed > 50 km/h. There is a significant shift of this curve towards lower speeds (5 km/h at speed of 35 km/h). This shift is more apparent in Figure 10 displaying a comparison of average interval speed distributions for week long measurements with display OFF and ON.

A comparison of daily interval average speed $\overline{V}_{day}$ and maximum speed $\overline{V}_{\max,day}$ separately for two consecutive measurements (7 and 8), for the same day of the week (Tue Feb 13 and 23), with display hidden and visible, respectively, was made. The daily average interval speeds $\overline{V}_{day}$ are found to be (54,6 and 48,7) km/h. The difference is 5,9 km/h, whereas that for $\overline{V}_{week}$ = 2,6 km/h. A great part of the difference between $\overline{V}_{day}$ and $\overline{V}_{week}$ is due to the averaging (by factor of about $\sqrt{7}$).

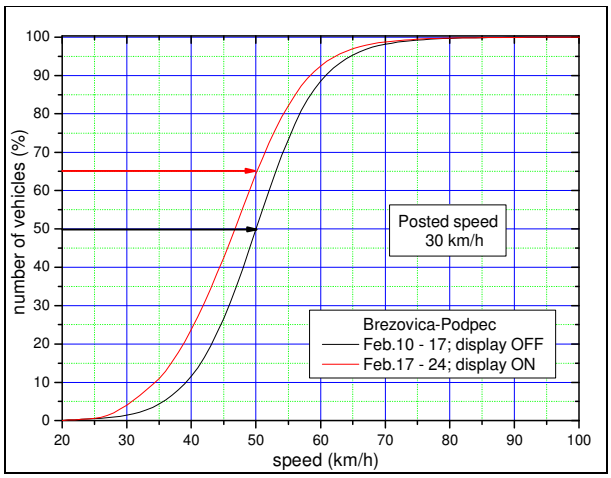

Figure 10: Comparison of accumulated number of vehicles for week long measurements vs. speed at Brezovica site with display OFF and ON

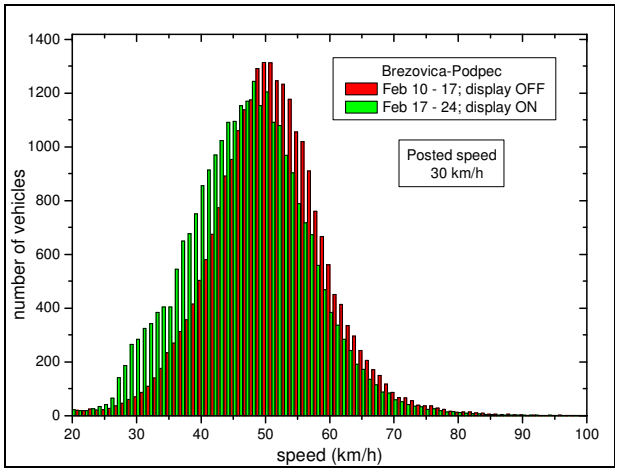

Figure 11: Comparison of average interval speed distributions for week long measurements at Brezovica site with display OFF and ON

CONCLUSION

In this study an attempt to evaluate the effectiveness of radar speed displays, model MHP50 produced by Sipronika d.o.o, using only the data a standard commercial unit provides, was made. From the measurements on two locations with different traffic flow characteristic and speed limits imposed. From the results the following conclusions are made:

On location 'Jurčkova':

- Week average of interval speeds $\overline{V}_{week}$ are close to the speed limit of 50 km/h, 48,6 km/h with the display visible and 49,0 km/h with display covered. The difference is small but indicative of a small increase with display covered. The result is expected.
- Week average of interval speeds over speed limit is large: 48,7 km/h with the display covered and 47,2 km/h with display ON.

- The daily average interval speeds $\overline{V}_{day}$ are found to be (49,7 and 47,3) km/h. There is a significant difference (2.4 km/h) with display OFF or ON. The stated reduction value is a lower limit. For reasons of working with average interval speeds rather then individual speeds and recording individual car speeds several times depending on its speed, a realistic reduction is estimated to be doubled.
- The daily average maximum interval speeds $\overline{V}_{\max,day}$ are large: 71,0 and 70,6 km/h with display OFF and ON, respectively. The result is telling that the speediest drivers are ignorant to the posted speed limit sign and radar speed warnings at this location.

On location 'Brezovica':

- Week average of interval speeds $\overline{V}_{week}$ are far from the speed limit of 30 km/h: (50,9 and 48,7) km/h with display covered or visible, respectively. The difference of 2,6 km/h is pronounced. Taking into account days of heavy snowing the difference should be doubled (5 km/h).
- Week average of interval speeds over speed limit is enormous. Drivers, to a large extent, do not observe (ignore) the 30 km/h speed limit sign.
- Almost half of drivers travel with speed > 50 km/h.
- There is a significant shift of speed distribution curves towards lower speeds (5 km/h at speed of 35 km/h) with radar display working.
- The difference in daily average interval speeds $\overline{V}_{day}$ are found to be 6 km/h.

Overall, the effectiveness of Sipronika radar speed detector and display system can be evaluated from the data stored. The results show a clear reduction of speeds, amount of which depends on the characteristics of traffic flow, speed limits imposed, location and the length of time the system has been installed. In view of eq. 4, all stated speed reductions are a lower limit. Considerations of this effect will be defined in a second publication.

ACKNOWLEDGEMENT

The work is a partial result of the research project 'REMSIS' supported by the Ministry of Science and Technology of R Slovenia and co-founded by EU incentive EUREKA.

LITERATURE

1. Rose E.R., Ullman G.L.: *Evaluation of dynamic speed displays sign*, Project 0-4475 (2004), TTI, T-DOT, USA;
2. Meyer E.: Long term effects of radar-activated speed displays,

http://www.matc.unl.edu/research/MwSWZDI/;
3. Perko K., Tekavec T., Golob S., Jarc J.: *Remote wireless control and supervision of radar speed displays and intelligent traffic signs*, Proceedings ISEP 2006, Ljubljana, C1, pages 5;