Effectiveness of variable feedback signs for speeds on secondary rural roads in the area of Bari (Italy)

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Synopsis
The paper reports some experimental studies on the impact of variable feedback signs for speeds on drivers' behaviour. For this aim spot speeds have been collected on a two lane rural roads of the hinterland of Bari appropriately chosen according to its geometric and environmental characteristics. Data were collected using both a hidden radar speed detector and a radar reporting actual speeds on a panel clearly visible by drivers. The study allowed to draw interesting conclusion about the effectiveness of these signs.

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While driving along most of the secondary road network (and not only), it is clearly perceivable how most of the vehicles move faster, and sometimes far faster, than the speed limits that are there enforced and signalled. Another clear sensation is that the speed limits themselves are too restrictive in comparison to the operative speed which is consistent with the geometric characteristics of the road. The observed operative speeds, in fact, are, quite often, far higher than the enforced speed limits. It is widely accepted that the operative speed of a specific road section is strongly dependent not only on the relevant speed limits but also on other explicative variables such: number of access, activity on road sides, width of lanes, width of shoulders, curve radius…. (*K. Fitzpatrick et al., 2003*). These variables decisively influence the driving behaviour and often lead to a huge gap between the enforced speed limit and the operative speed. In Italy, as all over the world, the enforced speed limits are, nearly always, lower than the operative speed. Repeatedly, then, has been raised the question of adopting speed limits which turn out to approximate the operative speed as much as possible. On the other hand, as for speed, it is not sensible to establish a unique criterion on which a road can be designed and enforcing the relevant limits wouldn't be sensible as well. In many cases, in fact, even though the environmental and geometrical characteristics could admit a high operative speed, some hidden or unpredictable dangers might exist and they must be considered as well. That is the reason why some extremely restrictive speed limits are often observed, in comparison to the potential operative speed of a specific road section. So, in rural roads it is quite easy to find the speed limit set to 50 km/h (the ordinary limit would be set to 90 km/h) even though that road section could admit a far higher operative speed. Evidently, the enforcement of such limits is explainable with the high probability of meeting farm tractors or other extremely slow agricultural vehicles. From there comes the need to narrow the existing gap between moving vehicles, as it is widely proven that one of the major source of road accidents is an excessive speed gap between moving vehicles (*R. Mussa, 2004*).
This problem clearly cannot be solved with the simple imposition of restrictive speed limits, but it is linked to other and more complex issues related to the management and the design of roads.

Moreover, the problem is that the frequent misuse of such limits leads drivers to a wrong perception of the actual danger that is behind such enforcement. Such limits, then, are often totally disregarded as it' was observed in the specific situation described in this study. So, when there's a real need to lower speed in order to reduce the risk of a road accident, it is necessary to improve the ordinary speed limit signals with other speed reducing devices such humps, rumble strips, narrowing road width, etc.. In this way, a good result is given even if only in the immediate surrounding of the site where such devices are installed (*M. Pau and S. Angius, 2001; R Elvik and T. Vaa, 2004*). In addition to such "mechanical" devices, there are other less invasive ones like automatic queue warning signs, individual feedback signs for headway, individual feedback signs for speeds, etc. Such signals basically warn drivers against their hazardous behaviour. But, on the other hand, if it's been possible to observe encouraging correlations between the use of such devices and the reduction of road accidents, it is equally true that, generally, the driver (in spite of having been warned) tends to maintain his behaviour considering himself in a safe position (*R Elvik and T. Vaa, 2004*). Truly, the only real way of inducing drivers to lower their speed, effectively and constantly, along a specific road section, is based on warning them of the real probability of being fined, which is achievable either with a remote surveillance system or with the physical presence of policemen (*C.A. Holland and M.T. Conner, 1996*).

At the Polytechnic of Bari an experimental investigation has recently carried out, whose aim is to study the drivers' speed behaviour along the secondary extra-urban road network of the hinterland of Bari. Among the global study, a first investigation has been carried out to study drivers' reactions in presence of individual feedback signs for speeds.

DESCRIPTION OF THE OBSERVATION SITE

The investigation was carried out on the secondary road SP90 Bitetto – Sannicandro, which is a rural road with an average lane width of 2.95 m (total width between side stripes is 5.90 m), width of shoulders 2.25 m, paved for 0.50 m and covered with bushes in the residual width, side low stone walls. This road was explicitly selected both because of its general environmental characteristics, which are absolutely typical of the secondary extra-urban road network in the hinterland of Bari, and because it is characterized by a sole tangent, 3 km long, with no curves. This aspect enabled to observe speed data that turned out to be absolutely free from any influence of the horizontal alignment. Even for the vertical alignments, in fact, the road is characterized by a sequence of low sags and crests such to be considered a level road section, with a 20% global length of no passing zones. As for speed limits, on the investigated direction (Bitetto – Sannicandro), no posted speed limits were found and, therefore, the ordinary legal speed limit enforced in this kind of roads (90 km/h) should be considered.

At approximately half-way some radar devices were installed in order to record speeds. The devices were an individual feedback sign for speeds (which will be subsequently called "panel" for the sake of brevity) that records speeds, displaying them to drivers on a panel, and a hidden speed radar (cp. fig.1-2).

Figure 1: view of the panel

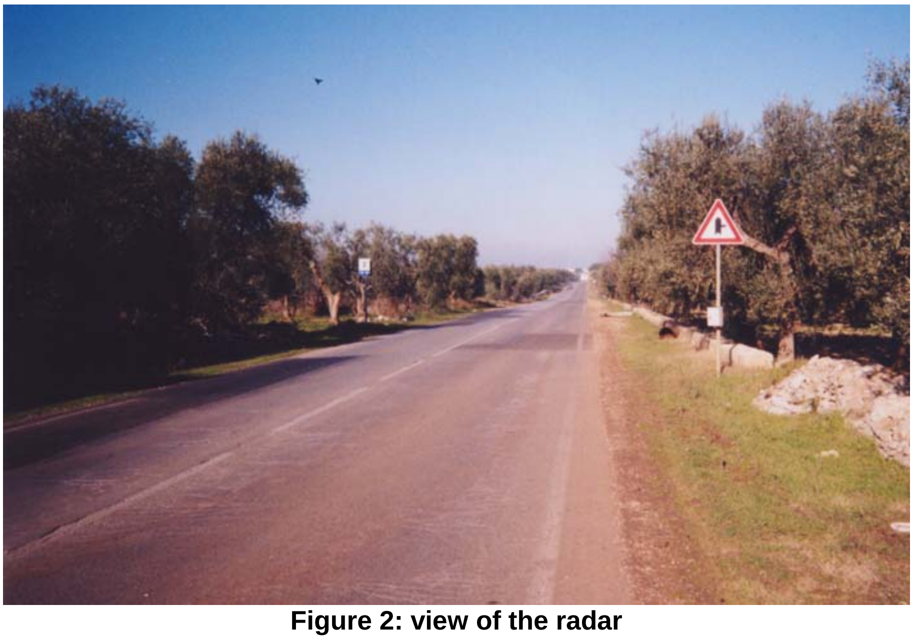

Figure 2: view of the radar

The panel was kept in site for 5 working days in succession, while the radar was positioned upstream, 350 m away from the panel, for one day. The observations were all carried out in daylight, with dry pavement and good whether. In such conditions, it was possible to record and study any change in speed gradually induced in drivers by the presence of the panel during the days of exposure, analysing changes in speeds recorded by the panel, in comparison to speeds recorded in the upstream section equipped with the hidden radar.

COLLECTED DATA

During the observations, an operator was constantly present so to record incidental irregularities in traffic that could invalidate the reliability of the recorded data. It's been possible, so, to sift data in order to discard all the speed figures influenced by abnormal vehicular traffic (not rarely, for example, some vehicles stopped at the side of the road to watch the device).

For each day of observation and for each device, it's been possible to build the curves of cumulative frequency distribution, from which the speed statistics have been assessed. The relevant data are reported in table 1.

Table 1: statistics of the observations

Observations	15th percentile Speed (V15%)	Average Speed (Vm)	85th percentile Speed (V85%)	Max Speed	N. Veic.
Radar	63,0	82,3	101,6	172	522
Monday - Feedback sign	61,2	81,5	101,9	147	999
Tuesday - Feedback sign	59,1	79,2	99,3	153	1100
Wednesday- Feedback sign	57,2	78,4	99,6	156	1009
Thursday - Feedback sign	54,6	75,8	96,9	145	1043
Friday - Feedback sign	55,8	76,9	98,0	155	1256

Before going on to the analysis of the data, it was necessary to make sure that the traffic flow did not significantly influence the recorded speed. For the sake of it, in any traffic observation the road level of service was calculated using the methodology of Highway Capacity Manual. The result was that, during the observations, the road has always operated within level of service B. It is, consequently, possible to conceive the irrelevance of the influence of traffic volume on speed. In confirmation of this, for example, figures 3-4 show the relationship traffic flow/average speed recorded by radar with hourly traffic volume data collected, respectively, every hour and every 15 minutes.

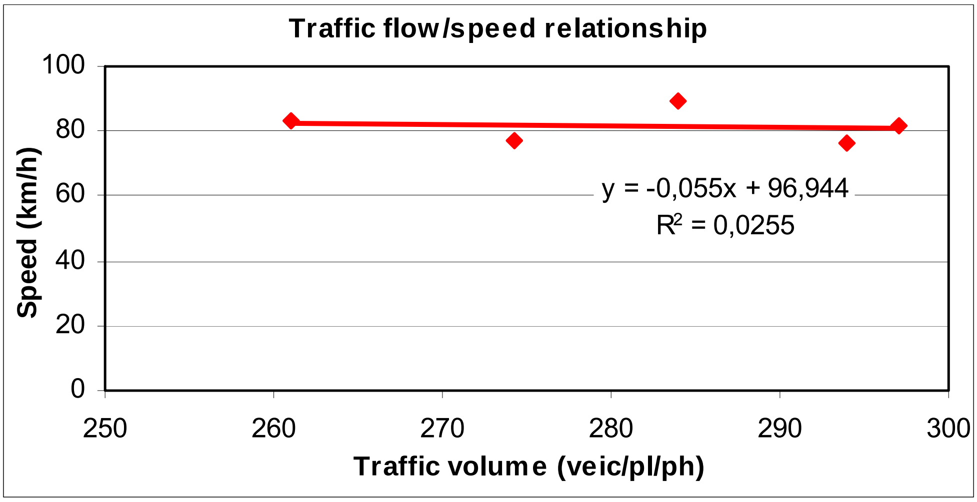

Figure 3: relationship traffic volume/average speed (1h)

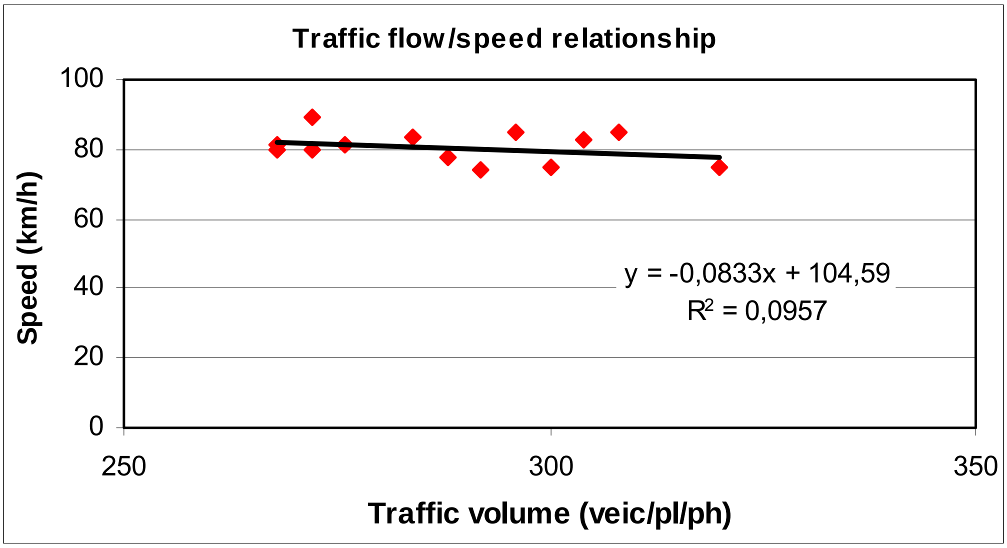

Figure 4: relationship traffic volume/average speed (15 min.)

From the figures, it can be easily noticed how R^2 values are always very low (below 0.1) so that it can be assumed that hourly traffic volume does not significantly influence speed.

ANALYSIS AND DISCUSSION

The statistics of recorded speeds are reported in table 1. Every speed sample has undergone the χ^2 test in order to ascertain the existence of a normal distribution. All the data turned out to show a normal distribution but for those recorded by the panel on Thursday and Friday (the 4th and 5th day of exposure). The non random distribution of speeds observed in those days (representing the two last days in the week of investigation) is probably due to the drivers' growing "awareness" of the presence of the panel; the relevant road section, in fact, is mostly attended by commuters who get gradually used to its presence (being it positioned always in the same road section) and who, preventively and presumably, change their driving behaviour in case an eventual violation could be discovered and fined.

To better analyse this phenomenon, figure 5 shows the cumulative frequency distribution of speed recorded in the five-day observation. Five curves (one for each day) refer to the data recorded by the panel, while the sixth one refers to data collected at the upstream post equipped with the hidden speed radar.

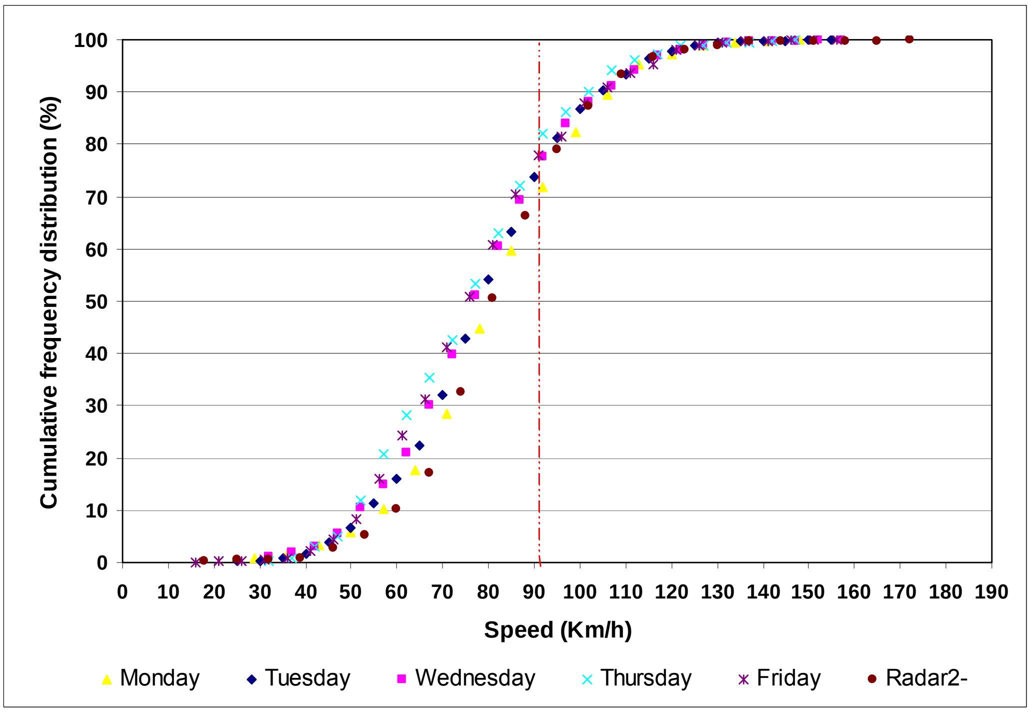

Figure 5: Cumulative frequency distribution of the observed data

From the graphic representation of speed distribution of the samples, it is appreciable how the curves that show speed distribution on Thursday and Friday move upwards, especially for the lower speed intervals. It is, then, understandable why, after three and four days of panel exposure, the drivers from Bitetto to Sannicandro (mainly commuters) tend to reduce their speed, more and more, in coincidence with the panel position.

It could be said that the longer the panel exposure the higher the drivers' awareness of the selected speed. So, the constant presence of the panel would seem to cause a real decrease in speeds.

Not being signalled any maximum speed limit on the relevant road section, we refer to the average legal speed limit enforced in that kind of road (90 km/h). The percentage of vehicles infringing the speed limit drops from the 30,2% recorded on Monday (first day of the panel exposure) to the 23,1% recorded on Friday (fifth day of the panel exposure) showing a decrease rate of 7% approximately (corresponding to about ¼ of the trespassers). The number of violations, then, drops as well, even though not so considerably. Moreover, if we analyse the data in table 2, it is shown how the mentioned decrease in speeds is concentrated in the last two days, as if the drivers gained an ever-increasing awareness of the presence of the panel.

Table 2: Percentage distribution of vehicles sorted per speed classes

Speeds (km/h)	Radar	Mon	Tue	Wed	Thu	Fri
>0	100	100	100	100	100	100
>10	100	100	100	100	99,81	100
>20	99,43	100	99,91	100	99,62	99,68
>30	99,43	98,90	99,64	99,31	98,75	99,36
>40	99,04	97,40	98,18	97,72	97,41	97,77
>50	95,98	94,29	93,01	91,48	90,12	92,52
>60	89,85	86,99	83,29	82,36	74,59	76,75
>70	78,54	73,77	67,39	64,82	60,79	59,63
>80	52,68	51,35	45,32	43,81	41,42	39,65
>90	28,74	30,23	26,07	26,26	22,44	23,09
>100	15,90	16,12	13,26	14,57	11,12	13,14
>110	6,13	7,21	6,63	7,53	4,12	6,21
>120	2,30	2,60	2,18	2,78	1,53	2,15
>130	1,15	0,60	0,54	0,69	0,58	0,80
>140	0,19	0,30	0,18	0,30	0,29	0,16
>150	0,19	0,10	0,09	0,10	-	0,08
>160	0,19	-	-	0,10	-	-
>170	0,19	-	-	-	-	-

We then can suppose that the latter produces a kind of disturbance that prevents samples from having a normal distribution.

We can try, consequently, to represent the "awareness" ξ with a numerical value, supposing it directly proportional with the number of days of panel exposure: $\xi = \xi(t)$.

It is then possible to imagine a numerical proportional scale in which to give the value "1" to the function of awareness in absence of the panel $\xi(0)=1$ (datum referring to the sample recorded by radar), and the other values increasing proportionally with the number of days of the panel exposure. So, we can try a linear regression of the awareness ξ on speeds for the days of the panel exposure. Table 3 reports data referred to the proposed function.

Table 3: Speeds variation related to the function $\xi = \xi(t)$

	$\xi(t)$	V15%	Vm	V85%
Radar	1	63	82,3	101,6
Monday - Feedback sign	2	59,8	80,9	102,1
Tuesday - Feedback sign	3	56,8	78,2	99,5
Wednesday- Feedback sign	4	55,1	77,5	99,8
Thursday - Feedback sign	5	53,6	75,3	96,9
Friday - Feedback sign	6	54,9	76,5	98,1

Figure 6 shows a strong correlation between speeds and the growing awareness of meeting the panel. A decrease in speed can be associated with the getting used to seeing the panel. Such a decrease is more clearly appreciable in V15%, while in Vm and, even more, in V85% the rate of decreasing speeds seems to be slightly lower. This aspect can be shown even graphically, considering that the regression line linking ξ to V85% is flatter than the other ones.

Such a result would seem to demonstrate that the presence of the panel has a stronger influence on more cautious drivers. In percentage, in fact, we can observe a higher decrease in V15% and Vm (13% and 7%, respectively) than in V85% (3.5%).

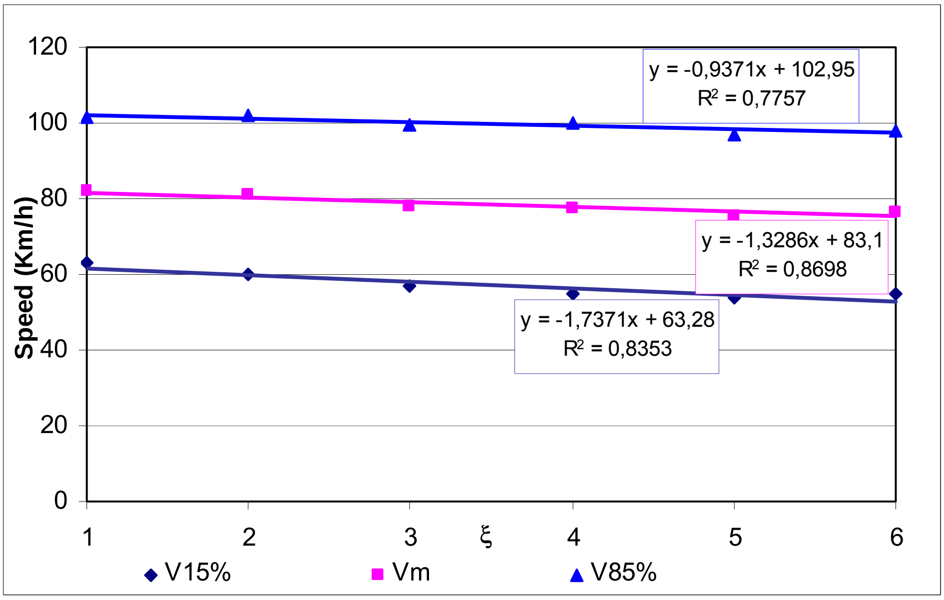

Figure 6: Graphic representation of the relationship speed Vs presence of the panel

The mentioned regression lines would seem to prove that a constant and permanent reduction of speed can be obtained with the progressive exposure of the panel. Such a behaviour, rather, has to be considered certainly not realistic. On the contrary, it could be plausible to assume that, after a certain period of time, the progressive decrease in speed (caused by the panel exposure) will stop.

As a matter of fact, it is plausible to assume that the impact produced by panel exposure on driving behaviour gradually decreases in connection with the increasing of the awareness of the presence o the panel itself.

What we call “impact” is the disturbance produced by the panel on normal driving behaviour. This can be read in figure 5 as the deviation that the curves of cumulative frequency distribution undergo, along the time, in comparison with the reference curve showing the speed data recorded in absence of the panel (normal driving behaviour). Substantially, we can admit that, along exposure time, the impact will increase with a lower and lower rate up to stabilize after a certain number of days.

To confirm this hypothesis, a further analysis was carried out in order to quantify such “impact”.
Every sample was, then, divided into 5 km/h classes of speed, considering in each class the number of vehicles moving within the relevant boundaries. In substance, the frequency for each speed sample and for each class of speed was evaluated.
Comparing, class by class, the frequencies of speed sample recorded by the panel with the frequencies of the speed sample recorded by the radar (in absence of disturbance), it is possible to identify a curve on Cartesian coordinates where on abscissa are the classes of speed and on ordinates are the differences in frequencies. The area included between the curve and the horizontal line for the zero value of Δfrequency, represents the “impact” of panel on drivers.
This operation is nothing else than the comparison between each speed sample recorded by panel and each speed sample recorded by radar. Considering that the sample recorded by radar is representative of the traffic flow condition not affected by the panel conditioning, the comparison shows how much the panel,

during its permanent presence at the side of the road, influences the flow conditions, which would be different in its absence.
As the frequencies of each speed sample recorded by panel have been compared with the frequencies of the speed sample recorded by radar, the horizontal line in the diagram above is representative of the condition of absence of the panel at the side of the road or representative of the condition of no influence of the panel on the subjects driving from Bitetto to Sannicandro.

Diagrams in figures form 7 to 11 show the different impact produced by the panel according to the duration of its presence at the roadside.

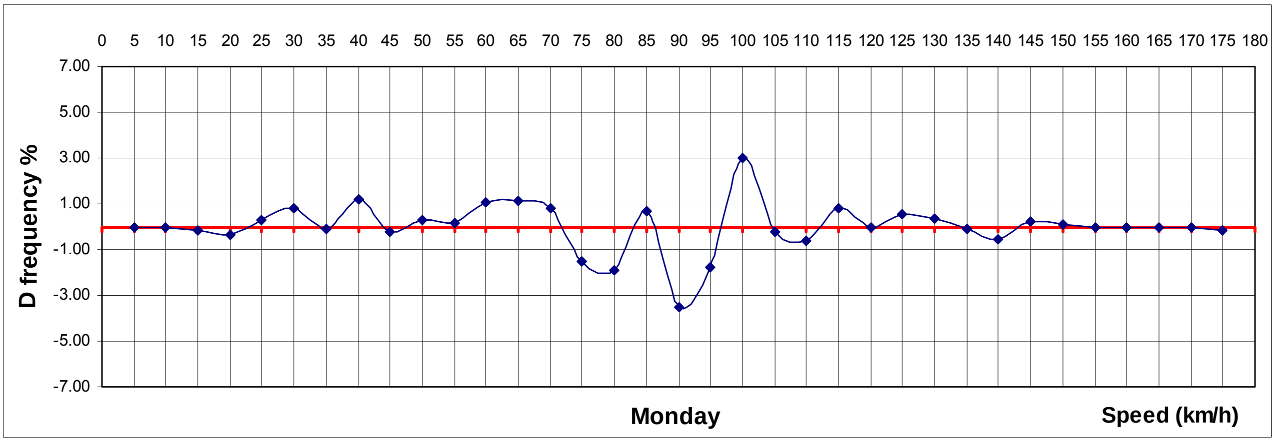

Figure 7: Impact area observed on Monday

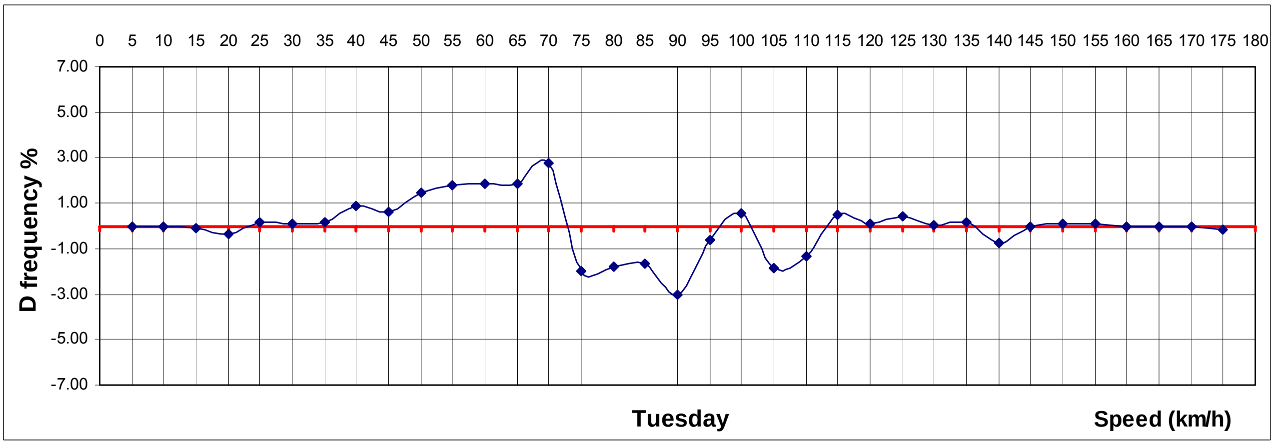

Figure 8: Impact area observed on Tuesday

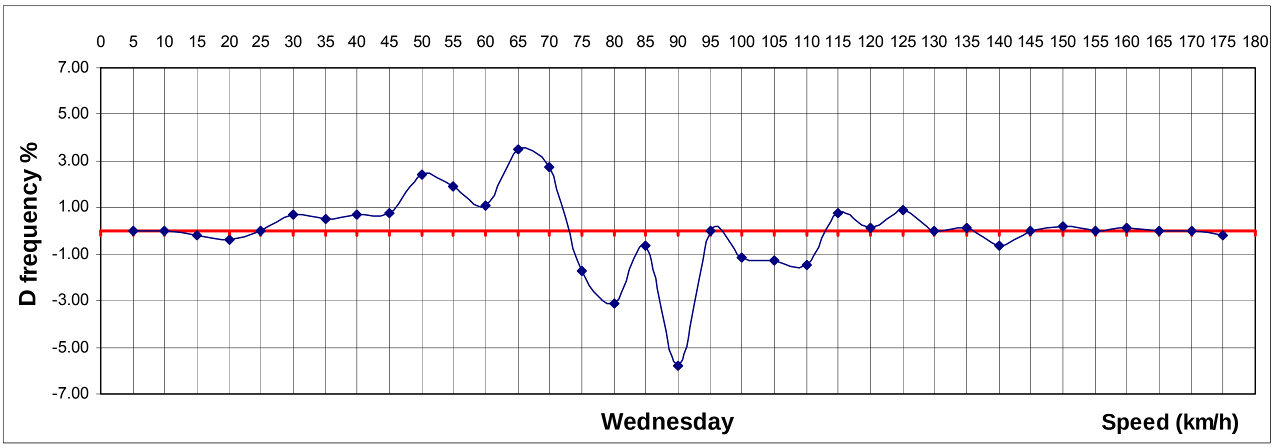

Figure 9: Impact area observed on Wednesday

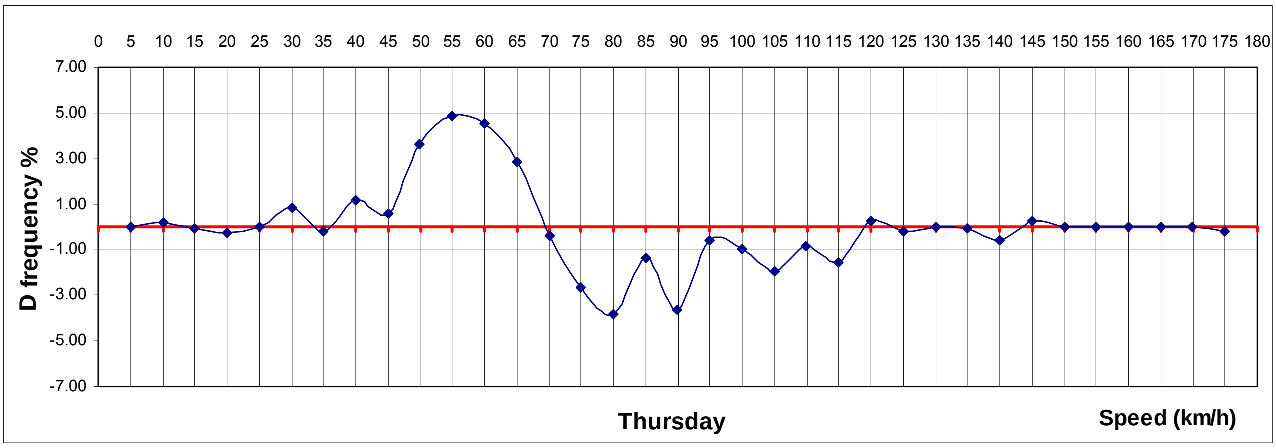

Figure 10: Impact area observed on Thursday

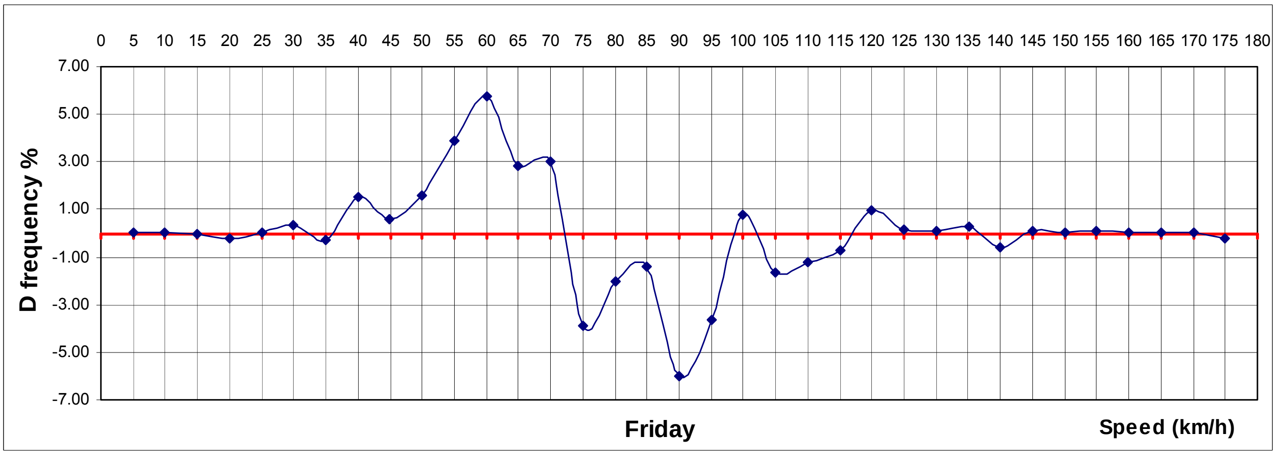

Figure 11: Impact area observed on Friday

It can be observed that the interpolative curves representative of differences of frequencies between samples recorded by the panel and samples recorded by the radar diverge more and more from the horizontal line with the increasing number of days of presence of the panel at the road side. The calculated values of the area included between the curves and the horizontal line are in table 4 where it is easily appreciable how the impact area increases with the increasing of the days of exposure of the panel.

Table 4: Amount of the impact

	Impact area *(km/h/veic.)*
Monday	2390
Tuesday	4957
Wednesday	6718
Thursday	8258
Friday	9134

Once quantified the “impact area” referred to each speed sample recorded by the panel in the five working days in succession, figure 12 shows the connection among those values and the period of permanent presence of the panel, obtaining a relationship whose determination coefficient is extremely near to 1.
It is noticeable how the impact of the panel on drivers raises with a decreasing rate with the increase in number of days of permanence of the panel at the side of the road. This means that the marginal increases in impact gradually drop in connection with the increasing of the number of days of permanent presence of the panel.

Trying also to forecast the future, we can assume a “knee” in the curve representative of change in impact area in coincidence with the seventh day of permanent exposure of the panel. This knee would mean that after the seventh day of permanent exposure of the panel the decrease in speed caused by the presence of the panel becomes almost irrelevant. Therefore, a hypothetical further permanence of the panel would not produce any other change in driving behaviour. This would confirm what initially assumed.

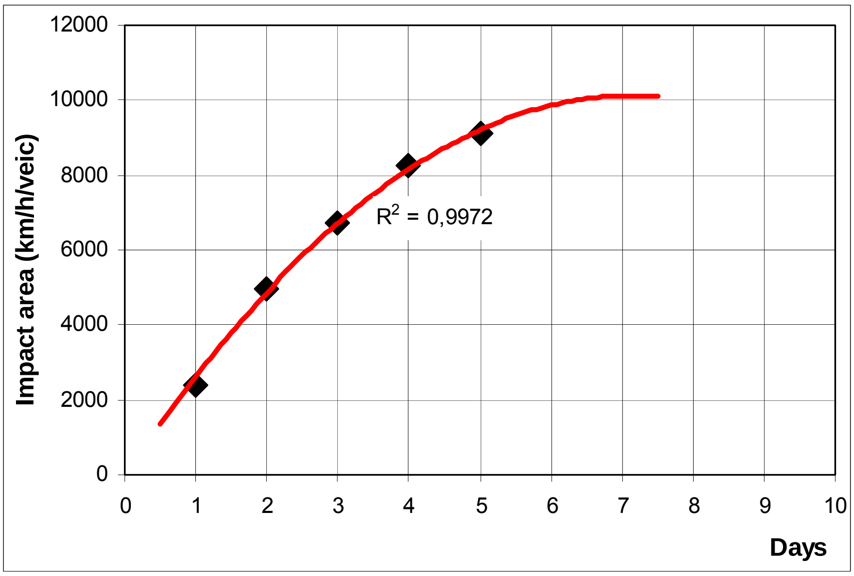

Figure 12: Impact area Vs exposure days of the panel

CONCLUSIONS

In the study presented in these pages, the Authors tried to assess the influence on driving behaviour that the installation of individual feedback signs for speeds would produce on the secondary extra-urban road network in the hinterland of Bari. With this aim, one of these devices was installed (always in the same site) for five days in succession (from Monday to Friday) in a road section explicitly chosen owing to its peculiar environmental and geometrical characteristics. In addition to that, an observation was carried out with a hidden radar that was placed 350 m upstream from the site of the individual feedback sign. In this way it was possible to obtain reference data on the operative speed in absence of disturbance.
The analysis of the collected data seems to suggest the existence of a function of "awareness" of drivers to the exposure of the panel. Furthermore, observing the deviation of the different cumulative frequency distribution, a tentative quantification of the impact of the panel on driving behaviour was also given, and a correlation between the drivers' awareness of finding the panel and the impact the it has on drivers behaviour was found.
Thus, it was possible to observe that:

- about the 30% of the drivers infringe the legal speed limit (90 km/h);
- the prolonged exposure of the panel produces a certain change in the number of violations of the speed limit (-7%, that corresponds to quite ¼ of the transgressors);
- the prolonged exposure of the panel has a stronger influence on more cautious drivers, having observed a decrease of 13% in V15%, and only of 3.5% in V85%;
- the impact of the panel on drivers increases with the time of exposure;
- the increasing rate of such impact, decreases with the time of exposure and, thus, with the increasing of the drivers' awareness of the presence of the panel;
- it is, then, possible to identify an upper limit beyond which the presence of the panel does not increase its effects any longer;
- this limit has been extrapolated, in the relevant situation, in 7 days of exposure.

One last consideration. It is plausible to imagine that, during these few days of investigation, the drivers behaviour may have been influenced by the uncertainty of he real reason for the presence of the panel along the road (do police use it to fine me? – is there a real danger I'm not aware of ?…). It will be interesting to confirm what previously observed by extending the investigation with a longer permanent exposure of the panel.

ACKNOWLEDGEMENTS

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