A Statistical Analysis of the Impact of Advertising Signs on Road Safety

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Abstract

This research aims to investigate the impact of advertising signs on road safety. An exhaustive review of international literature was carried out on the effect of advertising signs on driver behavior and safety. Moreover, a before-and-after statistical analysis with control groups was applied on several road sites with different characteristics in the Athens metropolitan area, in Greece, in order to investigate the correlation between the placement or removal of advertising signs and the related occurrence of road accidents. Road accident data for the 'before' and 'after' period on the test sites and the control sites were extracted from the database of the Hellenic Statistical Authority and the selected 'before' and 'after' periods vary from 2.5 to 6 years. The statistical analysis shows no statistical correlation between road accidents and advertising signs in none of the nine sites examined, as the confidence intervals of the estimated safety effects are non significant at 95% confidence level. This can be explained by the fact that, in the examined road sites, drivers are overloaded with information (traffic signs, directions signs, labels of shops, pedestrians and other vehicles, etc.) so that the additional information load from advertising signs may not further distract them.

Key words: road safety; advertising signs; driver distraction; before-and-after analysis.

1. Background

The complexity of the road environment, especially in urban areas, has been associated with increased driver workload and related driving behaviour (Edquist et al. 2012). Driving is getting even more demanding due to driver distraction factors, both in-vehicle (mobile phones, navigation systems, radio etc.) and external (road signs, labels, advertising signs etc.) (Young & Regan, 2007). Driver distraction from any cause constitutes a potential road accident risk factor (Holberry et al., 2006). The consequences of driver distraction of the vehicle's control and the correct perception of the road have been the subject of several studies internationally and a matter of concern for the various actors responsible for the safety of road networks.

Among the various external distraction factors, roadside advertising signs present a particularity, given that their purpose is to draw the attention of the maximum number of observers to the displayed product or service. Moreover, research has shown that advertising signs indeed constitute a factor of driver distraction (Stutts et al. 2001), and may become dangerous if their placement and their characteristics are not adequately studied and appropriately defined.

Several researches have dealt with the effect of advertising signs on driver behaviour and safety. The results vary depending on the methodology that has been followed. More specifically, the studies can be subdivided in the following categories: statistical methods, field experiments and simulator experiments. The existing research results on the effect of advertising signs on driver behavior and safety are summarized on Table 1.

Table 1: Extensive literature review

			Method							Results						
Main Researcher	Institute	Year	Questionnaire	naturalistic driving	Field survey	laboratory	simulator	statistical	"Before" and "after"	accidents	speed	Position on the lane	eye tracking	Reaction time	Accident risk of electronic signs	Distraction sources
McMonagle	Michigan study	1950						●								+
Staffeld	Minnesota study	1950						●		+						
Rusch	Iowa study	1951						●		+						
Madigan	New York State Thruway	1961						●		+						
Blanche	New Jersey	1965			●					no correlation						
Ady		1967							●	depends						
Hologan		1970			●					+						
Hologan		1970				●								+		
Wisconsin DOT		1994							●	+					+	
Stutts	AAA Foundation for Traffic Safety	2001							●							+
Beijer		2004		●									+			
Crundall	University of Nottingham	2005				●							+			
Horberry	Monash University	2005	●				●				-					
Tantala		2005						●		no correlation					no difference	
Smiley		2005		●	●								+			
Smiley		2005							●	+	-				no difference	
Lee	Virginia Tech institute	2007	●		●								+		+	
Patel	Middlesex University	2007	●													+
Young	University of Brunel	2007					●			+		+	+			
Chan		2008					●						+			+
Bendak	King Saud University	2009	●				●				+	+				+
Chattington	Transport Research Laboratory	2009	●				●								+	
Summary			**5**	**2**	**4**	**2**	**5**	**5**	**4**	**10**	**3**	**2**	**6**	**1**	**5**	**3**

In statistical methods, a comparison is typically carried out either between the number of road accident before-and-after the placement or removal of advertising signs at a given road site, or between road sites with advertising signs with similar road sites without advertising signs (the latter being the case in earlier studies). More specifically, early studies, mainly in the USA, indicate that roads with more complex road furniture (including advertising signs) may have increased numbers of road accidents, especially at junctions (McMonagle, 1952; Staffeld, 1953; Rusch, 1951; Blanche, 1965; Holohan, 1978). However, these results most likely reflect exposure patterns (i.e. increased traffic, many sources of distraction). In one of the earliest related reviews (Wechtel & Nerther, 1980), research results were already inconclusive as per the un-safety effect of electronic advertising signs.

The first statistical before-and-after comparison of road accidents following the placement of advertising sigs was carried out by Ady (1967), in which out of several sites examined, the only significant effect concerned an intensely coloured advertising sign placed after a sharp horizontal curve. Moreover, the Wisconsin Department of Transportation (1994) reported an increase of road accidents after the placement of an electronic advertising sign displaying sports results and advertisements. A more recent before-and-after study (Tantala & Tantala, 2005) showed that the 'upgrade' of existing conventional advertising signs to electronic ones does not lead to increased accident risk. Finally, Smiley et al. (2005) examined the effect of the placement of advertising signs along motorways and at intersections, with variable results, which the authors partly attribute to the low accident counts in the examined sites.

Another category of studies concerns field experiments, based on roadside or in-vehicle (i.e. naturalistic driving) measurements of driver behaviour while distracted by advertising signs, or on self-reported data (i.e. questionnaire responses). Beijer et al. (2004) used eye-tracking equipment on drivers driving along road sections with advertising signs and found that the number and duration of eye glances at the signs increased at lower speeds and at signs located more centrally within the driver's visual field. On the other hand, Lee et al. (2003) found no effect of large advertising signs (i.e. billboards) on the eye movements, the speed and the position on the lane of drivers.

Lee et al. (2007) compared the eye glances, speed, position on the lane and self-reported distraction sources of a sample of drivers after driving along a long road section with conventional and electronic advertising signs, and found no statistically significant differences between the two types of signs, with a slight tendancy to look at - and report looking at - electronic signs. Patel et al. (2008) carried out a questionnaire survey asking participant to rank various driver distraction sources and found that advertising signs were attributed a relatively low perceived risk, and ranked mid-scale. It is underlined that in none of these studies is the effect of advertising sings on road accidents examined.

Finally, a third category of studies concern video or simulator experiments. Holohan (1978) carried out an experiment in which participants were displayed videos of road sites and were asked to locate a 'stop' sign; the results suggested that the participants' reaction time increased in case advertising signs were placed at the displayed road sites. Horberry et al. (2006) report that, in a simulator experiment, drivers tended to drive at lower speeds in complex road environments with buildings, increased traffic

and advertising signs; however, the effect of advertising signs on drivers speed was not isolated in this study from the other factors.

Crundall et al. (2006) found increased influence of advertising signs on the probability of accident, when the sign is placed at the exit of a curve of the road or when it prevents the visibility of drivers in points that can constitute danger, e.g. in corners or turns. At the same time, it is indicated that advertising signs that are placed at the roadway level (e.g. on buses) attract more the attention of drivers. However, this is the only research that examines the influence of the location (i.e. height) of advertising signs on road accidents.

In a simulator experiment (Young, 2007), drivers drove roads with and without advertising signs, and an increased number of accidents, increased proportion of eyes-off-the-road time and inappropriate position on the lane were associated with the presence of advertising signs. In a similar simulator experiment, however, no significant change in driving behaviour or accident occurrence was found between driving on roads with and without advertising signs (Bendak et al., 2009). In this study, drivers also filled in a questionnaire on the perceived distraction from advertising signs, which was found to be higher for drivers >30 years old. Finally, Chattington et al. (2009) found increased duration of eye-glances and increased self-reported mental stress associated with electronic advertising signs.

In general, the accident risk of advertising signs is likely to vary depending on the type, the height, the content, the placement and more generally on the characteristics of the advertising sign. Specifically, the electronic signs, and more generally the signs with intense or reflective colours and movement, that differ a lot from the environment, attract more easily the attention of drivers. For this reason, the design of electronic signs should be similar to the design of conventional signs (Lee et al. 2007). Additionally, advertising signs that resemble traffic signs seem to confuse the driver (SWOV, 2006, Hagenzieker, 1994).

However, the existing studies do not allow for conclusions to be drawn, because of limitations related to the methodologies used (e.g. simulated environments, self-reported information) and the parameters examined (e.g. eye glances, behavioural parameters). Very few studies compare the actual accidents associated with the placement or removal of advertising signs in actual road sites, and on the basis of statistical techniques, and the results are often affected by the low numbers of accidents, often less than 30.

Finally, although most studies agree regarding the fact that advertising signs attract the attention of the majority of drivers, for a non negligible proportion of their driving time (Wallace, 2003; Regan et al. 2005), their contribution to road accident occurrence can not be confirmed by the existing studies, given that the results are quite diverse, the methods applied have non negligible limitations and emphasis is often put on behavioural effects, rather than safety effects. In any case, the contribution of advertising signs of road accidents appears to be low, compared to other distraction sources or other human factors (Department for Transport, 2008).

2. Objectives and Methodology

Research objectives

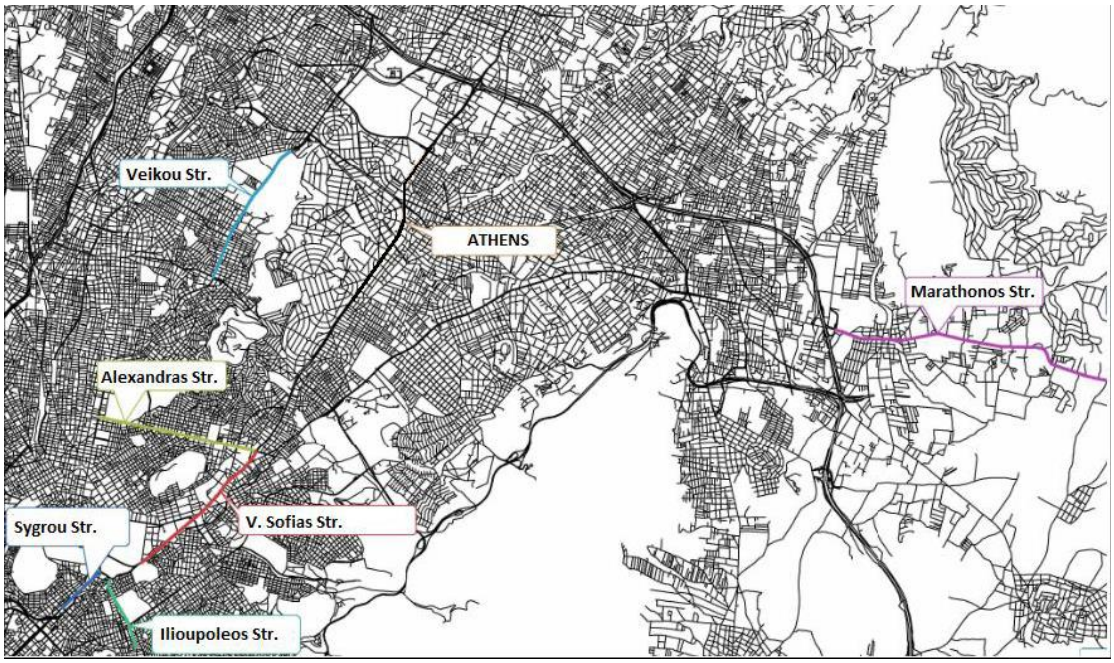
Within this context, this research aims to investigate the effect of advertising signs on road safety. More specifically, it examines whether the removal of advertising signs may lead to a significant reduction of road accidents. Moreover, it examines whether the placement of advertising signs can lead to significant increase of road accidents. For that purpose, a before-and-after statistical analysis is carried out on several sites with different characteristics in the Athens metropolitan area, in Greece, where placement or removal of one faced advertising signs (i.e. traditional billboards) took place.

Data selection and processing

The statistical analysis was carried out in nine different road sites within the greater Athens area, in Greece, in order to investigate the correlation between the placement or removal of advertising signs and the related evolution of road accidents.

In Table 2, the geometric and traffic characteristics of the nine road sites that were studied are presented (i.e. type, total length, number of lanes, traffic separation). The specific roads were chosen because detailed and accurate information on the placement or removal of advertising signs during the last decade was available, thus allowing for statistical analysis to be carried out. It can be seen that the test sites include urban and peri-urban roads, with or without separation and with different numbers of lanes per direction. Their location on the Athens metropolitan area is highlighted in Figure 1.

Figure 1: Test sites on a map of the greater Athens area



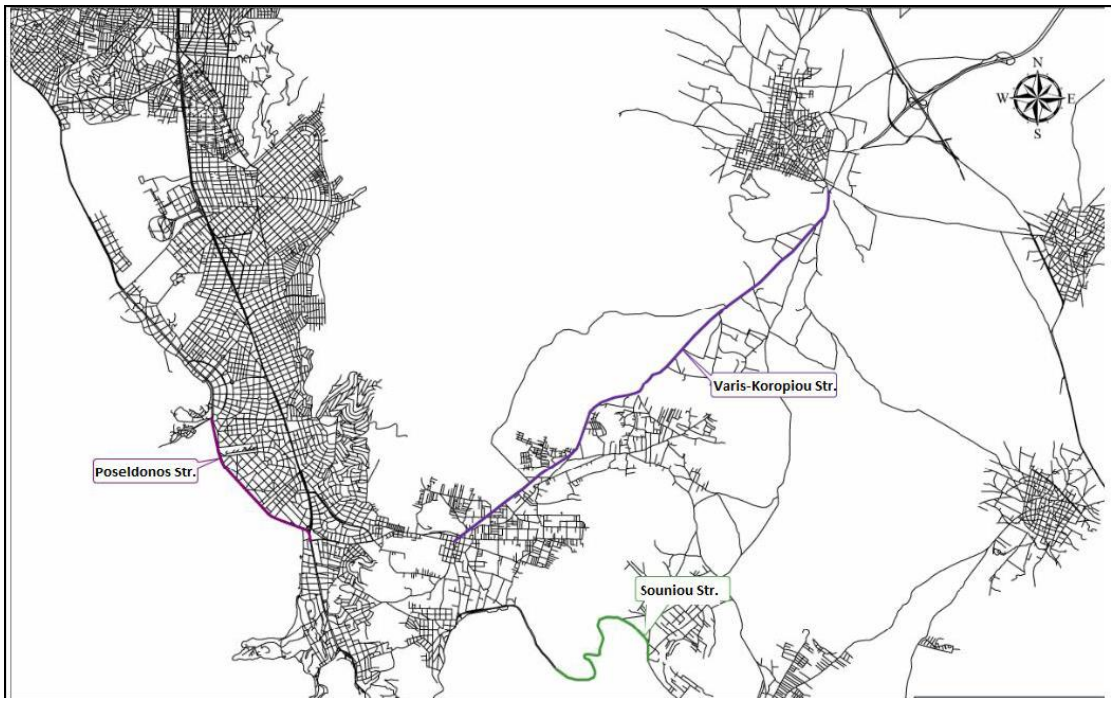

N
W
E
S
Varis-Koropiou Str.
Poseldonos Str.
Souniou Str.

Table 2: Test sites and control sites characteristics

	test sites						control sites					
	road axis	Type	Length (km)	Lanes	Directions	Traffic separation	road axis	Type	Length (km)	Lanes	Directions	Traffic separation
1	Veikou	periurban	1.50	2	2	yes	Veikou	periurban	3.00	2	2	yes
2	Marathonos	periurban	3.90	2	2	yes	Marathonos	periurban	10.30	2	2	yes
3	Varis-Koropiou	periurban	10.00	2	2	yes	Marathonos	periurban	10.30	2	2	yes
4	V. Sofias	urban	2.65	3	2	yes	Kifisias	urban	5.00	3	2	yes
5	Souniou	periurban	5.00	2	2	no	Souniou	periurban	10.00	2	2	no
6	Poseidonos	urban	2.10	3	2	yes	Poseidonos	urban	4.20	3	2	yes
7	Ilioupoleos	urban	1.30	2	2	no	Ilioupoleos-Vouliagmenis	urban	2.10	2	1	no
8	Sygrou	periurban	0.85	2	2	yes	Sygrou	periurban	2.40	4	2	yes
9	Alexandras	urban	2.70	3	2	yes	Kifisias	urban	5.00	3	2	yes

Special emphasis was given to the identification of the appropriate control groups for the before-and-after analysis, those being selected as neighbouring or not road sites with very similar geometric and traffic characteristics, as can be seen in Table 2. Moreover, the numbers of accidents with casualties on the examined road sites, as well as on the corresponding control sites, were quite high both in the 'before' and in the 'after' periods, allowing for statistical analysis. Furthermore, the selected 'before' and 'after' periods vary from 2.5 to 6 years, depending on the time of the placement / removal of the advertising signs and the availability of the road accident data.

More specifically, road accident data for the 'before' and 'after' period on the test sites and the control sites were extracted from the database of the Hellenic Statistical Authority (EL.STAT.), which contains detailed disaggregate data on all road accidents with casualties from 1985 onwards (until 2009 i.e. the last available year). The selected test and control sites were defined either on the basis of the road numbering (e.g. from number 85 to number 185 of road axis 7), which is the standard way of determining accident location inside urban areas in the ELSTAT database, or on the basis of intersections with other roads (e.g. road axis Sygrou between the intersections with Frantzi street and Athanasiou Diakou street).

A before-and-after statistical analysis with control groups was applied (placement or removal of advertising signs), so the comparison before and after the intervention in the examined site is carried out on the basis of the comparison with what would have happened if the intervention had not taken place.

Analysis Method

A before-and-after analysis with control group study uses an untreated control group of sites similar to the treated ones, to account for changes in road accidents unrelated to the intervention, such as time and traffic volume trends. The control group is used to calculate the ratio of observed road accident frequency in the after period to that in the before period. The observed road accident frequency in the before period at a test site is multiplied by this comparison ratio to provide an estimate of expected road accidents at the test site had no intervention been applied. This is then compared to the observed road accidents in the after period at the test site to estimate the safety effects of the intervention. In the present research, the method examines whether the placement of advertising signs leads to significant increase of road accidents, and whether the removal of advertising signs may lead to any significant reduction of road accidents.

The estimated effect for each test site (i) is estimated as follows:

Estimated effect (θ_i) = [Xa/Xb]/[Ca/Cb]

where:
Xa - the number of road accidents observed at the test site in the "after" period
Xb - the number of road accidents observed at the test site in the "before" period

Ca - the number of road accidents observed at the control site in the "after" period
Cb - the number of road accidents observed at the control site in the "before" period

In order to obtain a global estimate, the safety effects observed in each site are weighted on the basis of the total number of road accidents in the "before" and "after" period. The statistical weight of the estimate is:

$$w_i = \frac{1}{\frac{1}{\text{Xa}} + \frac{1}{\text{Xb}} + \frac{1}{\text{Ca}} + \frac{1}{\text{Cb}}}$$

Where Xa, Xb, Ca, Cb are the four numbers of the odds-ratio calculation.

The weighted mean effect for all the sites examined is then:

$$\textit{Weighted mean effect}(WME) = \exp\left(\frac{\sum_i w_i \ln(\theta_i)}{\sum_i w_i}\right)$$

with 95% confidence interval for the weighed effect is estimated as follows:

$$\left(WME \exp\left(\frac{z_{\frac{\alpha}{2}}}{\sqrt{\sum_i w_i}} \right), WME \exp\left(\frac{z_{1-\frac{\alpha}{2}}}{\sqrt{\sum_i w_i}} \right) \right)$$

The applicable value of the safety effect, i.e. the best estimate of accident reduction associated with the intervention (in percents), is calculated as (1-WME)*100 (Yannis et al. 2005).

3. Statistical Analysis

The results of the before-and-after analysis on each one of the examined road axis are presented in Table 3. In particular, the Table includes the number of accidents that occurred both in the test sites and in the appropriate control sites for both the before and after period. The estimated safety effects are also presented, together with their statistical significance.

Table 3: "Before" and "after" statistical analysis on the test sites

		1. VEIKOU	2. MARATHONOS	3.VARIS-KOROPIOU	4. V. SOFIAS	5. SOUNIOU	6. POSEIDONOS	7. ILIOUPOLEOS	8. SYGROU	9. ALEXANDRAS
Type of intervention		placement	placement	placement	removal	placement	removal	removal	removal	removal
Number of road accidents										
test	before period	40	32	100	558	51	56	92	214	387
site	after period	62	46	96	539	54	63	54	215	463
control	before period	82	112	267	502	62	82	283	217	368
site	after period	125	108	220	491	74	97	157	192	394
Odds ratio statistical method										
estimated effect (θ_i)		1.017	1.491	1.165	0.887	0.988	0.951	1.058	1.135	1.117
safety effect (%)		-1.7%	-49.1%	-16,5%	11,3%	1,2%	4,9%	-5,8%	-13,5%	-11,7%
lower limit*		-52.8%	-131.2%	-54,0%	-36,1%	-14,1%	-40,5%	-46,6%	-42,6%	-31,7%
upper limit*		32.3%	3.9%	11,8%	42,2%	14,5%	35,6%	23,6%	9,6%	5,2%
Statistical corellation		**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
**95% confidence interval*										

From the statistical analysis of the road sites selected, it was found that no statistical correlation between road accidents and advertising signs might be proved in none of the nine sites examined. The estimated safety effects are non significant in all road sites examined. More specifically, the number of road accidents increased in three road sites after the placement of advertising signs while in one road site the number decreased. Concerning the removal of advertising signs in two road sites the number of road accidents increased while in three road axes decreased. However, in all cases studied the upper and the lower limit of each safety effect range from negative to positive values, and thus the results are not statistically significant.

It is also noticed that the effect of advertising signs on road accidents is non significant as regards both placement and removal of advertising signs, both in urban and peri-urban roads, both in separated and non-separated roads and regardless the number of lanes. It may be deduced that the macroscopic effect of advertising signs on road accidents is not affected by road design or traffic characteristic.

Moreover, the global safety effects of placing / removing advertising signs and their confidence intervals are summarised in Table 4. These effects were estimated as the weighted mean effect of the effects estimated for the individual sites. It can be seen that the estimated safety effects are non significant, given that their confidence intervals, estimated at 95% confidence level, are too large and still range from negative to positive values.

Table 4: Global effects of the placement / removal of advertising signs

	Advertising signs	
	Placement	Removal
Number of test sites	4	5
weighted mean effect	1.125	1.052
safety effect	**-12.5%**	**-5.2%**
lower limit	-34.9%	-15.1%
upper limit	6.1%	3.8%

These findings can be explained by the fact that in the examined road sites, drivers are overloaded with a lot of information (traffic signs, directions signs, labels of shops, pedestrians and other vehicles traffic, etc.) so that the additional information load from the placement of advertising signs may not further distract their concentration on driving. Similarly, the reduction in the information load resulting from the removal of advertising signs is negligible, within a complex urban environment.

As regards peri-urban roads, in the present research these maintained many of the characteristics of urban arterials i.e. moderate speeds, buildings and commercial uses, traffic signal control etc., it is thus not surprising that the effects of advertising signs were not found to be significant. Only the peri-urban Souniou Ave. may be considered to conform to rural road design and operational features.

These results are in accordance with results from the international literature using actual data and similar statistical analysis methods (Department for Transport, 2008). Consequently, advertising signs as driver distraction factors do not seem to have a statistically significant impact on road accidents in urban and peri-urban areas. It is possible that some impact of advertising signs may be more identifiable in more specific cases (e.g. at less urban settings, at specific junctions, in relation to their specific placement location); however further investigation is necessary in order to extract conclusions for such specific cases.

4. Conclusion

This research aims to investigate the effect of advertising signs on road safety. Several types of researches have been carried out internationally in order to investigate this type of effects, including statistical methods (before-and-after, etc.), field research (cameras inside and outside the vehicle, naturalistic driving, etc.) and studies using a driving simulator.

In the present study a statistical analysis was carried out in nine different road sites within the greater Athens area, in Greece, in order to investigate the correlation between advertising signs and road accidents. A before-and-after statistical analysis with control groups was applied (both for the placement and removal of advertising signs) in which the safety effects observed were weighted by means of the odds-ratio of the total number of road accidents in the "before" and the "after" periods.

The statistical analysis concluded that no correlation between road accidents and advertising signs can be shown in any of the cases examined, i.e. in none of the specific sites and as a whole. This is in accordance with the results of existing related studies that report a negligible effect of advertising signs on road accidents in urban areas. It is noted that, several studies have proved that advertising signs do attract the attention of drivers, in terms of e.g. eye glances.

Drivers on urban and peri-urban roads are overloaded by information such as traffic signs, directions signs, labels of the shops on the road, pedestrians and other vehicle traffic, so that the additional information load from the advertising signs may not worsen their concentration into driving. Accordingly, the removal of advertising signs does not significantly reduce the information load that drivers receive. It is likely that other features of the road environment may be far more distracting than advertising signs, e.g. road side parking (Edquist et al. 2012), pedestrians etc.

Moreover, the distraction caused by advertising signs in urban and peri-urban areas may be considered as a part of everyday driving, making them thus no major distraction factor. Several studies have shown that advertising signs, especially electronic ones, may increase the accident risk, but research regarding driver familiarity can argue that commuter drivers may not even look at an advertising sign (FHWA, 2001).

Indeed, the present - and previous - results suggest that the distraction caused by advertising signs can be considered as a minor one. Overall, accidents that are caused by human factors constitute an important percentage of the total number of road

accidents (Salmon et al., 2011). However, driver distraction constitutes an individual contributory factor, which ranges in about 10-15% of the total road accidents (MacEvoy et al. 2007, Wang et al. 1996). Furthermore, the sources of driver distraction include both in-vehicle and external ones, while in relative researches it has been proved that in-vehicle distraction factors are more dangerous than external ones. More specifically, external sources of driver distraction were found to be a contributory factor in less than 1% of road accidents, while another 2% of road accidents are associated with in-vehicle distractions (Department for Transport, 2008). It is therefore not surprising that no significant effect of advertising signs on road accidents is identified in most studies.

The question of advertising signs and driver distraction is complex, and despite the fact that research internationally have applied various methods aiming at a better understanding, no conclusions can be drawn, because each method has different restrictions. As mentioned previously, the analysis of the influence of advertising signs on road safety can be problematic because the changes in the number of accidents before-and-after the placement or removal of advertising signs is usually small and makes the statistical analysis weaker. In the present research, there are various advantages compared to some of the researches described above, as the road axes examined have different road characteristics and the statistical analysis was carried out using sufficient road accident data (i.e. long before-and-after periods, sufficient road length, large number of sites as regards both placement and removal of advertising signs).

The present research however is limited to urban (and peri-urban) areas and to static advertising signs. It is possible that electronic advertising signs may have more considerable impact on road accidents, overall or under certain conditions. Moreover, it is possible that isolated advertising signs may in some cases have negative effect on road safety at local level; however, such effects can not be captured in a macroscopic before-and-after analysis.

Summarising, road advertising signs constitute a common type of advertising in urban areas, which is occasionally reported as factor of road accidents, due to driver distraction. However, both the exhaustive literature review and the statistical analysis carried out in the present research suggest that there is no statistical correlation between road accidents and advertising signs at macroscopic level. Taking into consideration all the above, no detrimental effect of advertising signs on road safety is expected, as long as the basic requirements concerning the appropriate locations and characteristics are met (i.e. size, placement, not resembling traffic signs, not affecting visibility)

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