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# The impact of roadside advertising on safe driving behaviour in cities: A driving simulator approach

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**Abstract**

The roadside billboards, as a distractor, seem to have been investigated and efforts have been made in order to determine the extent to which they affect the safe driving behaviour. Most studies suggest that the existence of roadside advertising billboards, in general, alters drivers' behaviour, but they are quite ambiguous in quantifying this impact. This research aims to investigate and quantify this effect by means of driving simulator experiment including 31 young participants. The experimental procedure included driving in urban environment in high and low traffic conditions, with or without advertising billboards on the roadside, while unexpected events were designed to take place. Regression statistical modelling techniques were developed in order to investigate the impact of roadside advertising on several driving performance measures. The models' application indicated that roadside advertising leads to slight decrease of the mean speed, but at the same time slight increase of the reaction time and lateral position of the vehicle from the right borderline.

*Keywords:* roadside advertising; driving simulator; lateral position; reaction time; speed, headway; road accidents

## 1. Introduction

The existence of roadside billboards as a distraction factor seems to have preoccupied the scientific community and efforts have been made to determine the extent to which they affect the behavior and safety of drivers. Most surveys agree that the existence of roadside advertising billboards change drivers' behavior. The results of the surveys, in some cases, may vary numerically or may be quite specific, however they show the general trend in the change of various parameters. Advertising billboards are an important distraction factor regardless of the position in which they are placed. In particular, advertising billboards located at street level distract a greater part of the driver's attention (compared to advertising billboards placed on poles), even in cases where the route has peculiar features and requires greater attentiveness (Crundall, 2006).

The phenomenon which is observed most frequently on routes containing advertising billboards is that of marked changes in the drivers' lane positioning. The changes in the drivers' position in their lane were much more marked when they were watching advertising video display boards compared to conventional billboards (Chattington, 2009). The difficulty of drivers in remaining in a relatively stable position within their lane is attributed to the fact that they could not focus their gaze on the road markings (Bendak, 2009). On routes with advertising billboards an increase in the time that drivers spend outside their lane is observed and this is attributed to increased eye movement while driving (Young, 2007).

The drivers' speed tends to decrease due to increased mental demands because of simultaneous driving and the increased attention paid to the advertising billboards. A significant reduction in speed was observed on routes that include billboards, as they create an overburdened driving environment which causes an additional psychological burden on the driver (Horberry, 2005). The most striking finding was the advertising message; the decrease in speed was greater, especially in the case of advertising video display panels (Chattington, 2009). Changes were also observed, by the international literature, in the drivers' reaction time. Drivers' attention was not focused on the purpose of their driving and therefore they were slow to react in difficult situations. On routes within the city, it was observed that drivers crossed over the dividing lines more carelessly, and this was attributed to the increase of the reaction time (Bendak, 2009). When drivers approached advertising billboards they appeared to brake more sharply because of the increased reaction time and this phenomenon is more pronounced if the advertising billboards contained a video (Chattington, 2009).

Within this context, the purpose of this research is to explore the extent to which the existence of advertising billboards affects the driving behavior of young participants, through a driving simulator experiment on an urban environment. More specifically, this paper aims to examine in which extent three critical driving performance parameters, namely, lateral position, average speed, and reaction time to an unexpected incident are significantly affected by the existence of advertising billboards. For this purpose, 31 drivers aged 21-31 years old were asked to participate in an experiment including driving in a driving simulator as well as filling in a driving behavior questionnaire. The paper is structured as follows: In the beginning, the background of the research was provided including several similar researches. Then, in the methodology section the experimental procedure is presented regarding both the data collection as well as a first explanatory analysis of the results. Finally, the statistical models implemented regarding lateral position, average speed, and reaction time are presented and discussed and some concluding remarks are provided.

## 2. Methodology and data

### *2.1. Overview of the experiment*

The driving simulator experiment took taking place on Department of Transportation Planning and Engineering of the National Technical University of Athens (NTUA), where the FOERST Driving Simulator FPF is located. Foerst Driving Simulator is a quarter-cab simulator with a motion base and three 40" LCD monitors was used for the experiment. The experiment concerned the driving performance of 31 young active drivers aged between 21 and 31 years (aver. 25.5 y.o. ± 5.1). The sample of drivers is consisted of 16 males and 15 females, most of which were students of the National Technical University of Athens with a valid driving license and an average driving experience of 4 years.

In preparation for the experiment, exploratory journeys were carried out in the streets of Athens in various areas. The aim was to identify the types of billboards used in an urban environment which was familiar to the participants and also to determine the distance at which they are placed alongside the road. After the completion of these

exploratory journeys, the content of the billboards was determined and appropriately inserted in the simulator environment by programming tools (Figure 1).

Figure 1. Screenshot of the simulated environment with the roadside billboards

The experimental procedure started with a familiarization session. The driving simulator provides a "Free Driving" scenario (with an approximate duration of 10 minutes) that familiarizes the participants with the demands of the simulated environment. During this first introductory driving session, the participant practiced in handling the simulator and the experimental vehicle, keeping the lateral position of the vehicle, keeping stable speed, appropriate for the road environment, braking and immobilization of the vehicle.

Then, all participants were asked to drive four driving scenarios (with an approximate duration of 4 minutes each): an urban route that is 1,7km long, at its bigger part dual carriageway, separated by guardrails, and the lane width is 3.5m. The urban environment included traffic lights, pedestrian movements, roundabout, shop windows and oncoming traffic. Two traffic scenarios and two distraction conditions are examined in a full factorial within-subject design. The traffic scenarios are:

- $Q_L$: Moderate traffic conditions - with ambient vehicles' arrivals drawn from a Gamma distribution with mean m=12 sec, and variance $\sigma^2$=6 sec, corresponding to an average traffic volume Q=300 vehicles/hour.
- $Q_H$: High traffic conditions - with ambient vehicles' arrivals drawn from a Gamma distribution with mean m=6 sec, and variance $\sigma^2$=3 sec, corresponding to an average traffic volume of Q=600 vehicles/hour.

The distraction conditions examined concern:

- no advertising billboards at the roadside
- advertising billboards at the roadside

In all four scenarios the driving was designed to be under good weather and in daylight so that the drivers would not be distracted or disturbed by other factors, apart from the billboards, the influence of which this research intends to study. Moreover, the scenarios were fully randomised in order to avoid any learning effects or biased data.

Additionally, various unexpected incidents were designed and programmed to take place during the driving. More specifically, incidents concern the sudden appearance of an adult pedestrian or of a child chasing a ball on the roadway or of a car suddenly getting out of a parking position and getting in the road. The hazard did not appear at the same location between the trials, in order not to have learning effects.

All the participants were asked to drive exactly as they would in their everyday life; it is worth noting that they did not know the objectives of the study. The research coordinator was present during the experiment and he was located at some distance from the drivers so as not to affect their behavior. His exclusive role was to make the necessary settings on the simulator, to resolve any questions the participants might have and to collect the data after the completion of the route of each participant. After the completion of the above procedure, every participant filled out a questionnaire, which was mainly concerned with the recording of certain details of the drivers.

## 3. Results

### *3.1. Preliminary findings*

Before moving on to the core of the statistical analysis some preliminary analysis was applied regarding the questionnaires and the three examined driving performance measures namely lateral position (vehicle's distance from the right border of the road in meters), average speed (mean speed of the driver's vehicle along the route, excluding the small sections in which incidents occurred, and excluding junction areas) and reaction time at unexpected incidents (time between the first appearance of the incident on the road and the moment the driver starts to brake in milliseconds).

Firstly, from the questionnaires collected it is worth noting that the participants do not consider the existence of roadside billboards to be particularly dangerous. More precisely, 39% of respondents believe that the existence of billboards in a residential area is a little dangerous, 32% moderately dangerous and only 9% believe that it is quite or very dangerous.

Moving on, some initial observations are drawn from the initial approach made on the measurements of the simulator and comparing the sizes under the same traffic conditions. Table 1 indicates the results of the average speed, the average lateral distance from the right boundary, and the average reaction time, with or without the existence of advertising billboards at the roadside. In the same traffic volume conditions, it appears that in the scenarios with billboards the participants had a tendency to drive at a slightly lower speed. In addition, in driving scenarios with advertising billboards, it could be claimed that the drivers had slightly worse reaction time and a slightly wider lateral position in comparison to the driving scenarios in which there were no billboards.

Table 1: Preliminary analysis of the three examined driving performance parameters

| | Low traffic conditions | | High traffic conditions | |
|---|---|---|---|---|
| | Without roadside billboards | With roadside billboards | Without roadside billboards | With roadside billboards |
| Mean speed (km/h) | 35,69 | 34,51 | 32,22 | 32,08 |
| Lateral position (m) | 2,35 | 2,56 | 2,32 | 2,43 |
| Reaction time (millisec) | 1.099 | 1.182 | 1.386 | 1.543 |

### *3.2. Analysis method and models development*

The driving simulator parameters and the questionnaires have brought out a large number of variables, which will next be used to develop models that will determine the influence of advertising billboards on the behavior and safety of drivers. Certain specific criteria were implemented in order to accept an independent variable or not for the model. First, in order for a variable to be accepted for a model, it should be statistically significant and thus a separate t-test or a control coefficient Wald was carried out for each variable. Secondly, the correlation between the variables was tested so that the independent variables are linearly independent of each other because, otherwise, it is not possible to verify their influence to the three examined dependent variables. In each case, an effort was made so that the independent variables would also be distinguished by the ability to perform physical interpretation.

After a series of exploratory tests, regarding the average reaction time to an unexpected incident, the application of the linear regression method was selected and the implementation of the lognormal regression method with respect to the average driving speed, and the average lateral position was selected: $y_i = \Sigma\beta x_i + \varepsilon_i$, where $y_i$ is the response variable, $x_i$ are continuous or discrete explanatory variables, $\beta$ are parameters to be estimated and $\varepsilon_i$ the error component $\varepsilon \sim N(0, \sigma^2)$. A variable was kept in the final model if the corresponding parameter estimate was significant at 95% confidence level. In particular, a variable was considered statistically significant only if the respective value of the t-test was higher than 1,7 while the quality of the model was determined by means of the $R^2$ coefficient (Ben-Akiva and Lerman, 1985).

### *3.2.1. Average Speed*

The identification of the effect of advertising roadside billboards in an urban environment on the average driving speed was achieved by developing a lognormal regression model. The results of the model are included in Table 2, which depicts the regression coefficients and the corresponding values of the coefficient t for each variable of the model. Additionally, the significance level of each independent variable is also included.

Table 2: Average Speed Model

Dependent Variable: **Log Speed**

| | **Unstandardized Coefficients** | | **Standardized Coefficients** | | |
|---|---|---|---|---|---|
| **Model** | **B** | **Std. Error** | **Beta** | **t** | ***Sig.*** |
| Constant | 1,404 | ,041 | | 34,338 | *,000* |
| Distractor | -,010 | ,003 | -,094 | -1,847 | *,048* |
| Sex | ,035 | ,007 | ,323 | 4,790 | *,000* |
| Age | ,004 | ,002 | ,177 | 2,335 | *,021* |
| acc_in | -,016 | ,008 | -,149 | -2,008 | *,047* |
| Traffic | -,030 | ,007 | -,274 | -4,300 | *,000* |
| Dang_adv_in | -,009 | ,004 | -,173 | -2,453 | *,016* |
| BrakeAverage | ,016 | ,002 | ,447 | 6,827 | *,000* |
| RspurAverage | -,012 | ,005 | -,149 | -2,240 | *,027* |

Distractor: driving in an urban environment with the presence of billboards at the roadside (1 = yes, 0 = no)
sex: driver's gender (men= 1, woman=0)
Age: driver's age
acc_in: questionnaire - if the participant was involved in an accident in an urban environment (1 = yes, 0 = no)
Traffic: traffic conditions on the road (0=low traffic conditions, 1=high traffic conditions)
Dang_adv_in: questionnaire - how dangerous the participant considers the existence of billboards in urban environment (1=none, 2=low, 3 = medium, 4 = high, 5=very high)
BreakAverage: percentage of the route the driver stepped the brake
RspurAverage: mean distance from the central axis (m)

It is observed that the sign of B coefficient corresponding to the variable representing the presence or absence of billboards in the model of the average driving speed is negative. This means that as this variable increases, i.e. the closer it gets to the value 1 (driving in an urban environment with billboards at roadsides) results in reducing the average driving speed. This result can be explained by the fact that, when the participants were asked to drive in a more burdened with distracting factors (billboards) environment, they tried to counterbalance their behavior by driving at a lower speed. Regarding the rest independent variables, the sex and the traffic volume have the higher impact on the speed.

### *3.2.2. Lateral Position*

The identification of the effect of advertising roadside billboards in an urban environment on the lateral position from the right boundary was achieved by developing a model through lognormal regression. The results of the model are included in Table 3, which depicts the regression coefficients and the corresponding values of the coefficient t for each variable of the model. Additionally, the significance level of each independent variable is also included.

Table 3: Lateral Position Model

Dependent Variable: **Log Lateral Position**

| | **Unstandardized Coefficients** | | **Standardized Coefficients** | | |
|---|---|---|---|---|---|
| **Model** | **B** | **Std. Error** | **Beta** | **t** | ***Sig.*** |
| Constant | ,181 | ,052 | | 1,901 | *,049* |
| Distractor | ,033 | ,012 | ,141 | 1,910 | *,050* |
| acc_in | ,060 | ,022 | ,251 | 2,682 | *,008* |
| Age | -,011 | ,005 | -,222 | -2,422 | *,017* |
| AverageSpeed | ,005 | ,002 | ,202 | 2,243 | *,027* |
| num_adv | -,064 | ,028 | -,200 | -2,234 | *,027* |

| | | | | | |
|---|---|---|---|---|---|
| GearAverage | ,097 | ,034 | ,252 | 2,891 | *,005* |

Distractor: driving in an urban environment with the presence of billboards at the roadside (1 = yes, 0 = no)
acc_in: questionnaire - if the participant was involved in an accident in an urban environment (1 = yes, 0 = no)
Age: driver's age
AverageSpeed: mean speed (km/h)
num_adv: questionnaire - if the participant observed change to his driving behavior by the existence of billboards (1 = yes, 0 = no)
GearAverage: the average gear used at gearbox

The sign of B coefficient corresponding to the variable representing the presence or not of advertising billboards is observed to be positive, indicating that as the value of the variable increases, the value of the dependent variable increases, too. It seems that the drivers kept longer lateral distance on routes where there were billboards alongside the road compared to the routes where there were no billboards. Regarding the rest independent variables, the self-declaration of accidents (a risky driver), the self-declaration of driving behavior change when billboards are present and the average gear used at the gearbox have the higher impact on the lateral position.

### *3.2.3. Reaction Time*

The identification of the influence of roadside advertising billboards in an urban environment on the driver's reaction time to an unexpected event was achieved by developing a linear regression model. The results of the model are included in Table 4, which depicts the regression coefficients and the corresponding values of the coefficient t for each variable of the model. Additionally, the significance level of each independent variable is also included.

Table 4: Reaction Time Model

Dependent Variable: **Reaction Time**

| | **Unstandardized Coefficients** | | **Standardized Coefficients** | | |
|---|---|---|---|---|---|
| **Model** | **B** | **Std. Error** | **Beta** | **t** | ***Sig.*** |
| Constant | 1113,238 | 212,319 | | 5,243 | *,000* |
| Distractor | 145,675 | 82,603 | ,148 | 2,002 | *,041* |
| Dist_week_in | 145,533 | 51,554 | ,238 | 2,825 | *,006* |
| Dang_adv_in | 99,071 | 40,685 | ,208 | 2,435 | *,016* |
| HWayAverage | -3,737 | 1,250 | -,253 | -2,990 | *,003* |
| BrakeAverage | -66,432 | 27,245 | -,208 | -2,438 | *,016* |

Distractor: driving in an urban environment with the presence of billboards at the roadside (1 = yes, 0 = no)
dist_week_in: questionnaire - distance travelled per week in km in urban environment (<15= 1, 16-50= 2, >51= 3, don't know= 0)
dang_adv_in: questionnaire - how dangerous the participant considers the existence of billboards in urban environment (none = 1, low = 2, 3 = medium, 4 = high, very high= 5)
HWayAverage: middle distance of the vehicle ahead
BreakAverage: percentage of the route the driver stepped the brake

The sign of coefficient B, which corresponds to the variable representing the presence of advertising billboards or not, is observed to be positive, indicating that the more the value of this variable increases, i.e. the closer it gets to value 1, which means that "driving in an urban environment with billboards at roadsides, the higher the value of the dependent variable gets". The existence of roadside billboards has a detrimental effect on reaction time of the drivers. It should also be noted that the distractor has the greatest impact on the dependent variable (reaction time) compared to the other factors.

## 4. Conclusions and discussion

The aim of this research was to explore the extent to which the presence of billboards affects the young drivers' behavior using a driving simulator in an urban environment. To collect the necessary data, 31 young drivers were recruited in order to go through a driving simulator experiment. For the development of models and the statistical procession of data, methods of linear and lognormal regression analyses were used in order to quantify the impact of the roadside advertising billboards on the driving behavior as reflected by three key safe driving performance parameters, namely, mean speed, lateral position, and reaction time. After the statistical analysis was completed, this research concludes that the billboards alongside the road in an urban area appears to have a significant and quantifiable impact on the driving behavior as indicated in three mathematical models that were developed.

Firstly, regarding the average driving speed, it is concluded that the presence of roadside billboard led the participants to lower driving speeds in a significant level. This could be a counterbalanced driving behavior indicating that young drivers know that the presence of roadside billboards is dangerous and distracting and for that reason they try to counterbalance their driving behavior by reducing their speed and be more conservative and careful. The riskiest driving profile, regarding the mean speed, extracted from the model application is a male driver, in low traffic conditions.

Moving on to the average lateral distance from the right boundary of the road, it emerges that the presence of roadside advertising billboards leads the drivers more closely to the central axis of the road, which indicated a more careless and potentially risky driving behavior. The riskiest driving profile extracted from this model application is a younger person who doesn't admit that the existence of roadside billboards is dangerous and has a history with accidents.

Finally, regarding the driving average reaction to an unexpected incident, it seems that the presence of roadside billboards leads to worse reaction times. The existence of roadside billboards has a significantly negative impact on reaction time of the drivers. This result can be interpreted by the divided attention caused by the roadside advertising billboards which leads to larger reaction time and possibly higher accident probability constructing a dangerous framework with detrimental negative effect towards road safety.

This study tried to simulate an everyday phenomenon in urban roads, namely the existence of roadside advertising billboards and examine their impact on road safety. Research results allow a clear view of the extent and manner in which driving conditions in conjunction with driver's characteristics affect to driving performance. The next steps of the present research should focus on examining more driving parameters that significantly affect the driving behaviour among the different environments. It would be interesting to examine a larger sample for safer results and different age groups so that to compare them. Finally, it would be interesting to carry out a research equivalent to this one, but on different road environments (e.g. motorways) or under the influence of other environmental conditions, such under the rain or in fog.

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