Investigation of traffic and safety behavior of pedestrians while texting or web-surfing

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Objective: More and more pedestrians use mobile phones in their daily traffic activities by the roadside or even when crossing the street. The objective of this research is to examine pedestrians' traffic and safety behavior while texting or web-surfing, when crossing signalized intersections.

Methods: In order to compare the behavior of distracted and non-distracted pedestrians, an experimental process through video recording was carried out in real road conditions, in three signalized intersections in the center of Athens in Greece. Demographic and behavioral characteristics were observed, including use of mobile device. For the statistical analysis, two multiple linear regression models were developed to investigate the association of pedestrians' speed and distraction caused by mobile phone use. Additionally, binary logistic regression models were developed in order to determine the influence of distraction on pedestrians' safety characteristics and more specifically on near misses with oncoming vehicles.

Results: Observers recorded crossing behaviors for 2,280 pedestrians and noticed that nearly one-fifth (16.6%) of them performed a phone-distracting activity while crossing. Distractions included texting or web-surfing (6.3%), listening to music (5.4%) and using a handheld phone (4.9%). This research indicated that distraction caused by texting or web-surfing had a negative impact on pedestrians' main traffic and safety characteristics. Results pointed out that in high pedestrian traffic, distracted pedestrians who were texting or web-surfing on their mobile phone present lower speed than non-distracted pedestrians, regardless of their age, as they may be not aware of traffic conditions due to distraction and therefore, they have higher crossing times. Furthermore, their probability of a near miss increases with increasing pedestrian volume as the more pedestrians who occupy the pedestrian crossing the more difficult is for them to observe carefully the rest traffic.

Conclusions: Mobile phones are integral to contemporary daily life and their use and penetration is increasing rapidly as well. For this reason, it is crucial to investigate the impacts of distracted walking on pedestrians' traffic and safety behavior. Various measures and strategies should be implemented and further research should be conducted as texting and web-surfing distraction is associated with a rather high risk.

Keywords: distraction; pedestrians; traffic behavior; safety behavior; signalized intersection; mobile phone

Introduction

Despite considerable efforts and noteworthy progress, road safety still remains a major issue that concerns the majority of countries worldwide, as road traffic injuries are the eighth-leading cause of death for people of all ages. It is estimated that about 1.35 million people lost their lives as a result of road crashes in 2016 (World Health Organization 2018). An important aspect of the problem is vulnerable road users. Pedestrians suffer, due to their vulnerability to the speed of vehicles and increased exposure to multiple vehicles in high traffic volumes, and thus are at increased risk of serious injury or even death when involved in road crashes. In 2017, there were 5,220 pedestrian fatalities due to road crashes in the European Union, which account for 21% of all road fatalities. However, a significant decrease of 36% has been observed in pedestrian road fatalities during the last decade (CARE database 2019). It is also remarkable that pedestrian actions and behavior may account for 15% of pedestrian fatalities (Thompson et al. 2013).

Another factor that needs to be investigated is the association of pedestrian crashes with the use of mobile phone. The expansion of mobile phones has caused a rising number of pedestrians who use mobile phones in their daily traffic activities by the roadside or even when crossing the street. A recent survey conducted in six major European capitals found that a significant proportion of pedestrians crossing the street made use of their mobile phone (DEKRA 2016). According to a recent observational study conducted in China, one third of pedestrians presented mobile phone distracted activity while crossing the street (Zhao et al. 2015). Distracting activities due to the use of mobile phone are a quite common phenomenon for young pedestrians. The records of an observational study related to the crossing behavior of students near four major schools in Germany showed that about 10.5% of students were looking at their mobile phone or typing while crossing the street (Vollrath et al. 2019). Another study carried out in the United States using data for the period 2004-2010, indicated that pedestrian injuries due to mobile phone use increased relative to the number of total pedestrian injuries (Nasar and Troyer 2013).

Distracted behavior is common among pedestrians and it was observed that technological and social distractions increase crossing times, with text messaging being associated with the highest risk and the highest proportions of unsafe crossing behaviors (Thompson et al. 2013; Chen et al. 2017). Another study tested how talking on the phone, texting, listening to music may influence pedestrian safety and it was observed that participants distracted by music or texting were more likely to be hit by a vehicle in the virtual pedestrian environment than were non-distracted participants (Schwebel et al. 2012). An outdoor-environment experiment was carried out in China and the results pointed out that mobile phone distractions cause different levels of impairment to pedestrians' crossing performance, with the greatest effect from text distraction (Jiang et al. 2018). Another study showed that pedestrian behavior was riskier when pedestrians were using the Internet and crossing the street at the same time (Byington and Schwebel 2013). Moreover, pedestrians who use mobile phones while crossing the street behave less safely and pedestrians who text or view content on the phone have higher chances not to finish at the marked pedestrian crossing than non-distracted pedestrians (Pešić et al. 2016). Another recent study based on pedestrians' performance and electroencephalography data pointed out that pedestrians performed better while they were only walking than when texting while walking (Courtemanche et al. 2019).

Researchers have also examined the way in which pedestrian crossing speed is affected by texting or web-surfing distraction. The results of an indoor experiment in Japan indicated higher risk of crashes among pedestrians who are using mobile phones and lower speed of pedestrians who are texting in comparison with the speed of the control group (Haga et al. 2015). Regarding non-distracted pedestrians, it has been observed that it was higher than the speed of distracted pedestrians, which leads to larger exposure to conflicts with vehicles (Muley et al. 2017). However, the results of a recent survey pointed out that talking and texting while walking were not statistically significantly associated with walking speed, indicating that pedestrians may be accustomed to walking while talking or texting and do not significantly slow or increase their walking speeds (Russo et al. 2018).

Based on the above, the objective of this paper is to investigate traffic and safety behavior of pedestrians who are texting or web-surfing when passing through signalized pedestrian crossings. This study is the first of its kind in Greece and endeavors to identify the differences between the behavior of distracted and non-distracted pedestrians.

Methods

Data collection

For the purpose of this research, an experimental process through video recording was carried out in real road conditions, in three signalized intersections in the center of Athens in Greece. The selection of the road sections for the experiment and consequently the selection of the pedestrian crossings was based on the high pedestrian volumes typically found in the area, ensuring sufficient sample size, and the presence of a pedestrian traffic light on each crossing. Taking into account these criteria, the pedestrian crossings chosen were namely:

- Akadimias Street (3 lane road, pedestrian crossing length=9.90m, pedestrian crossing width=6.30m) at intersection with Ippokratous Street, (44 distracted pedestrians who were texting or web-surfing and 649 non-distracted pedestrians)
- Ippokratous Street (2 lane road, pedestrian crossing length=8.10m, pedestrian crossing width=6.30m) at intersection with Akadimias Street, (47 distracted pedestrians who were texting or web-surfing and 428 non-distracted pedestrians)
- Skoufa Street (1 lane road, pedestrian crossing length=6.50m, pedestrian crossing width=5.50m) at intersection with Filikis Eterias Square, (51 distracted pedestrians who were texting or web-surfing and 824 non-distracted pedestrians)

The experiment's video recording was conducted during daylight hours and clear weather conditions. For each signalized crossing, data was collected through one half-hour video recording on a weekday (15:30-16:00) and through one half-hour video recording on the weekend (13:00-13:30) as peak hours were examined on both cases. The camera was set up in such way so as the observer was able to easily identify and list each pedestrian's distraction type while recording as the entire crossing and pedestrian traffic signals were visible during each recording. A total of 3 hours of video were collected and subsequently analyzed, resulting in the observation of several pedestrians and their demographic, traffic and safety characteristics, while their distraction type was also verified through the video analysis. The study was based on ordinary roadway observation and all data were completely anonymized. The Head of the Department of Transportation Planning and Engineering of the National Technical University of Athens has also approved this study. Moreover, the faces of the examined pedestrians have been blurred and after examination of the video footage, no personal evidence or too detailed information such as smartphone screens were visible. The extracted data are the following:

- Pedestrian distraction, recorded as one of four discrete categories: texting or web-surfing on mobile phone, talking on the phone, listening to music using headphones, no distraction.
- Pedestrian gender
- Pedestrian age estimate: 0 to 17 (child), 18 to 34 (young), 35 to 64 (middle) and 65 or older (old)
- Pedestrian crossing length and width
- Crossing time
- Pedestrian speed
- Number of road lanes
- Pedestrian volume: number of pedestrians crossing the street at the same time
- Pedestrian was accompanied by someone else: yes or no
- Pedestrian traffic light: green or red
- Pedestrians' trajectory while crossing the street: direct or not direct
- Conflict with other pedestrian: yes or no
- Illegal vehicle passing: yes or no
- Vehicle on crossing: yes or no
- Weekday
- Waiting time for pedestrian green light
- Near miss (temporal headway between pedestrian and vehicle less than two seconds): yes or no

2,280 pedestrians were observed and the analysis of the videos revealed that 142 of them were texting or surfing the Internet, 113 were talking on the mobile phone, 124 were listening to music using headphones and 1,901 pedestrians were non-distracted. Table 1 presents summary statistics for pedestrian observations in the three examined pedestrian crossings regarding distraction. Texting or web-surfing was the most common distraction activity among the pedestrian sample.

Table 1. Summary statistics for pedestrian observation regarding distraction

Distraction	**Count**	**Percentage**
Distracted Texting or Web-Surfing	142	6.2%
Distracted Music (headphones)	124	5.4%
Distracted Talking	113	5.0%
Non-Distracted	1,901	83.4%
Total	2,280	100.0%

Statistical analysis

Data obtained from the videos were analyzed using Microsoft Excel and IBM SPSS Statistics (version 21). Afterwards, statistical analyses were carried out using two modelling approaches; multiple linear regression and binary logistic regression models. The basic equation of the multiple linear regression model is the Eq. (1) as presented below:

$$Y_i = \beta_0 + \beta_1 * X_{1i} + \beta_2 * X_{2i} + \ldots + \beta_v * X_{vi} + \varepsilon_i \quad (1)$$

The accuracy of the model is assessed through the coefficient of determination R squared (R^2). R^2 shows the percentage of the variability of the dependent variable Y explained by the independent variables X included in the model. R^2 takes values between 0 and 1, with 1 meaning that the independent variables X explain fully the dependent variable Y.

Linear regression models have the assumption that the dependent variable is continuous. However, in many cases the dependent variable is not continuous and discrete outcome models should be applied instead. When the discrete outcomes are two, binary logistic regression models can be applied. The best fitting model which describes the linear relationship between a binary (dichotomous) dependent variable and a number of explanatory variables is pursued. If the “utility function” is given by Eq. (2), then the probability P is given by Eq. (3):

$$U=\beta_0+\beta_i*X_i \quad (2)$$

$$P=e^U/(e^U+1) \quad (3)$$

Most of the tests for goodness of fit of a model are carried out by analyzing residuals; however, such an approach is not feasible for a binary outcome variable. In this case, the goodness of fit of the model can be assessed with the Hosmer & Lemeshow Test (Hosmer and Lemeshow 1989).

In the case of this study, four statistical models were developed. More specifically, two multiple linear models with pedestrian speed as the dependent variable and two binary logistic regression models for the dependent variable of near miss.

Results

A high number of regression model tests were conducted for different combinations of variables, with or without the use of an intercept term. This included different variable forms such as logarithmic and square forms of certain variables, however without simultaneous inclusion of multiple forms of one variable. The best combination of variables was the one that had an adequate number of statistically significant variables. This procedure resulted in the final statistical models that capture the correlation between dependent and independent variables. At first, several model tests were conducted including “distraction” as one of the independent variables. However, the results mostly concerned the impact of traffic characteristics at the sample of 142 distracted and 1,901 non-distracted pedestrians, which was not the primary aim of this study. Therefore, we selected the present approach which involved calibrating models separately for distracted and non-distracted pedestrians. The independent variables were selected to be exactly the same for each one of the following models with the same dependent variable in order to enable meaningful comparison of coefficients between the models for distracted and non-distracted pedestrians. Tables A1 and A2 placed in the Appendix present the correlation coefficients between the selected variables. The dependent variables of the models are:

- Models 1a, 1b: Pedestrian Speed (The logarithm of pedestrian speed)
- Models 2a, 2b: Near miss (Binary: Yes/No)

Table 2. Statistical model for pedestrian speed

	Distracted Pedestrians			Non-Distracted Pedestrians		
Independent Variables	β_i	t	Sig.	β_i	t	Sig.
Age	-0.018	-1.781	0.077	-0.033	-6.562	0.000
Accompanied	-0.052	-2.093	0.038	-0.063	-6.194	0.000
Crossing Length	0.021	7.676	0.000	0.026	15.231	0.000
(Pedestrian Volume)^2	-6.056E-005	-2.662	0.009	-3.627E-005	-3.200	0.001
Adjusted R^2	0.638			0.556		

All the parameters are statistically significant at 95% confidence intervals for both models except age for the distracted pedestrians' model which is statistically significant at 90% confidence interval. The adjusted R^2 are 0.638 and 0.556 respectively, which lead to the acceptance of these models as robust. Regarding the modelling results, it can be observed that the independent variables affect similarly the speed of distracted and non-distracted pedestrians, as the signs of the β coefficients are the same in both cases. More specifically, results indicate for both models the following:

- The variable "Age" has a negative relationship with the dependent variable, showing that as pedestrian age increases, the speed of the pedestrian decreases.
- The negative sign of "Accompanied" variable shows that if someone else accompanies the examined pedestrian, pedestrian speed decreases.

- The variable “Crossing length” has a positive relationship with the dependent variable, showing that as crossing length increases, the speed of the pedestrian increases as well.
- Pedestrian speed is lower for higher pedestrian volumes.

Sensitivity analyses were also conducted for the findings of the previous models and figures based on sensitivity analysis were developed to better understand the influence of the independent variables on the speed of the two types of pedestrians. As it can be observed in Figure 1, at low pedestrian volumes distracted children move at higher speeds than non-distracted young pedestrians, as children are very familiar with the use of the mobile phone and their speed is not greatly affected. Moreover, at high pedestrian volumes, distracted pedestrians who were texting or web-surfing on their mobile phone present lower speed than non-distracted pedestrians, regardless of their age, as they may be not aware of traffic conditions due to distraction and have higher crossing times.

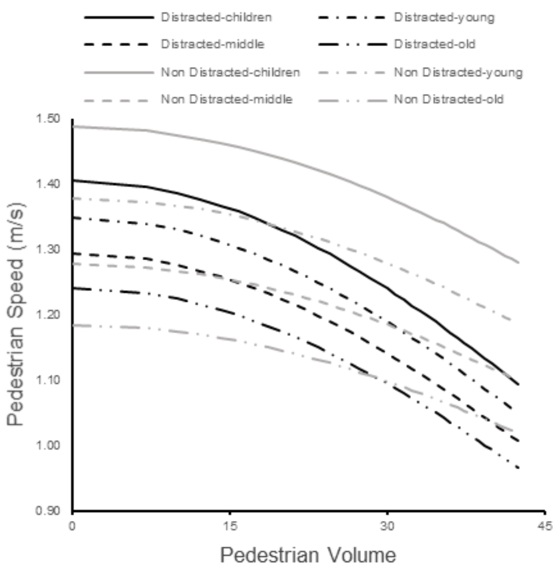

Figure 1. Pedestrian Speed to Pedestrian Volume (non-accompanied pedestrians)

The association between independent variables and the probability of a near miss to occur was investigated using binary logistic regression. In these statistical models the occurrence of a near miss is the dependent variable; this variable takes two values (0: no near miss and 1: near miss happened). The explanatory variables are the sign of pedestrian traffic light, the logarithm of pedestrian speed, the pedestrian volume and the crossing length.

Table 3. Statistical Model for Near Misses

	Distracted Pedestrians			**Non-Distracted Pedestrians**		
Independent Variables	β_i	Wald	Sig.	β_i	Wald	Sig.
Red Pedestrian Traffic light	3.287	11.399	0.001	2.269	8.095	0.004
Pedestrian Volume	0.083	3.711	0.054	-0.074	4.328	0.037
Log(Speed)	6.158	2.354	0.125	3.866	1.860	0.173
Crossing Length	-0.820	19.907	0.000	-0.543	25.724	0.000
Hosmer & Lemeshow Test	0.954			0.578		

The p-value of Hosmer & Lemeshow Test for goodness of fit is higher than 0.05 meaning that one cannot reject the null hypothesis of the test for both logistic regression models, which suggests these models can be considered as acceptable. The results indicate the following:

- Both distracted and non-distracted pedestrians who started walking through the crossing when the pedestrian traffic light was red present higher probability of a near miss.
- The positive sign of pedestrian speed shows that there is an increase in the probability of a near miss, if pedestrian speed increases for both models. However, the speed parameter is not statistically significant at 90% confidence interval.
- The probability of a near miss is higher for pedestrian crossings with lower crossing length.

- Pedestrian volume does not affect in the same way the probability of a near miss for distracted and non-distracted pedestrians. The positive sign of the variable in the distracted pedestrians' model shows that as pedestrian volume increases, the probability of a near miss for distracted pedestrians with a vehicle is higher. However, the sign of pedestrian volume in the non-distracted pedestrians' model is negative indicating that an increase in pedestrian volume leads to lower probabilities of a near miss.

Figure 2 shows the change in the probability of a near miss depending on the pedestrian volume for pedestrians who started crossing the street with red pedestrian traffic light. Regarding distracted pedestrians, the probability of a near miss increases with increasing pedestrian volume as the more pedestrians who occupy the pedestrian crossing the more difficult is for them to observe carefully the rest traffic. On the contrary, the probability of a near miss for non-distracted pedestrians decreases with increasing pedestrian volume. This may be attributed to the fact that non-distracted pedestrians are fully aware of the traffic conditions and they can perceive the danger early by observing the behavior of other pedestrians. Another remarkable conclusion that derived from the sensitivity analysis is that the probability of a near miss for non-distracted pedestrian remains very low and almost equal to zero when pedestrian volume increases, while for distracted pedestrians it presents an increasing trend.

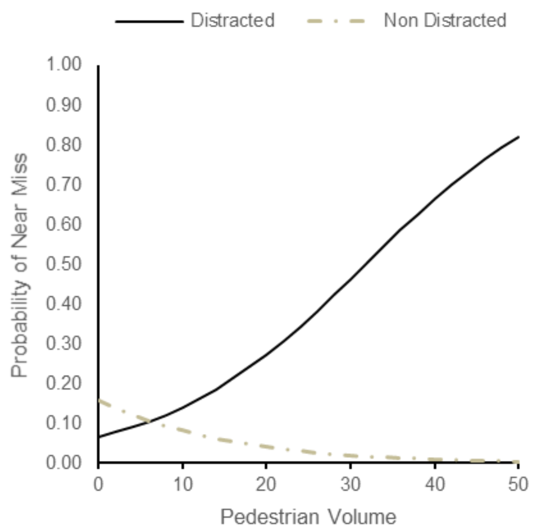

Figure 2. Probability of a near miss to pedestrian volume (red pedestrian traffic light)

Discussion

This study used data derived from an outdoor experimental process through video recording which was carried out in three signalized intersections in the center of Athens and the results of this paper shed light to the characteristics that affect traffic and safety behavior of distracted and non-distracted pedestrians. The analyses pointed out that in high pedestrian traffic, mobile use not only decreases pedestrians' speed, regardless of their age, but also increases their probability of being involved in a crash with an oncoming vehicle. Moreover, it was found that distraction caused by texting or web-surfing on the mobile phone affects negatively pedestrians' main traffic and safety characteristics.

Pedestrian distraction is a global problem, and to the extent of the authors' knowledge, there are typically no road safety measures to reduce pedestrian distraction in modern road networks. To counter this, various measures and strategies should be implemented. A type of restriction on walking while using a mobile phone (as compared to the driver mobile phone prohibition) might be foreseen in busy roads where road crashes involving pedestrians are a frequent phenomenon. Several cities in the United States have already enacted similar laws and Honolulu is the first major city to ban texting while walking in a crosswalk (National Public Radio 2017). Furthermore, mobile applications which warn pedestrians that they are moving towards a pedestrian crossing or that a vehicle is approaching them could be developed. Additionally, the GPS of the mobile phones could recognize that the pedestrians are moving and disable some specific features while walking. Lastly, engineering solutions in the design of road crossings and public places (e.g. green and red lights on the ground) may also contribute to distracted pedestrians' safety. A recent laboratory study suggests that Light Emitting Diodes embedded in pathways could be an effective solution to address the problem of mobile phone distraction while walking (Larue et al. 2020).

One of the limitations of this survey was the choice of two pedestrian crossings at the same location (different intersection's legs) which may lead to the repetition of the same pedestrians in the study. However, after analyzing the recordings, only a few pedestrians (about 10%) were spotted crossing both road crossings. Therefore, whatever bias may have occurred by repetition is assumed to be negligible. Regarding future research in this topic, it would be extremely interesting to expand this experiment in a larger sample of pedestrians and signalized intersections located in different areas, and to conduct a comparative analysis to see which pedestrians incur higher risks. It would also be useful to carry out the same experiment during the nighttime in order to identify the differences in pedestrians' behavior as well as examine other factors that could possibly affect them, such as traffic volume. Concluding, given the fact that mobile technology continues to change rapidly, our society should stay up to date with these changes to reduce the safety risks of distracted walking. To that end, the results of the present research allow for an overall assessment of pedestrians' safety in signalized intersections.

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Appendix

Table A1. Correlation matrix – Distracted Pedestrians

	Age 0-17 (child)	Age 18-34 (young)	Age 35-64 (middle)	Age 65 or older (old)	Accompanied	Crossing Length
Age 0-17 (child)	1.000	-0.286	-0.138	-0.059	-0.081	-0.072
Age 18-34 (young)	-0.286	1.000	-0.760	-0.327	-0.082	0.180
Age 35-64 (middle)	-0.138	-0.760	1.000	-0.157	0.137	-0.093
Age 65 or older (old)	-0.059	-0.327	-0.157	1.000	-0.001	-0.165
Accompanied	-0.081	-0.082	0.137	-0.001	1.000	-0.232
Crossing Length	-0.072	0.180	-0.093	-0.165	-0.232	1.000
(Pedestrian Volume)^2	-0.014	-0.105	0.054	0.135	0.271	-0.496
Traffic Light	-0.011	0.262	-0.104	-0.335	0.002	0.196
Pedestrian Volume	-0.008	-0.120	0.051	0.165	0.244	-0.502
Log(Speed)	-0.040	0.202	-0.117	-0.151	-0.286	0.475

	(Pedestrian Volume)^2	Traffic Light	Pedestrian Volume	Log(Speed)
Age 0-17 (child)	-0.014	-0.011	-0.008	-0.040
Age 18-34 (young)	-0.105	0.262	-0.120	0.202
Age 35-64 (middle)	0.054	-0.104	0.051	-0.117
Age 65 or older (old)	0.135	-0.335	0.165	-0.151
Accompanied	0.271	0.002	0.244	-0.286
Crossing Length	-0.496	0.196	-0.502	0.475
(Pedestrian Volume)^2	1.000	-0.103	0.959	-0.391
Traffic Light	-0.103	1.000	-0.084	0.113
Pedestrian Volume	0.959	-0.084	1.000	-0.411
Log(Speed)	-0.391	0.113	-0.411	1.000

Table A2. Correlation matrix – Non-Distracted Pedestrians

	Age 0-17 (child)	Age 18-34 (young)	Age 35-64 (middle)	Age 65 or older (old)	Accompanied	Crossing Length
Age 0-17 (child)	1.000	-0.197	-0.190	-0.129	0.171	-0.014
Age 18-34 (young)	-0.197	1.000	-0.581	-0.393	0.038	0.029
Age 35-64 (middle)	-0.190	-0.581	1.000	-0.379	-0.099	0.011
Age 65 or older (old)	-0.129	-0.393	-0.379	1.000	-0.030	-0.040
Accompanied	0.171	0.038	-0.099	-0.030	1.000	-0.118

Crossing Length	-0.014	0.029	0.011	-0.040	-0.118	1.000
(Pedestrian Volume)^2	0.040	-0.006	-0.043	0.035	0.128	-0.559
Traffic Light	0.095	-0.036	-0.014	0.003	0.122	0.059
Pedestrian Volume	0.048	-0.021	-0.027	0.029	0.152	-0.605
Log(Speed)	-0.018	0.206	0.000	-0.237	-0.278	0.445

	(Pedestrian Volume)^2	**Traffic Light**	**Pedestrian Volume**	**Log(Speed)**
Age 0-17 (child)	0.040	0.095	0.048	-0.018
Age 18-34 (young)	-0.006	-0.036	-0.021	0.206
Age 35-64 (middle)	-0.043	-0.014	-0.027	0.000
Age 65 or older (old)	0.035	0.003	0.029	-0.237
Accompanied	0.128	0.122	0.152	-0.278
Crossing Length	-0.559	0.059	-0.605	0.445
(Pedestrian Volume)^2	1.000	-0.059	0.970	-0.349
Traffic Light	-0.059	1.000	-0.048	-0.159
Pedestrian Volume	0.970	-0.048	1.000	-0.389
Log(Speed)	-0.349	-0.159	-0.389	1.000