Investigation of Illegal Pedestrian Crossings at Crosswalks in the Center of Athens, Greece

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Abstract

Urban centers are trying to achieve safer and more sustainable mobility, but understanding pedestrian behavior at crossings remains a key challenge. In cities where dense traffic and diverse road users intersect, like in the case of Athens, illegal pedestrian crossings are a persistent and hazardous phenomenon. This study explores the issue of pedestrian non-compliance, referring to the red light and jaywalking violations, at designated signalized crossings, in the center of Athens. A Stated Preference (SP) survey was structured in order to examine decision-making scenarios based on varying conditions of travel time, perceived crash risk, and personal comfort. A dataset of 212 responses was collected and analyzed by using binary logistic regression to examine the likelihood of illegal crossing, and generalized linear models to investigate the trade-offs pedestrians make between safety, time, and convenience, given three different scenarios of camera use, a traffic light with a timer, and the baseline scenario to choose from. The models highlight the influence of time pressure, traffic conditions, and social components on individual decisions. The results aim to showcase the importance of pedestrian decisions in preventing road crashes and, in this way, support more behavior-aware policy design, ultimately contributing to safer urban mobility systems.

***Keywords**:* Pedestrian behavior, Illegal crossings, Stated Preference survey, Logistic regression, Urban mobility, Road safety

1 Introduction

Pedestrian traffic behavior is an important issue in modern cities, especially in areas with intense urban activity and high traffic density, such as the center of Athens. The center of Athens is of great interest for study as it has a great diversity in the ways and transport modes people choose to move around, such as cars, public transport, and on foot. Depending on the day and time, there are people moving to or from work, people moving for leisure and recreation, and tourists.

The illegal crossing of pedestrians, i.e., crossing outside designated crossings, crossing at red light, or in prohibited areas, is a major cause of road crashes involving pedestrians. Pedestrian behavior is influenced by many factors, such

as lack of infrastructure or poor road conditions. Examples of factors include the absence of crossings, the poor condition of pavements, and the lack of lighting. Another important factor in pedestrian behavior is low perception of the level of risk, as pedestrians may cross the road distracted or when vehicles are moving at high speed [1,22]. An important factor in pedestrians' decision to cross a road illegally, despite the high risk involved, is cutting down on journey time, which may often exceed their need for safety.

It is essential to correlate the data collected from the center of Athens with demographic, environmental, and behavioral characteristics of the city's pedestrians. A number of studies demonstrate the complexity of pedestrian behavior and the high number of factors that influence it. Illegal crossings are not only caused by negligence or inattention but are influenced by: infrastructure factors such as waiting time at traffic signals, length of crossing, crossing design and traffic volume; socio-demographic factors such as age, gender, education level, occupation and income; psychological factors such as time pressure, convenience, familiarity with the area and distraction; social factors: such as the influence of other pedestrians and the presence of escorts; driver behavior: such as non-compliance with the traffic code and dangerous driving at pedestrian crossings [10,11,16].

Objectives & Questionnaire Methodology

A questionnaire was designed to collect data through stated preference. Six scenarios were developed, which were repeated for three different types of signalers (18 in total). The scenarios had two alternatives, illegal crossing or not, for different values of travel time and crash probability.

After data collection, statistical analysis was performed to produce appropriate mathematical models, which were necessary to identify the factors influencing the respondents to the alternatives given to them.

Numerous tests with various combinations of independent variables were required until the six appropriate models were developed using binomial logistic regression and one GLM model in which the factors influencing the respondents' choice of both the scenarios and the questions about their behavior were shown.

2 Methodology

Experiment

The questionnaire was created to collect data on the movement of pedestrians in the center of Athens and their characteristics and behaviors when crossing traffic lights. It was comprised of four parts and had a duration of 8-10 minutes to be completed. The questions had the main objective of being easy to comprehend in order not to confuse the respondent. The total number of questionnaires collected was 212, a sufficient number to obtain significant results from the statistical analysis. The process of collecting the responses

lasted two weeks, and emphasis was given on having a large sample in terms of age, gender, and residence, as it is important to test the behavior of pedestrians who are familiar or not with commuting in the center of Athens.

The third part of the questionnaire contained the scenarios given to the participants regarding a typical commute in the center of Athens. Participants had to choose whether or not they would cross a crossing illegally based on their time, comfort and safety. The fourth part of the questionnaire collected responses about the demographic information of the respondents.

Summary Statistics

Based on the data collected, it is clear that the respondents covered a wide age range, which is important for the interpretation of the results with the majority being young people aged 25-34 years old. It is strongly observed that the respondents consider very important to have traffic control buttons with an indication of the remaining time on the traffic light. In the case of the remaining time indicator, the pedestrians tend to think that they know how long they will have to wait until they can cross safely and therefore have more patience.

After the collection of the questionnaire responses, all of them were coded using Microsoft Excel software. Then they were transformed into numbers to be identified by the Python Jupyter program and used for statistical analysis with GLM and Binomial logistic regression.

Statistics Theory

The method of logistic regression is used both in the development of the binary model, where the alternatives are two, and in the development of a model with more alternatives, the multinomial model. The result is a mathematical model for predicting the probability of choosing an alternative scenario, as well as describing the mode and magnitude of the influence of independent variables.

$$Ui=a_0 + a_1x_1 + a_2x_2 + \dots + a_nx_n \quad (1)$$

Where Ui is the utility function of event i, x1…xn, are the variables of the problem, a0 is the constant term that shows the effect of all factors that influence the choice and have not been included as variables in the mathematical model, a1…an are the coefficients of the variables.

The above method has been used extensively in transportation studies, in which the prediction of the influence of certain characteristics on the choice of an event is requested. The purpose of using this method is to develop a mathematical model for predicting public choice [28].

Generalized Linear Model (GLM) is a statistical regression model used when the dependent variable has more than two categories. This model examines the effect of the independent variables on the probability of an observed value in the classified dependent variable. Specifically, ordinal logistic regression is a generalization of binary logistic regression and analyzes how the independent

variables affect the probability of an observed outcome belonging to one of the possible categories. This serves to understand changes in the level of the dependent variable in response to the independent variables. The GLM method is useful for a multitude of applications, such as preference evaluation, product ranking and risk assessment [29].

3 Model Development

Description of the process

Statistical analysis involves the development of statistical models that aim to describe the choices made by respondents as a function of independent variables. The binomial regression method is based on the third part of the questionnaire, namely the questions concerning the probability that pedestrians' choice to cross illegally at a crossing would change if certain conditions, such as the presence of a control camera or a countdown indicator, were changed. The respondents' choices were either Yes or No. In contrast, the generalized linear model method is also based on the third part of the questionnaire, which contains three different scenario conditions, each containing 6 scenarios. In these scenarios, respondents were asked to choose whether they would run a red light at a crossing depending on the travel time and the probability of a crash contained in each scenario. Statistical analysis was performed using the Python programming language and the open-source application Visual Studio Code.

Models

The model building process requires that the dependent variable of each model, as well as the independent variables, be defined. The dependent variable must be binary, i.e., it must take values of 0 or 1. To find the appropriate variables that will define the models as acceptable, several tests are required, specifically 6 mathematical models were created, for each of the dependent variables: camera use, police, absence of vehicles, presence of pedestrians with the same intention, no presence of pedestrians on the same side, camera use, and countdown. Several combinations of independent variables related to gender, age, and pedestrian behavior were tested. Most of the combinations resulted in non-accepted models as they showed less than the acceptable 95% reliability.

Table 1: Binary Logistic Regression Results

Variable	CAMERA_USE		POLICING		NO_CARS		ILLEGAL_PED		ILLEGAL_REM_ TIME		ILLEGAL_ CAMERA_TIME	
	coef	pvalue	coef	pvalue	coef	pvalue	coef	pvalue	coef	pvalue	coef	pvalue
ACCIDENT_DR IVE	-2,085	0,005										
ACCIDENT_ WALK					-3,226	0,008						
ANY_OPPORT UNITY					-0,712	0,019					1,317	0,034
ACCEPTABLE _OTHERS							-0,615	0,007				
ATH_ RESIDENT							1,386	0,005				
BUTTON	-2,860	0,003	-1,258	0,054					-1,502	0,008		
CENTER_ ATH			-3,222	0,001								
DIAGONALLY_ CROSS			-0,915	0,001	-0,545	0,026					-1,438	0,006
DISTRACTED	1,504	0,004										
DRIVERS_ SPEEDING	-1,390	0,004							-0,560	0,013		
EDUCATION					-0,636	0,043						
EMPTY_ ROAD	1,837	0,000	0,788	0,002	-0,362	0,019	-0,422	0,012				
ENCOURAGE_ GROUP	0,828	0,013									-1,971	0,000
ENTERTAINME NT_2	4,035	0,025										
ENTERTAINME NT_3	2,290	0,006									-1,675	0,047
FAM_ STATUS_3	-4,960	0,036					3,731	0,016	-5,715	0,000	-3,668	0,004
FASTER	0,476	0,054	0,548	0,007								
ILLEGAL CROSS	1,571	0,007	1,527	0,004								
INCOME	0,960	0,000	0,543	0,006								
IN_HURRY	0,942	0,007							-0,591	0,005	-1,020	0,003
JOB_2	-1,655	0,017							-1,037	0,027		
JOB_3	-5,916	0,027										
JOB_5	-3,949	0,000									3,819	0,005
LARGE_ URBAN_ ROADS	2,060	0,000	0,508	0,034								
MORE_ CAUTIOUS			-0,656	0,006								
NO_ OPPOSING	-2,437	0,000	-0,747	0,004							2,003	0,001

Table 2: Binary Logistic Regression Results

Variable	CAMERA_USE		POLICING		NO_CARS		ILLEGAL_PED		ILLEGAL_REM_ TIME		ILLEGAL_ CAMERA_TIME	
	coef	pvalue	coef	pvalue	coef	pvalue	coef	pvalue	coef	pvalue	coef	pvalue
NO_VISIBILITY	-1,623	0,000										
PEDESTRIAN_E DUC									-0,524	0,019		
PHONE_TEXT	-0,756	0,037										
PUBLIC_ TRAN_CAR	-0,658	0,012									-0,747	0,009
RED_LIGHT_ OTHERS			-0,681	0,038			-0,895	0,000	-0,772	0,000		
REM_TIME	3,340	0,022	2,214	0,009					-1,552	0,052		
RISK_ OUTSIDE_ CROSS	-1,117	0,001	-0,750	0,005								
RISK_SAVE_ TIME					-0,478	0,027						
SHORT_DIST									0,743	0,003		
SHORTEST_ ROUTE	-1,100	0,001	-0,802	0,000								
SIGNS_ CLEAR							0,484	0,018			-0,811	0,008
TALK_ LISTEN	0,776	0,019	0,590	0,008								
TRAF_LIGHT_R OUTE			-0,553	0,029			0,423	0,046				
URBAN_ STREETS											-0,729	0,013
WALK_ CENTER					1,324	0,036						
WALK_ HEALTH					0,553	0,003						
WEATHER							1,650	0,000	0,993	0,022		
WORK_ EDUC_2					2,745	0,024						
WORK_ EDUC_3	2,525	0,008			1,062	0,026						
WORK_ EDUC_6	4,784	0,000										

In the case of the given scenarios in section C, the respondent was required to choose whether to cross illegally at a crossing, with different conditions for each option, such as additional waiting time, crash probability, and type of signal. Next, the variables delta_time and delta_risk were created, where the difference between the additional waiting time in each scenario and the difference in the probability of a crash are denoted. The creation of these variables is necessary to take them into account in the models and to check for their influence on the response.

Table 3: Generalized Linear Model Results

GLM Regression Scenarios			GLM Regression Scenarios		
Variable	**Coef.**	**P>|z|**	**Variable**	**Coef.**	**P>|z|**
Intercept	-5,477	0,000	**TRAF_LIGHT**	-2,820	0,001
C(light_type)[T.classic]	1,266	0,000	**SHORT_DIST**	0,281	0,000
C(light_type)[T.countdown]	0,883	0,000	**PUBLIC_TRAN_CAR**	-0,198	0,000
time	0,836	0,000	**NO_CHOICE**	-0,299	0,000
risk	-0,083	0,000	**SAVES_TIME**	0,457	0,000
ATH_RESIDENT	-0,608	0,001	**DRIVERS_DISRESPECT**	-0,536	0,000
CENTER_ATH	-0,764	0,001	**DRIVERS_SPEEDING**	0,392	0,000
WALK_CENTER	0,932	0,000	**LESS_LIKELY**	0,364	0,000
ACCIDENT_WALK	0,578	0,037	**FASTER**	0,284	0,000
WEATHER	-0,880	0,000	**MORE_CAUTIOUS**	-0,264	0,000
BUTTON	1,401	0,000	**TRAF_LIGHT_ROUTE**	-0,320	0,000
REM_TIME	1,100	0,000	**SHORTEST_ROUTE**	0,424	0,000
WORK_EDUC_2[T.True]	-3,395	0,000	**ANY_OPPORTUNITY**	-0,345	0,000
ENTERTAINMENT_2[T.True]	1,865	0,000	**RISK_OUTSIDE_CROSS**	-0,158	0,043
ENTERTAINMENT_3[T.True]	0,625	0,000	**RISK_SAVE_TIME**	0,505	0,000
ENTERTAINMENT_4[T.True]	3,174	0,000	**SIGNS_CLEAR**	-0,123	0,030
FAM_STATUS_2[T.True]	-0,792	0,000	**DIAGONALLY_CROSS**	0,243	0,002
FAM_STATUS_3[T.True]	-1,362	0,002	**NO_OPPOSING**	0,284	0,000
JOB_2[T.True]	1,171	0,000	**INCOME**	0,119	0,007
JOB_6[T.True]	1,224	0,000	**EDUCATION**	-0,310	0,001
WORK_EDUC_WEEK	-0,333	0,000	**CAR_MOTO**	0,900	0,000
			PROTECTED_CROSS	-0,193	0,007

4 Conclusion

Objectives & Methodology

An analysis of pedestrian behavior in an area with heavy traffic is necessary, as pedestrian crashes are increasing rapidly. This paper investigates illegal crossings in the center of Athens and identifies the factors that influence them. After defining the objective of the study, a literature review of related research

followed to identify the characteristics of pedestrians that most influence their decision to cross illegally. After data collection, statistical analysis was performed to produce appropriate mathematical models. Through the models, it was necessary to determine the factors influencing the respondents to the alternatives given to them.

Conclusions

The conclusions that emerged from the research conducted were quite significant. It was strongly observed that a statistically significant percentage of attempts illegal crossing occur when the traffic light is red, which confirms the importance of the problem and the need to address it immediately. Overall, the presence of a camera is the strongest deterrent to violation, as it significantly reduces offending behaviour and increases the perception of surveillance. The reasons why pedestrians tended to break the rules were mainly waiting time and the feeling that they were being delayed; the longer the waiting time, the greater the likelihood that the pedestrian would cross illegally. Another interesting observation is that residents of Athens or those who move to the city center show higher levels of infringement because they feel more familiar with their surroundings, therefore they feel more comfortable crossing illegally.

Furthermore, it has been observed by many that the sense of danger acts as a protective factor, as those who have experience of crashes and show greater compliance with the rules and caution, perhaps in fear of the consequences of their dangerous act. In fact, factors such as weather, short distance, and the absence of traffic reduce compliance with the rules, and the sense of ease that seems to exist in these circumstances may act as an excuse to break the rules. An important factor in their decision to cross illegally was also the social pressure and the intention of other pedestrians at the crossing that influence but do not always determine their final decision. As it was found, sometimes the intention of others to cross illegally pushes some people to cross imitating their behavior, while at other times it seems to act as a deterrent, projecting a more positive behavior in relation to others. Finally, it was observed that route choice reflects and biases attitudes towards the rules. Those who choose routes with traffic signals or protected crossings are less likely to break the rules, while the same does not go for those who choose the shortest route or cross diagonally where they show an increased propensity towards illegality.

Proposals for the exploitation of the results

Based on the results obtained from this paper, it was considered crucial to present proposals for their use in the implementation of new measures and for further research. Some suggestions for utilization of the research are to promote the importance and the need to improve the infrastructure and the conditions under which pedestrians move in the center of Athens, to reduce the rates of crashes and injuries to pedestrians, which are a burden both economically and socially for the Hellenic state. In addition, it is considered important to implement measures that will offer pedestrians safety during their movements and a case- point analysis in areas with increased pedestrian traffic, in particular the counting of pedestrians at key crossing points in order

to correctly calculate green times and waiting times, a process that should be repeated frequently in areas where the volume of traffic is increasing.

Except of that, it would be crucial to organize awareness campaigns to inform citizens about the risks involved when travelling. Also, as the conclusions refer, it is necessary to redesign crossings, addition of safety islands and improve lighting and signaling with the inclusion of countdown indicators and control cameras. Finally, the worldwide use of computer vision to analyze movements, timing, and interaction with traffic lights to facilitate data analysis would be helpful too.

Suggestions for Further Research

In this paper, the behavior of pedestrians during their movement and the factors that influence their decisions on whether to cross while the traffic light is red were examined. However, there is room for further research as this is an area of concern to the scientific community worldwide. First, the sample must be expanded to include a larger part of the population that is not exclusively from the internet, and more cities in Greece or abroad have to take part in this survey, to explore possible similarities or differences and their causes.

After all the changes that will take place, the survey must be repeated at a reasonable interval to identify changes in pedestrian behavior. Also, it would be interesting if a combination of surveys for pedestrians and drivers were created to get a comprehensive picture of their interaction and how drivers are affected by the image of pedestrians. A long-term study in specific locations would help to monitor illegal crossings over time, for example, before and after infrastructure projects or social interventions. A further analysis could be done related to the estimation of the economic costs of illegal crossings through traffic delays and traffic crashes, to reinforce the need to improve road safety. Finally, it would be very helpful to conduct field mapping with the help of citizens for dangerous points with GIS tools, to personalize the analysis and improvement of the points.

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