How environmental charging policies affect urban road safety?

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Abstract

Urban traffic problems are a key challenge in modern cities internationally; in terms of traffic congestion, road safety, and environment. The need for sustainable transport policies is increasingly recognized and receives more and more attention. The objective of the present paper is to investigate the socioeconomic impact of the implementation of an environmental transport charging policy on road safety in terms of fatalities and injuries within a 15 years horizon. Specifically, an environmental transport charging policy called Green Car Access Card (GCAC) is examined for the daily access of a passenger car in the center of Athens, Greece with the charging being adjusted according to the Euro class of the car. To achieve that objective, a stated preference survey has been conducted leading to the development of a mixed binary logistic regression model to estimate the public acceptance of the examined environmental charging policy. For the road safety assessment, the number of road fatalities and injuries in the "Do nothing" Scenario and in the "GCAC" Scenario as well as the human cost per fatality and injury are taken into account. For the road safety estimation in the next 15 years, the technological renewal of passenger cars as well as the change of the average speed in the centre of Athens are considered. During the first two years of the GCAC policy operation a significant higher road safety cost is estimated in the "GCAC" Scenario compared to the "Do nothing" Scenario but in the following years of operation the road safety benefit in terms of fatalities and injuries as well as in monetary units increases in relation to the "Do nothing" Scenario. In a time horizon of 15 years is estimated an overall road safety economic benefit 74,647,722 €.

Keywords: road safety, sustainable urban mobility, charging policies, stated preference, mixed binary logistic regression

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1. Introduction

Considering that the majority of European citizens live in urban environment, with over 60% living in urban areas of over 10,000 inhabitants [1], the life quality in urban areas is of vital importance. Consequently, cities face the challenge to enhance the quality of urban environment reducing traffic congestion, environmental pollution and road accidents. Within this framework, several cities apply traffic access regulations into urban areas such as Congestion Charging Zones, Low Emission Zones or a combination of both [2], [3]. In Europe, the costs attributable to congestion are estimated to be around 1% of annual gross domestic product (GDP) [4] while the health costs of air pollution attributable to road transport were estimated at about $0.85 trillion per year [5].
Moreover it cannot be denied that road safety is considered great importance for sustainable mobility in urban environments since it appears that crash fatalities have platooned during the recent years with the global number of deaths rising to 1.35 million annually [8]. Specifically, according to WHO (2021) road accidents cost most countries 3% of their gross domestic product. However, the impact on road safety from the implementation of traffic management policies is explored partially by the literature [9].
Athens is the capital and largest city of Greece, and among the most important economic centers in Southeastern Europe. The city of Athens (Municipality of Athens) has a population of 664,046 inhabitants [10] of which 315,210 are men and 348,836 are women, and a land area of 38.96 km^2. Residencies correspond to a 35% of the metropolitan area's total land uses, while 7% of that land corresponds to industrial activities, 6% to administration, 5% to recreation and 26% to commerce and other activities [11].
Focusing on mobility, passenger cars constitute 69% of the total vehicle fleet in Attica, followed by motorcycles (motorcycles and mopeds) with 24%, trucks with 6.7% and buses with 0.3% [12]. Considering passenger cars there is a steady annual increase (1.2% on average) after the year 2013. Noise and air pollution are two fundamental problems facing the Region of Attica today. According to the latest Strategic Noise Map published by the Ministry of Environment and Energy in 2013, more than half of the residents of Athens (53%) living or moving in the city center, experience daily noise values of 65-70 dB. During 2018, the highest NO2 air pollution emissions of the last five years were identified [11].
The current management traffic system called Athens Ring (Daktylios Athinon) controls the private car access in the city centre according to an odd/even system. The odd/even restrictions correspond the last number of a vehicle's license plate number to the calendar date. The Athens Ring originally designed and intermittently implemented from July 1979 and later imposed as a permanent solution to control traffic congestion in 1982. The Athens Ring allows environmentally friendly vehicles (electric cars and vehicles categorized as Euro5 or Euro6) to circulate without restriction on any day at any hour as of September 2012. Unfortunately, the number of private cars in modern day Athens has more than quadrupled since 1982 and legislation has not been revised to reflect this phenomenon.
Based on the above the objective of the present research is to investigate the road safety impact from the implementation of an environmental transport charging policy called Green Car Access Card (GCAC) which aim is to restrict the access of old technology passenger cars in the centre of Athens. In order to achieve paper's objective, the number of road fatalities and injuries in the "Do nothing" Scenario and in the "GCAC" Scenario are estimated in a time horizon of 15 years as well as the human cost per fatality and injury are taken into account. The present paper is structured as follows. In the next chapter critical factors of road accidents are presented with focus on the investigation of speed as a key contributory factor and the vehicle age and technology. The methodological part of the survey is then presented, followed by the sample used and the theoretical background of the analysis. Finally, the results including descriptive analysis results, the estimation of the policy acceptance and the impact on road safety in casualties and monetary units are developed and some conclusions are further discussed.

2. Critical Factors of Road Accidents

Road accidents constitute a major social problem in modern societies, accounting 42 road deaths per million inhabitants in the EU and more than 180 road deaths per million. inhabitants worldwide in 2020 [13]. It is established that the three main factors of a road accident is driver/road user behavior, road environment/design and vehicle, as well as combinations of these three contributory factors; driver behavior has been determined as the critical factor for about 94% of total road crashes [14], [15].

Speed can be characterized as a driver behavior factor but can be significantly affected by the road environment (road layout, surface quality), vehicle (vehicle power, maximum speed), traffic and whether conditions. There is a strong relationship between the mean speed of traffic and road safety, stated as the number of fatalities and the number if injury accidents [16]. Speed affects the risk of being involved in an accident and the severity of an accident [17]. Also, speed has been found to be an important contributory factor in around 10% of all accidents and in around 30% of the fatal accidents [18], [19]. Several speed related measures are often used including, average speed, speed variability, 85th percentile speed, maximum speed [20], [21], [18].
According to ERSO (2006) [17], the relationship between speed and accident risk is a power function; with increasing speed, the accident risk increases more as the absolute speed is higher. Nilsson, G. (2004) [22] proposed 6 power relationships connecting changes in traffic speeds with changes in road crashes at various levels of injury severity. Specifically, he developed the following formula to describe the effects of a speed change on the number of injury accident rates. In words, the number of injury accidents after the change in speed (A2) equals the number of accidents before the change (A1) multiplied by the new average speed (V2) divided by the former average speed (V1), raised to the square power.

$$\boldsymbol{A2} = \boldsymbol{A1} \times \left(\frac{V2}{V1}\right)^{\mathbf{2}} \quad (1)$$

Regarding vehicle factors, the age of the vehicle or the date of the vehicle's first registration consists an important contributory factor of a road accident. It was found that a driver of an older vehicle is more likely to be fatally injured as compared to a driver of a newer vehicle [23], [24], [25]. Specifically, SICIŃSKA (2019) [24] concludes that a driver in a vehicle of age >21 years is 3 times more likely to be fatally injured than a driver in a vehicle of age 5 years. Therefore, the risk of causing a fatal road accident increases with the age of the vehicle involved. Also, due to the technological improvements that can be applied to the newest vehicles (vehicle construction and design, driver assistance technologies, etc.), the renewal of the passenger vehicle fleet is expected to contribute to the road safety improvement.

3. Data and Methodology

3.1 Survey

Within the framework of the present research, a personal interview, questionnaire-based survey was undertaken, aiming at collecting information on the level of understanding and accepting environmental charging policies for private cars access in Athens. The questionnaire survey included questions on travel characteristics of respondents, environmental awareness and sensitivity, stated preference on alternative annual card cost and demographics. Questionnaire filling time was on average 10 minutes. The first part of the questionnaire focused on the drivers' travel profile and on the characteristics of their cars.
Respondent's travel profile included information on the main transport mode used for accessing workplace/ education or leisure, the number of weekly trips, the travel cost, if they travel through the Athens centre and the drivers' satisfaction on their typical daily trip. Concerning the car's characteristics, there were questions about the cubic capacity, the year of first registration and fuel type are included.
The second section investigated respondents' environmental awareness and sensitivity. In particular, it includes a series of questions related to perceptions of key environmental issues of road transport as well as some general environmental questions. Respondents were asked to state their opinion on environmental pricing measures, such as environmental vehicle registration fees, environmental incentives for old-technology vehicles withdrawal, environmental incentives to purchase new-technology and environmental friendly vehicles, environmental car access fees in urban areas, and environmental tolls.
The third part examined a hypothetical scenario of replacing the current car access mobility restrictions (Small Ring) in the centre of Athens with the environmental transport charging policy for private car's access under consideration (GCAC). It targeted at identifying the public acceptance of the GCAC policy, considering the annual charging depending on the year of the vehicle's first registration and the time saving of a typical trip. This refereed to the stated preference part of the questionnaire which will be further analysed in the statistical analysis section.
Finally, the fourth part collected information on demographics characteristics of respondents (gender, age, income, education level and so on).

3.2 Sample Characteristics

Data were collected through a questionnaire that was completed in the form of interviews in areas of northern, southern, central and western suburbs of Athens. Quality and validity check performed lead to 370 questionnaires. The sample size considered sufficient for the purposes of the study.

The collected data were interpreted using descriptive statistics. As targeted, the percentage of men (49%) who answered the questionnaire is approximately equal to the percentage of women (51%). Also, almost equal percentages were observed in the age categories 18-30 and 31-55. The age group >55, constitutes the smallest percentage (16%) of the sample. Results confirm that the sample follows a properly balance stratification with respect to these parameters (Fig. 1).

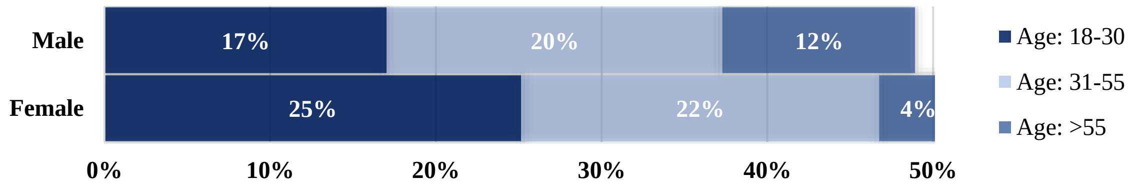

Figure 1: Age distribution per gender of participant drivers.

3.3 Theoretical Background

Discrete choice analysis is a well-established approach for analyzing individual behavior [26]. After the data collection and based on the database, it was decided that binary logistic regression would be appropriate to define the public acceptance for the implementation and operation of the examined environmental transport charging policy GCAC. Specifically, a mixed binary logistic regression model was developed to model how parameters of the GCAC annual cost, travel time saving, date of private car's first registration, influence the public acceptance of the GCAC for private cars access in the center of Athens.
Based on Washington (2010) [27], in developing the logistic regression equation, the LN of the odds represents a logit transformation, where the logit is a function of covariates such that:

$$\boldsymbol{Yi = logit(Pi) = LN\left(\frac{Pi}{1-Pi}\right) = \beta_o + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \cdots + \beta_\kappa X_{\kappa,i}} \tag{2}$$

and where β0 is the model constant and the β1, …, βK are the unknown parameters corresponding with the explanatory variables (X_k, k = 1, …, k the set of independent variables).
In the case of repeated observations, such as the case of stated preference surveys with multiple responses, one often needs to capture the correlation across observations from the same individual. Mixed effects logistic regression is used to model binary outcome variables, in which the log odds of the outcomes are modeled as a linear combination of the predictor variables when data are clustered or there are both fixed and random effects.
In the analysis under consideration, the dependent variable was considered to be discrete taking into account the fact that it corresponded to values 0 (I do not accept the GCAC) and 1 (I accept the GCAC). The final model was evaluated considering the common statistical tests (R^2, t- test etc.) but also based on the logical explanation of the results. In order a variable to be accepted as an independent variable, it should be statistically significant and thus a control coefficient Wald test was carried out for each variable. A variable was considered in the final regression 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 [26].

4. Results

4.1 Descriptive Analysis

A preliminary part of the analysis focused on interpreting collected data using descriptive statistics. The year of the 1st registration of the majority of private passenger cars in the sample is between 2006 and 2015. More specifically, the year of the 1st registration of 37% of private cars is from 2011 to 2015 and 30% from 2006 to 2010. Only 6.5% of the private cars in the sample are older than 20 years. Also, respondents rated on a scale of 1 (not at all) to 5 (very much) the importance of their mobility characteristics. As shown in Fig. 3, the most important feature was the accessibility to Public Transport (3.8/5). Less important for the sample is the pollution caused by urban mobility (2.3/5) as well as the parking (2.4/5) aspect.

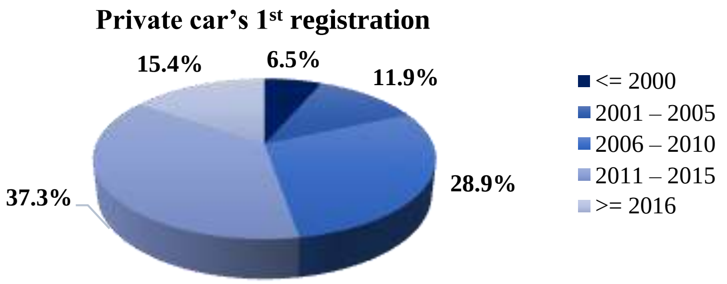

Figure 2: Private car's 1st registration.

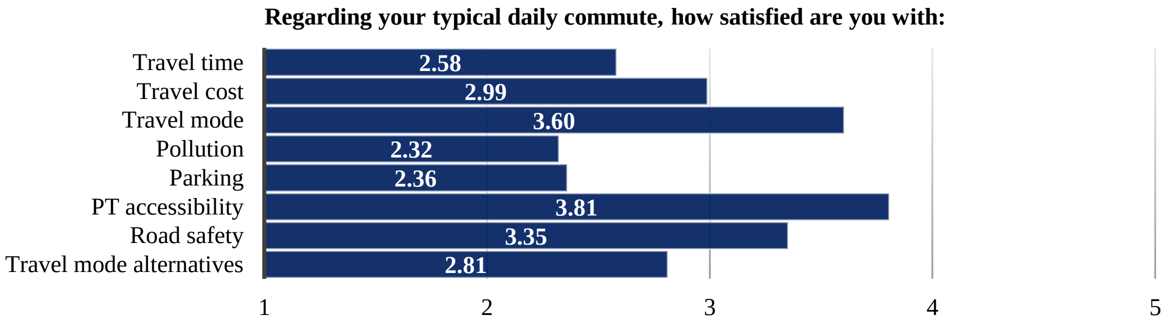

Figure 3: Level of satisfaction considering a typical daily commute.

According to Fig. 4 respondents satisfactorily accept the proposed GCAC system for their access into the center of Athens. In fact, the respondents who drive the newest and oldest technology vehicles seem to accept the proposed policy to a greater extent compared to those who drive a car with a registration date between the years 2001 to 2010. Moreover, most survey participants (57%) prefer or they are neutral considering the examined system instead of the existing management traffic system in the center of Athens which is an odd/even system (Athens Ring). In particular, it is observed that the owners of vehicles with 1st registration date after 2015 are more positive towards the GCAC system.

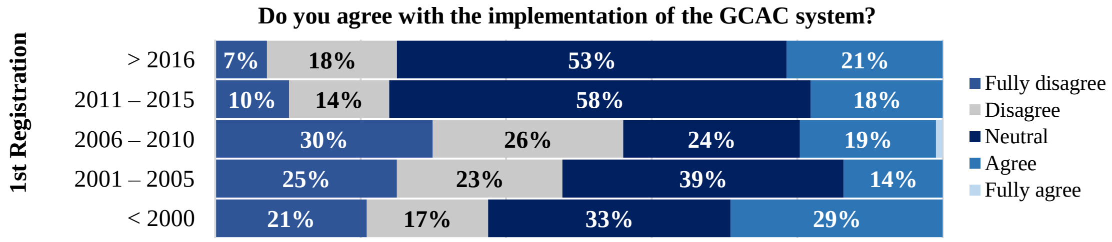

Figure 4: Acceptance of the GCAC system according to the year of private car's 1st registration.

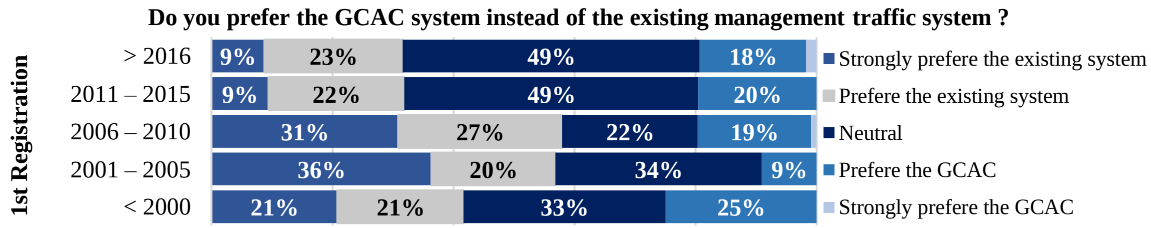

Figure 5: Preference level of the GCAC system instead of the current system in the center of Athens according to the year of private car's 1st registration.

4.2 Public Acceptance

As part of the survey, a stated-preference experiment was designed and implemented; its aim was to provide quantitative insights on replacing the current car access mobility restrictions (Small Ring) in the centre of Athens with the environmental transport charging policy under consideration (GCAC) for private car’s access. Two possible answers were considered for the acceptance of examined the environmental transport charging policy (I do not accept the GCAC and I accept the GCAC) while two attributes (GCAC annual cost, and travel time) with values depending from the private car’s 1st registration were selected for representing choice preferences. Specifically, each respondent was asked to answer if she/he is willing to pay the set GCAC annual cost depending on the private car’s 1st registration in order to reduce by 5, 10 or 15 minutes her/his typical travel time.
The following figure presents the GCAC annual cost that the participants of the survey were asked depending on the age of their passenger car. The oldest in technology and most polluting passenger cars were charged for their access to the center of Athens at a higher annual cost.

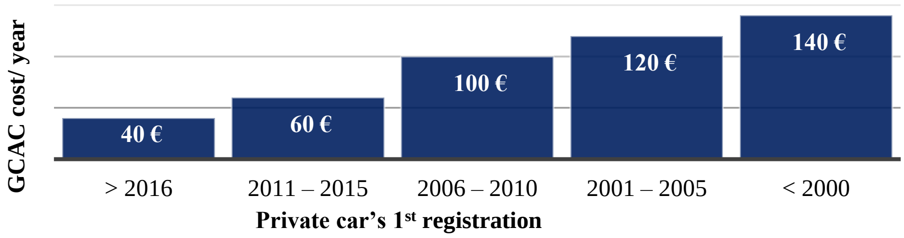

Figure 6: Annual GCAC cost depending on the age of the passenger car

Based on this part of the survey a mixed binary logistic regression model was developed to capture how parameters of the GCAC annual cost, travel time saving, date of private car’s first registration, affect the public acceptance of the examined environmental charging policy for private cars access in the center of Athens. In The analysis was conducted using SPSS Statistics [28]. Based on the above, the mixed binary logistic regression specification is shown in the following table. All variables are considered statistically significant at the typical 95 % level, and they are reported when they are within to up to the 90 % level.

Table 1: Mixed binary logistic regression specification

	Parameter	Coefficient	Std. Error	t-test	Sig.
	Intercept	10.337	1.042	9,924	0
	GCAC annual cost	-0.032	0.005	-6.235	0
	Travel Time	-0.408	0.026	-15.774	0
Car’s 1st Registration	**>= 2016**	-1.906	0.824	-2.313	0.021
	2011 – 2015	-2.041	0.781	-2.613	0.009
	2006 – 2010	-1.300	0.849	-1.532*	0.126*
	2001 – 2005	-1.756	0.869	-2.021	0.043
	=< 2000	0	-	-	-

The “Travel time” variable represents the time in minutes of a typical everyday trip in case of the implementation of the GCAC policy and corresponds to three values (25 min., 20 min., 15 min.) considering that a typical trip in Athens without the implementation of the GCAC is considered to be 30 minutes. The “GCAC annual cost” variable represents the cost of the GCAC per year for a passenger car for its access in the center of Athens and corresponds to the prices values that presented in the Fig. 2 depending on the year of 1st registration of the respondent's car. Both variables have been determined negatively correlated with public acceptance of the GCAC, meaning that an increase in cost or travel time lowers the public acceptance of the environmental transport charging policy under consideration (GCAC) for private car’s access in the center of Athens. Finally, the variable “Private car’s 1st registration” represents the year of the first registration of the respondent’s private car and corresponds to five age groups. The age group “<2000” corresponds to the oldest passenger cars under consideration (Euros Class I, II) and the reference group.
To investigate the impact of the implementation of the GCAC policy in Athens on road safety in terms of fatalities and injuries in a 15 years’ horizon, it is necessary to estimate the utility functions for each age group of passenger cars. Based on Table 1, the estimated utility functions are presented in the following table.

Table 2: Utility functions

$U_{>2016}$ =	8.43	-0.408* Travel Time	-0.032* GCAC annual cost
$U_{2011-2015}$=	8.30	-0.408* Travel Time	-0.032* GCAC annual cost
$U_{2006-2010}$=	9.04	-0.408* Travel Time	-0.032* GCAC annual cost
$U_{2001-2005}$=	8.58	-0.408* Travel Time	-0.032* GCAC annual cost
$U_{<2000}$ =	10.34	-0.408* Travel Time	-0.032* GCAC annual cost

Consequently through the equation $Pi = \frac{e^{Ui}}{1+e^{Ui}}$, the public acceptance (%) of the examined transport environmental policy is calculated, giving the "GCAC annual cost" variable for each age group the annual costs presented in the Fig. 6 and assuming that the time of a typical daily trip in the center of Athens is reduced to 10 minutes due to the implementation of the GCAC policy.

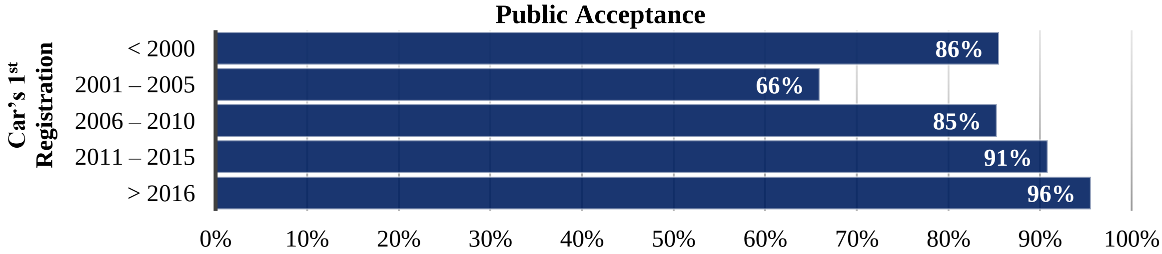

Figure 7: Public Acceptance.

4.3 Road Safety Impact

For the road safety assessment considering the implementation of the examined environmental transport charging policy (GCAC) for the daily access of a passenger car in the center of Athens, the number of road fatalities and injuries in the "Do nothing" Scenario and in the "GCAC" Scenario as well as the social cost per fatality and injury are taken into account [29]. For the road safety estimation in the next 15 years taking into account the implementation of the GCAC policy, the technological renewal of passenger cars as well as the change of the average speed in the center of Athens are considered. Due to the lack of accident data per year of the 1st registration of a passenger vehicle, to estimate the fatalities and injuries taking into account the change of the average speed in the first 2 years, the equation that relate changes in the number of injury accidents to changes in the mean speed of traffic was applied (Eq. 6).

The annual road safety cost in each Scenario is estimated with the following equation in which i represents the year (i=2020,…2030) and k the vehicle's age group (k= > 2016, 2011 – 2015, 2006 – 2010, 2001 – 2005, < 2000).

$$\textbf{Road Safety Cost}\ (€) = \sum_{k}^{i} \textbf{Fatalities}_{i,k} \times (€/\textbf{Fatality}) + \textbf{Serious Injuries}_{i,k} \times (€/\textbf{Serious Injury}) + \textbf{Light Injuries}_{i,k} \times (€/\textbf{Ligth Injury}) \quad (3)$$

where:

- $$\textbf{Fatalities}_{i,k} = \textbf{Fatalities}_{i-1,k} \times \left(\frac{\%PassengerCars_{i,k}}{\%PassengerCars_{i-1,k}}\right) \times \left(\frac{V_{GCAC_i}}{V_{Do\_nothing_i}}\right)^2 \quad (4)$$
- $$\textbf{Serious Injuries}_{i,k} = \textbf{Serious Injuries}_{i-1,k} \times \left(\frac{\%PassengerCars_{i,k}}{\%PassengerCars_{i-1,k}}\right) \times \left(\frac{V_{GCAC_i}}{V_{Do\_nothing_i}}\right)^2 \quad (5)$$
- $$\textbf{Light Injuries}_{i,k} = \textbf{Light Injuries}_{i-1,k} \times \left(\frac{\%PassengerCars_{i,k}}{\%PassengerCars_{i-1,k}}\right) \times \left(\frac{V_{GCAC_i}}{V_{Do\_nothing_i}}\right)^2 \quad (6)$$

where:

- %PassengerCars: the percentage of private passenger cars in Attica by age group (1st registartion)
- V_{GCAC}: the average speed in the "GCAC" Scenario
- $V_{Do\_nothing}$: the average speed in the "Do nothing" Scenario (15.3 km/h)

The average speed in the center of Athens was calculated for the year 2020 through a traffic simulation model developed by the Traffic Engineering Laboratory of National Technical University of Athens. The investigated network created in Aimsun Next mobility software is the city of Athens. Therefore, through the model it emerged

that in the "Do nothing" Scenario the average speed on the small Ring of central Athens in 2020 is 15.3 km/h. Considering the GCAC policy acceptance from the questionnaire as a simulation input, it emerged that in the "GCAC" Scenario the average speed on the small Ring of central Athens in 2020 will be 21 km/h.
For the estimation of the average speed in the next 15 years, it is assumed that in the "Do nothing" Scenario it remains equal to 15.3 km/h. Therefore, in the "do nothing" Scenario, the average speed of passenger cars in the center of Athens remains the same for the next 15 years, so the road safety estimation is based only on the renewal of the passenger car fleet. Also, it is assumed that in the "GCAC" Scenario the first year of the policy's implementation the average speed is 21 km/h, the second year decreases to 16.5 km/h and after the second operation year it is almost balanced with the existing situation, 15 km/h.
To estimate the distribution of the passenger car fleet in Attica in the year 2019 by age group (1st registration), the new registrations of new and used passenger cars per year were collected for the years 1985 to 2019 from the Hellenic Statistical Authority and grouped into the following five age categories (> 2016, 2011 – 2015, 2006 – 2010, 2001 – 2005, < 2000). The withdrawal of passenger cars was then calculated as the difference between all passenger cars in Attica in 2019 and all new registrations of new and used passenger cars from 1985 to 2019. The calculated withdrawal was deducted in a weighted manner from the passenger car fleet previously allocated to the five age categories. In particular, it was considered that the withdrawn passenger cars with 1st registration > 2016, 2011 – 2015, 2006 – 2010, 2001 – 2005 and < 2000 were 5%, 15%, 20%, 20% and 40% of the total withdrawal, respectively. Therefore, the distribution of the passenger car fleet in Attica in the year 2019 to the five age groups was calculated as shown in the following table.

Table 3: 2019 passenger car fleet in Attica by 1st registration

Age Group	Fleet	%
> 2016	276.699	9.3%
2011 – 2015	206.132	6.9%
2006 – 2010	614.354	20.7%
2001 – 2005	709.907	23.9%
< 2000	1.167.557	39.3%
Total	**2.974.649**	**100%**

For the projection of the distribution of the passenger car fleet in Attica and the estimation of the renewal of the fleet in the next 15 years the following assumption were taken into account. In the "GCAC" Scenario, the total annual growth of the Athens passenger car fleet was considered to be 1% according to the estimate for the increase of the vehicle fleet in Greece the following 10 years as mentioned in the National Energy and Climate Plan. Subsequently, for the change of the passenger car fleet per year, an overall annual withdrawal of 2.3% was considered, with 1.5% being removed from the oldest age group (< 2000) and 0.8% from the 2001 – 2005 age group. At the same time, 80% of the withdrawal was allocated to the newest technology cars under consideration while 20% were allocated to the next category of new technology passenger cars (2011 – 2015).
Similarly, in the "Do nothing" Scenario, a lower rate of annual withdrawal of 1.5% was taken into account, with 1% being removed annually from the oldest age group (< 2000) and 0.5% from the 2001 – 2005 age group. Then 60% of the withdrawal was allocated to the newest technology passenger cars under consideration while 40% to the next newest ones. Thus, in the "Do nothing" Scenario there was an annual decrease in average age of the fleet by 0.4 years while in the "GCAC" Scenario there was a greater annual decrease by 0.6 years on average.
For the road safety estimation in each Scenario, the number of fatalities, seriously injured and slightly injured in a road accident involving a passenger car, in the Region of Attica in 2019 were collected using as a data source the Hellenic Statistical Authority (ELSTAT). Specifically, the casualties are classified according to the severity and the year of the 1st registration of the involved passenger car in the specified age groups under consideration.
Also, in order to estimate the annual road safety social cost for each scenario under consideration, the human cost per road fatality, serious and light injury in Greece is used. Kourtis et al. [30] calculated the unit prices for each type of accident as presented in the following table. It is highlighted that the costs of crash victims suggested are in line with the other similar calculations in Europe, such as the European H2020 project SafetyCube in collaboration with the project InDeV, where the road crash costs where estimated for 31 European countries, and found that total costs per fatality range from 0.7M€ to 3M€, with Greece being in 9th place, with a cost around 2M€ [31].

Table 4: Human cost per road fatality and injury

	Human cost
Fatality	2,148,034 €
Serious Injury	273,574 €
Ligth Injury	51,373 €

Based on the road safety in 2019, the aforementioned assumptions and the Eq. 3-5, the following table presents the fatalities and injuries as calculated for the first 15 years of operation of the examined environmental transport charging policy (GCAC). Also, taking into account the Eq. 2, the calculated casualties per year in each Scenario and the unit human costs (Table 4) is estimated the road safety cost per year as well as the impact on road safety in monetary terms (€) from the operation of the examined environmental transport charging policy (GCAC).

Table 5: Impact on road safety

Year	Light Injuries		Serious injuries		Fatalities		Cost (€)		Benefit (€)
	Do nothing	GCAC	Do nothing	GCAC	Do nothing	GCAC	Do nothing	GCAC	
2020	1,128	2,113	31	57	33	62	138,206,963	257,922,559	-119,715,597
2021	1,132	1,301	30	35	33	38	137,825,179	157,289,662	-19,464,483
2022	1,135	1,072	30	28	33	31	137,447,176	128,405,629	9,041,548
2023	1,139	1,069	30	28	33	30	137,072,916	126,835,502	10,237,414
2024	1,142	1,066	29	27	33	29	136,702,361	125,280,921	11,421,439
2025	1,145	1,063	29	27	32	29	136,335,474	123,741,732	12,593,742
2026	1,148	1,060	29	26	32	28	135,972,221	122,217,783	13,754,438
2027	1,152	1,057	28	26	32	28	135,612,564	120,708,922	14,903,641
2028	1,155	1,054	28	25	32	27	135,256,468	119,215,001	16,041,467
2029	1,158	1,051	28	25	32	27	134,903,897	117,735,870	17,168,027
2030	1,161	1,048	28	24	31	26	134,554,818	116,271,385	18,283,433
2031	1,164	1,046	27	24	31	25	134,209,194	114,821,399	19,387,795
2032	1,167	1,043	27	23	31	25	133,866,993	113,385,770	20,481,223
2033	1,170	1,040	27	23	31	24	133,528,180	111,964,355	21,563,825
2034	1,173	1,037	26	22	31	24	133,192,721	110,557,013	22,635,708
2035	1,176	1,035	26	22	30	23	132,860,584	109,163,606	23,696,978
						Present Value (SDR=3%)	**1,704,478,561**	**1,668,961,609**	**74,647,722 €**

The above table summarizes the estimated changes in road fatalities and injuries in the first 15 years of operation of the examined environmental transport charging policy (GCAC), compared to conditions without the GCAC policy in Athens. During the first 2 years of the GCAC policy operation a significant higher cost in the "GCAC" Scenario compared to the "Do nothing" Scenario is estimated due to the increase in average speed. However, in the following years of operation the road safety benefit in terms of fatalities and injuries as well as in monetary terms increases notably in relation to the "Do nothing" Scenario. The examined policy is expected to lead to decrease of 34 fatalities, 12 serious injuries and 291 light injuries in a time horizon of 15 years. Also, the present value considering a social discount rate (SDR) 3% [32] is equal to 74,647,722 €.

5 Conclusion

The present research aimed to investigate the road safety impact from the implementation of an environmental transport charging policy called Green Car Access Card (GCAC) which aim is to restrict access of old technology passenger cars in the centre of Athens with a charging fee being adjusted according to the Euro class of the car (year of 1st registration).

In order to achieve that objective, a stated preference survey has been conducted aiming to examine a hypothetical scenario of replacing the current car access mobility restrictions (Small Ring) in the centre of Athens with the environmental transport charging policy for private car's access under consideration GCAC. Based on 370 drivers' responds in Athens, Athenians satisfactorily accept the GCAC system for their access into the center of Athens while the majority of survey participants (57%) prefer the examined management traffic system instead of the existing one (Athens Ring). So, despite the fact that it is a charging policy, the majority of drivers in Athens seem to accept it.

Based on survey results, a mixed binary logistic regression model was calibrated to capture how the GCAC annual cost, travel time, date of private car's 1st registration, correlate with the GCAC policy acceptance and finally to estimate the policy acceptance. The GCAC annual cost is negatively correlated with the policy acceptance, meaning that an increase in the annual cost at which the private passenger vehicle is charged for its access to Athens centre, lowers the public acceptance of the environmental transport charging policy under consideration. The travel time is a factor that affects also negatively the policy acceptance since increasing the travel time of a typical everyday trip is not something desirable especially for Athenians living in the fast-paced Athens.

Respondents driving old technology cars, older than twenty years, are more likely to accept the implementation of GCAC system compared to respondents who own newer technology cars. Possibly, this is explained by the fact that with the current traffic management system a new technology private car (Euro 6 with $CO_2 \leq 120$g/km, BEV and hybrid) has a free access to the center of Athens.

For the road safety assessment, the number of road fatalities and injuries in the "Do nothing" Scenario and in the "GCAC" Scenario as well as the human cost per fatality and injury are taken into account. For the road casualties

estimation within the next 15 years, the technological renewal of passenger cars as well as the change of the average speed in the center of Athens are considered. During the first 2 years of the operation of the GCAC policy a higher cost is estimated in the “GCAC” Scenario compared to the “Do nothing” Scenario due to the increase in the average speed from 15.3km/h to 21 km/h resulting from the reduced cars access to the center of Athens due to the implementation of the examined policy.
However, in the following years of the policy operation the road safety benefit in terms of fatalities and injuries as well as in monetary terms increases notably and rapidly in relation to the “Do nothing” Scenario. This is explained by the fact that the traffic is balanced in the current traffic conditions after the first two operation years, and the fleet of private cars in Athens is expected to technologically renewed significantly.
Results of the present research indicate that modern societies are ready to incorporate environmental policies that aim to improve traffic congestion, road safety, and environmental pollution. However, in order these policies to be acceptable by the citizens it is very important to set the respective charging prices based on specific parameters and characteristics that are estimated in the present research and in this way balance with the needs and priorities of citizens and tourists of each city.

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