# Attitudes of Greek drivers towards autonomous vehicles – a stated preference approach

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The advent of autonomous vehicles will soon transform transportation in a substantial way, but at the same time the question of their public acceptance remains. There have been several international studies examining this very issue, but to the best of our knowledge none conducted in Greece. The purpose of this paper is to add to current literature by surveying Greek drivers on their acceptance and willingness to obtain an autonomous vehicle, as well as their opinion on self-driving technology in general. Moreover, this study is one of the first attempts to utilize Stated Preference (SP) methods and Discrete Choice models for that purpose. In our approach, we included hypothetical scenarios of cost, time, and safety, which were distributed in a carefully developed questionnaire. By applying random parameters multinomial logistic and binary logistic models it was possible to explore drivers' attitude towards autonomous vehicles and, also, to account for unobserved heterogeneity. Results showed that this attitude is dependent on cost, time, and level of safety of said vehicles, the existence of driving support systems (GPS, parking assistant) in cars today, their opinion on the traffic of autonomous public transport and taxis on the roads, their driving experience, age, and family income.

Keywords: Autonomous vehicles; self-driving; random parameters multinomial logit, stated-preference method

## 1. Introduction and Background

The possible introduction of autonomous vehicles is likely to change not only the way we utilize the transportation network but even the way we live. Considering that, it is not strange that over the past several years, autonomous vehicles have inspired research investigating their operation, as well as their impact on transportation and society in general. These research papers have mostly tackled the issue from a hypothetical stance, due to the fact that the technology is, indeed, not readily available and the vast majority of people are not yet familiar with autonomous vehicles.

Greece, in particular, presents an interesting case in that the city of Trikala, in the region of Thessaly, has already implemented the pilot platform of Automated Road Transport Systems (ARTS) as part of the CityMobil2 project. A research published in 2016 (Portouli et al, 2016) showed that 76 percent of respondents would drive an autonomous vehicle, while 22 percent would not even consider it. 51 percent of those who would drive an autonomous vehicle stated they would buy one, whereas 49 percent would prefer a car pooling or sharing service instead. The same research showed that the most critical factor in accepting autonomous vehicles is safety. 70 percent believe autonomous vehicles are as or more safe than conventional vehicles. According to the researchers, a percentage of negative answers could be attributed to misinformation or a degree of cautiousness towards the technology of autonomous vehicles.

Howard and Dai (2014) found that safety and comfort were the most attractive attributes in autonomous driving with 75 and 61 percent respectively, while legal responsibility and cost were the least attractive attributes with 70 and 69 percent respectively. Overall, over 40 percent of respondents were prone to buying an autonomous vehicle. Schoettle and Sivak (2014) conducted an investigation among 1533 participants in the US, United Kingdom, and Australia with 57 percent of respondents expressing a positive attitude towards autonomous vehicles. The advantages of autonomous driving were the reduction in accidents, pollution, and consumption according to most participants, while there was significant concern over the effect of autonomous vehicles in increasing traffic congestion and travel time. The same research showed that women were more concerned than men, and were more conservative over the potential benefits derived from autonomous driving.

One of the largest research in scale was conducted online by Kyriakidis et al. (2014) in 109 countries gathering over 4,886 questionnaires. Results revealed that 33 percent of participants would prefer autonomous to traditional driving, but there are significant concerns, namely software hacking, legal matters, and safety. In general, people showed great interest in autonomous vehicles, but reluctance in actually paying to buy one.

As far as methodology is concerned, most research was based on the stated-preference method via questionnaire, while different types of regression analysis were utilized depending on the actual objective of the paper. Lustgarten and Le Vine (2016) used a stated-preference model to offer a choice between a traditional vehicle or bus, an airplane flight, a semi-autonomous vehicle, and a fully autonomous vehicle in a scenario based questionnaire, regarding the visit of a family member in a distant part of the country. The variables in these scenarios were cost, duration, and maximum speed of travel. A multinomial logistic regression and mixed logit model were used for the analysis. Variables of cost and travel time turned out to have a negative influence, as it was expected, with respondents showing a strong preference to the cheapest and fastest means of transportation in each scenario. Respondents, also, valued the maximum speed of travel, regardless of the total duration of the trip.

Howard and Dai (2014) used logistic regression for the analysis of most questions and a log-linear approach for the «how often would you use an autonomous taxi» question. Payne et al (2014) used hierarchical linear regression to find the variables in using an autonomous vehicle. The dependent variable was the «would I be ready to use an autonomous vehicle instead of a traditional car» question. Menon (2015) used ordinal logistic regression, since all dependent variables used were ordinal in nature, meaning there was an order in the possible values of these variables. Thus, an ordinal logistic regression was used to analyze consumer familiarity, their beliefs on the advantages and concerns on autonomous vehicles, and their intention to adopt this technology.

More recently, Daziano et al. (2017) examined the willingness to pay for automation in a nationwide sample consisting of 1260 participants. Using discrete choice models, the survey concluded that the average household is willing to pay $3.500 for partial automation and $4.900 for full automation. Interestingly enough, some are not willing to pay anything and some are willing to go over $10.000 for full automation.

It can be observed that studies analyzing choices of people regarding autonomous, semi-autonomous, and traditional vehicles are relatively scarce. Consequently, this study attempts to add to current literature as it is one of the first attempts to utilize Stated Preference (SP) methods and Discrete Choice models for that purpose. In our approach, we included hypothetical scenarios of cost, time, and safety, which were distributed in a carefully developed questionnaire. By applying a random parameters multinomial logistic and binary logistic models it was possible to explore drivers' choices towards autonomous vehicles. More specifically, the purpose of the study is twofold: first, understand the factors affecting respondents' preferences given a set of alternatives by simultaneously accounting for unobserved heterogeneity and secondly, the investigation of factors affecting the probability of respondents to select or not an autonomous vehicle.

## 2. Data

A questionnaire was designed and handed out during a three-week period in October-November 2016. At the same time, an online version was created using SurveyMonkey's software (www.surveymonkey.com). We do have to note, however, that the purpose of this was not to conduct a full online survey, but use a more modern approach in filling out the questionnaire with a hand-held tablet device. The questionnaire itself was split into four parts spanning seven pages, including the cover. The average time of completion was approximately 13 minutes per questionnaire, which is considered to be above the normal threshold, but still acceptable. In practice, people found the subject to be of particular interest and showed no signs of fatigue while being surveyed.

### *2.1 Questionnaire Structure*

The first part of the questionnaire included a number of questions with the purpose of gathering general information on the habits and attitudes of drivers. The second part included a small introduction to the concept of autonomous driving, in order to provide a simple definition and maybe clear some of the misconceptions around autonomous driving. That ensured that all participants understood what autonomous driving means and would be able to make an informed decision regarding the pros and cons of autonomous vehicles. The third part included 8 scenarios, in which participants had to choose between a traditional, a semi-autonomous, and a fully autonomous vehicle depending on the values of three variables (cost and duration of travel, and safety level) in a hypothetical home-to-work trip. Duration of travel represents the total time required for a home to work and back trip. Different scenarios take into consideration possible special traffic lanes and time to park, with values ranging from 30 to 60 minutes, in total. Cost of travel takes into consideration the operational costs like gas prices, insurance costs, and parking fees. Values range from 20 to 60 euros per trip. The fourth and final part was used to build the demographics of the sample that is gender, age, education, profession, marital status, and income.

The survey was developed with maintaining a high level of cohesion and understanding in mind. As a result, questions were framed as simple as possible, using a four point Likert scale (‘None’, ‘Little’, ‘Enough’, ‘Very’) to make the respondents as little confused as possible and the analysis less complicated. To participate in the survey the individual was required to have a driver's license and be over 18 years old. Overall, a total of 144 valid questionnaires were gathered. The following graphs illustrate demographic information.

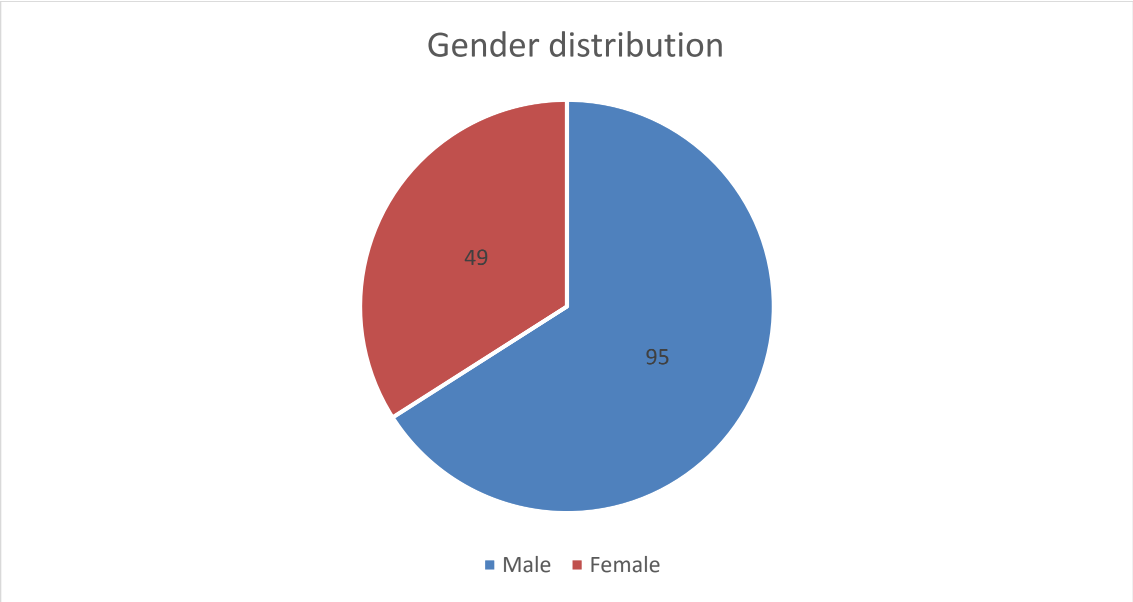


Figure 1. Gender distribution.

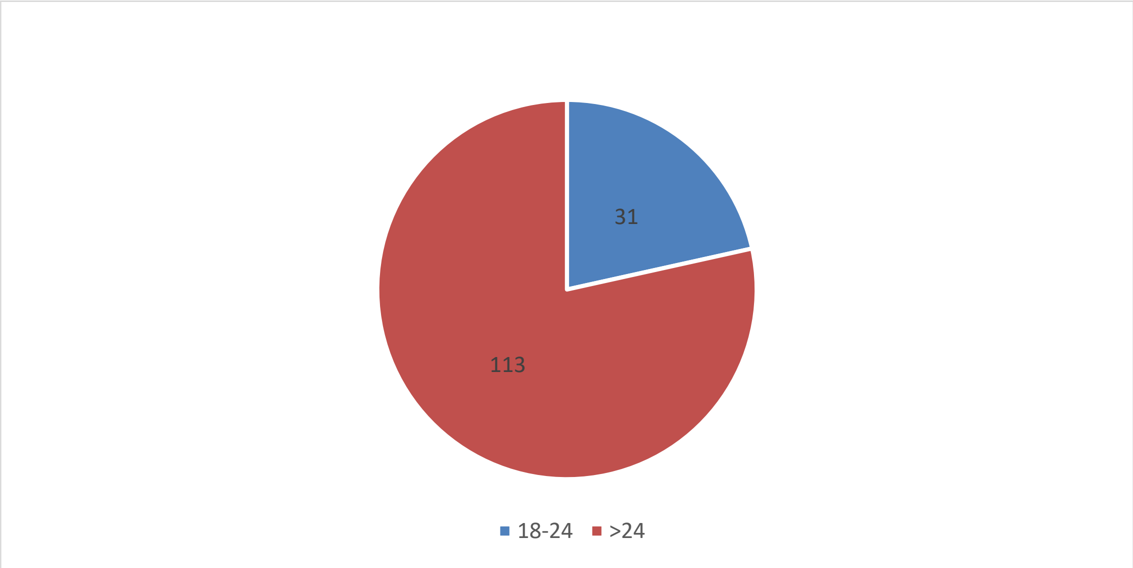


Figure 2. Age distribution.

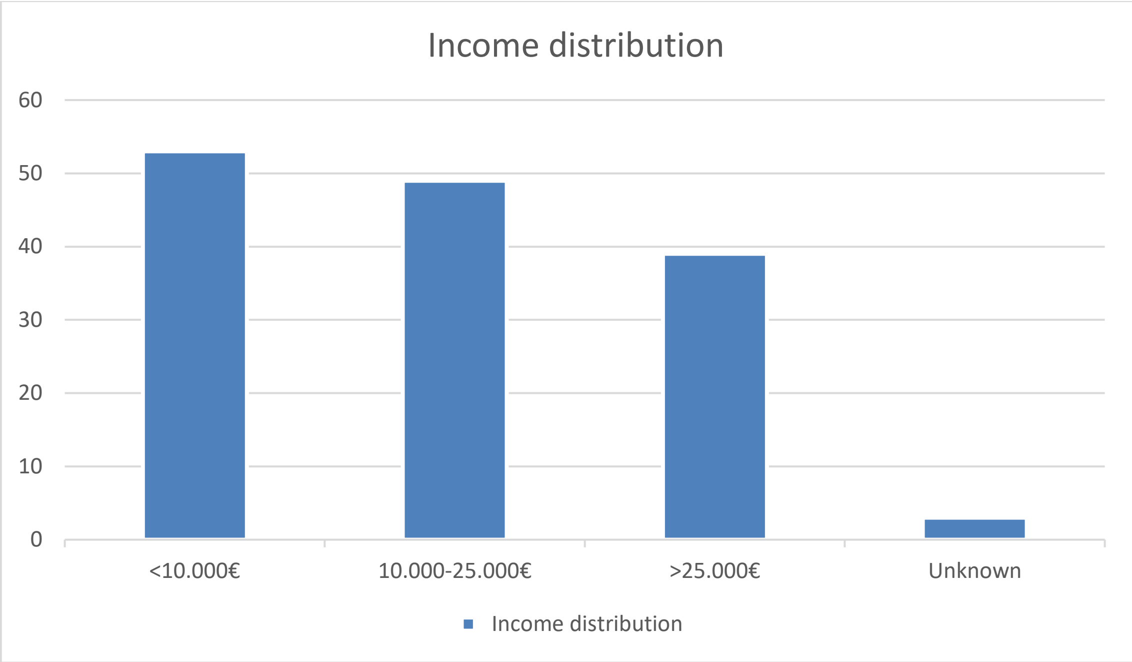


Figure 3. Income distribution.

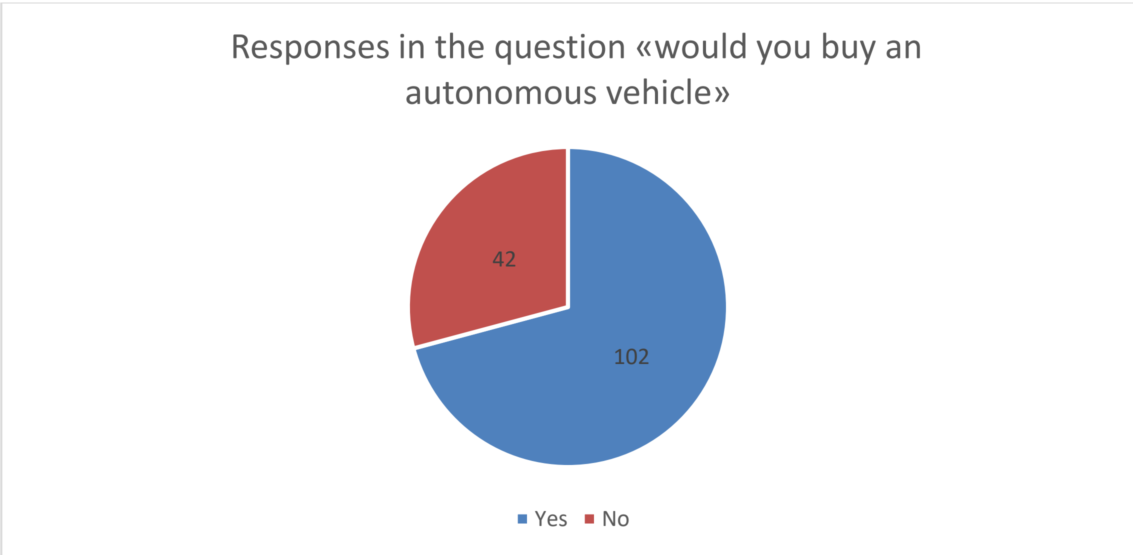


Figure 4. Responses in the question «would you buy an autonomous vehicle».

| | Gender | | Age | | Income | | |
|---|---|---|---|---|---|---|---|
| | Male | Female | 18-34 | >34 | <10.000€ | 10.000-25.000€ | >25.000€ |
| **Yes** | 47% | 24% | 51% | 20% | 26% | 23% | 22% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **No** | 19% | 10% | 23% | 6% | 11% | 11% | 6% |

Table 1. Statistical distribution of the sample in the «would you buy an autonomous vehicle» question, based on gender, age, and income.

## 3. Methods of Analysis

In our paper, two modeling approaches were utilized. In order to analyze people's preferences towards various levels of autonomy (traditional, semi-automated, fully-automated) and in order to account for unobserved heterogeneity, a random parameters multinomial logit model was applied. In the random parameters approach, parameters may vary across observations, in a sense that they follow a distribution, e.g. normal, uniform etc.

Following Washington et al. (2010), random-parameter model has for observation n, outcome probabilities defined as $P_n^m(i)$:

$$P_n^m(i) = \int_x P_n(i) f(\beta|\varphi) d\beta \tag{1}$$

where $P_n(i)$ is the probability of observation n having discrete outcome i, f(β|φ) is the density function of β with φ referring to a vector of parameters of that density function (i.e. mean and variance). Finally:

$$P_n^m(i) = \int_x \frac{\exp[\beta_i X_{in}]}{\Sigma_I \exp[\beta_i X_{in}]} f(\beta|\varphi) d\beta \tag{2}$$

where I denotes all possible outcomes for observation n, while $i \in I$.

As for the second part of the analysis, a binary logistic model was used since the variable of interest takes only two values. In the binary logistic regression, if the 'utility function' is U:

$$U = \beta_0 + \beta_i * x_i \quad (3)$$

then the probability P is:

$$P = \frac{exp^U}{exp^U + 1} \quad (4)$$

where, $\beta_o$ is the model constant, $\beta_i$ are the values of the coefficients, and $x_i$ are the values of the independent variables ($x_i$, i=1,2,3,…n the set of independent variables). The goodness-of-fit of the model can be assessed with the McFadden $R^2$, which is based on the likelihood ratios of the full model ($L_f$) and the empty model ($L_0$). Values over 0.2 suggest a reasonable fit.

## 4. Results

### *4.1 Random Parameters Multinomial Logit Model*

Data from the questionnaire were analyzed in R-Studio using a multinomial logistic regression approach. The dependent variable was the choice of transportation (traditional, semi, or fully autonomous vehicle) and the independent variables were a combination of variables that was chosen after a number of trials depending on their significance on the model. Variables included in the above equations are:

- *cost*, variable of cost
- *time*, variable of time
- *safety3, safety4, safety5,* safety level Middle, Low, and Very Low respectively
- *A8e8*, the value ‘Very’ in the question ‘How important is the existence of driver support systems in a car (GPS, parking assistant, etc.)’

- *B6a8*, the value ‘Very’ in the question ‘How important is to you the reduction in accidents by the adoption of autonomous vehicles’
- *D52*, the value ’10.000 - 25.000€’ in the question ‘What is your family income’
- *D53*, the value ‘Over 25.000€’ in the question ‘What is your family income’
- *A22*, the value of ‘5 to 10 years’ in the question ‘How many years have you been driving’
- *A23*, the value ‘Over 10 years’ in the question ‘Home many years have you been driving’
- *A48*, the value ‘Over 1 hour’ in the question ‘How many hours are you driving daily’
- *D28*, the value ‘Over 24’ in the question ‘How old are you’

Table 2 below shows the variables along with their Abbreviations, Coefficient, and Significance.

| **Abbreviation** | **Coefficient** | **P-value** | **Variable** |
|---|---|---|---|
| 1: constant | -4.651 | <0.001* | - |
| 2: constant | -0.060 | 0.9 | - |
| cost | -0.060 | <0.001* | Cost of transport |
| time | -0.104 | <0.001* | Duration of transport |
| safety2 | 0.329 | 0.3 | High safety level |
| safety3 | -1.595 | <0.001* | Medium safety level |
| safety4 | -3.702 | <0.001* | Low safety level |
| safety5 | -3.355 | <0.001* | Very low safety level |
| 1: A22 | 0.110 | 0.8 | The value of ‘5 to 10 years’ in the question ‘How many years have you been driving’ |
| 2: A22 | -1.390 | 0.003* | |
| 1: A23 | -0.299 | 0.6 | The value ‘Over 10 years’ in the question |

| | | | |
|---|---|---|---|
| 2: A23 | -1.609 | 0.002* | ‘Home many years have you been driving’ |
| 1: A48 | 0.492 | 0.2 | The value ‘Over 1 hour’ in the question ‘How many hours are you driving daily’ |
| 2: A48 | 0.703 | 0.04* | |
| 1: A8e8 | 1.420 | <0.001* | The value ‘Very’ in the question ‘How important is the existence of driver support systems in a car (GPS, parking assistant, etc.)’ |
| 2: A8e8 | 1.120 | 0.0004* | |
| 1: B6a8 | 2.824 | <0.001* | The value ‘Very’ in the question ‘How important is to you the reduction in accidents by the adoption of autonomous vehicles’ |
| 2: B6a8 | -0.139 | 0.8 | |
| 1: D28 | -0.303 | 0.6 | The value ‘Over 24’ in the question ‘How old are you’ |
| 2: D28 | 1.049 | 0.04* | |
| 1: D52 | -0.267 | 0.5 | The value ’10.000 - 25.000€’ in the question ‘What is your family income’ |
| 2: D52 | -0.399 | 0.3 | |
| 1: D53 | 1.433 | 0.002* | The value ‘Over 25.000€’ in the question ‘What is your family income’ |
| 2: D53 | 1.225 | 0.004* | |

Table 2. Results of the random parameter multinomial logit model.

It’s worth noting, the traditional vehicle was selected as the reference level. As a result, the two utility functions, for the autonomous and semi-autonomous vehicles, are both interpreted in reference to someone choosing the traditional vehicle. As shown in Table 2, the variables of cost, time, and safety are common between the two utility functions.

However, the rest of the variables are assigned different values in each function. More specifically, the prefix “1:” in the Abbreviation column denotes that the value of said variable is assigned to the function describing the choice of autonomous vehicle. Accordingly, the prefix “2:” denotes that the value of said variable is assigned to the function describing the choice of semi-autonomous vehicles.

Regarding the model fit, McFadden $R^2$ was at 0.33 and Loglikelihood ratio was at 687.71. As for the random parameters, the normal distribution was chosen. 200 Halton draws were used as recommended by Bhat (2003).

This analysis revealed that by increasing the cost of transport, the probability of choosing an autonomous or semi-autonomous vehicle is reduced. At the same time, increasing the duration of transport results in a reduction in choosing an autonomous or semi-autonomous vehicle over a traditional one. Following the same general pattern, reducing the safety level results in a significant drop in the probability of choosing an autonomous or semi-autonomous vehicle over a traditional one.

It’s worth noting, that drivers who value the existence of driver support systems in a car (GPS, parking assistant, etc.) exhibit a preference towards autonomous or semi-autonomous vehicles over traditional ones, and so do drivers who believe a reduction in car accidents would be possible thanks to autonomous technology in modern vehicles.

Showing a general preference towards semi-autonomous vehicles over traditional ones, are drivers who spend over 1 hour per day behind the wheel and drivers over 24 years old. Drivers with an annual family income of over 25,000€ showed a preference towards autonomous or semi-autonomous vehicle.

### *4.2 Binary Logistic Regression*

For the purpose of examining the willingness to buy an autonomous vehicle, binary logistic regression method was selected. The dependent variable was a ‘Yes’ or ‘No’ value in the question ‘would you buy an autonomous vehicle’ and the independent variables were a combination of variables that was chosen after a number of trials depending on their significance on the model. The utility function of willingness to buy is:

$$U = -1.209*A6new2(1) + 1.077*A8enew(1) - 1.895*B4(1) - 1.821*B4(2) + 1.376*B5new(1) + 1.182*Age2(1) \quad (5)$$

Variables included in the above equation are:

- *A6new2(1)*, the value ‘Over 10.000€’ in the question ‘How much did your car cost to buy’
- *A8enew(1)*, the value ‘Very’ in the question ‘How important is the existence of driver support systems in a car (GPS, parking assistant, etc.)’
- *B4(1)*, the value ‘The same’ in the question ‘Do you believe autonomous vehicles will be less, the same, or more safe than traditional vehicles’
- *B4(2)*, the value ‘More’ in the question ‘Do you believe autonomous vehicles will be less, the same, or more safe than traditional vehicles’
- B5new(1), the value ‘Very’ in the question ‘How comfortable would you be with autonomous taxis and public transport’
- *Age2(1)*, the value ‘over 34’ in the question ‘How old are you’

| **Abbreviation** | **Variable** | **Coefficient** | **P-value** | **Odds Ratio** |
|---|---|---|---|---|
| A6new2(1) | value ‘Over 10.000€’ in the question ‘How much did your car cost to buy’ | -1.209 | .021 | 0.3 |
| A8enew(1) | value ‘Very’ in the question ‘How important is the | 1.077 | .021 | 3 |

| | | | | |
|---|---|---|---|---|
| | existence of driver support systems in a car (GPS, parking assistant, etc.)’ | | | |
| B4(1) | value ‘The same’ in the question ‘Do you believe autonomous vehicles will be less, the same, or more safe than traditional vehicles’ | -1.895 | .002 | 0.2 |
| B4(2) | value ‘More’ in the question ‘Do you believe autonomous vehicles will be less, the same, or more safe than traditional vehicles’ | -1.821 | .007 | 0.2 |
| B5new(1) | value ‘Very’ in the question ‘How comfortable would you be with autonomous taxis and public transport’ | 1.376 | .011 | 4 |
| Age2(1) | value ‘over 34’ in the question ‘How old are you’ | 1.182 | .042 | 3 |
| Constant | | 1.191 | .082 | 3 |

Table 3. Variables included in the binomial logistic regression model, along with their Coefficient, Significance, and Odds Ratios.

Coefficients follow a sensible pattern that is in accordance to international bibliography, while at the same time no correlation exists between variables. $R^2$ value was at 0.399, which is considered very adequate for such models.

From this analysis, one can draw a few worth-mentioning conclusions. Firstly, drivers who own a car worth over 10,000€ are 70 percent less likely to buy an autonomous vehicle. This can be explained by the fact that buying a car is considered an investment, and if this investment exceeds 10,000€ someone might seem reluctant to spend at least that much in a new car. In fact, most Greek drivers believe that an autonomous vehicle will cost between 10,000€ and 30,000€, with a significant percentage even going over 30,000€.

Furthermore, drivers who believe autonomous vehicles to be on the same level of safety or less, in relation to traditional vehicles, are 80 percent less likely to buy an autonomous vehicle. Safety, of course, plays an important role, thus this conclusion is inevitable. On the same note, those who would feel comfortable with autonomous public transport and/or taxis on the road are four times more likely to buy an autonomous vehicle in the future.

Last but not least, drivers over the age of 34 seem to be more willing to buy an autonomous vehicle. This may not appear, at first, to be expected as young people are, generally, more prone to the adoption of new technologies. In the case of autonomous vehicles, however, the cost of purchase seems to be a deciding factor. Half of Greek drivers over 34 years old stated family income over 25,000€, while 45 percent of young people state family income below 10,000€. This means that older drivers have more money, which they can spend on buying a new car. Another factor could, also, be safety. Drivers over 34 years old are less skeptical in regards to the safety level an autonomous vehicle might offer compared to today’s cars.

**5. Conclusions**

Our study used a stated preference survey in order to investigate Greek drivers’ attitudes towards autonomous vehicles. Both multinomial and binary logistic regression models revealed that Greek drivers show, in their majority, reluctance towards fully autonomous vehicles, while at the same time exhibiting a more positive behavior towards semi-autonomous vehicles. Specifically, as long as travel time is reduced, the probability of choosing semi or fully autonomous vehicles appears to grow. On the other hand, as travel time increases drivers seem to prefer traditional vehicles.

Further investigation shows that reducing the cost and duration of a trip, as well as safety levels, results in a lower probability in choosing semi of fully autonomous vehicles. This is expected and in accordance with international research. It’s, also, evident in this survey where drivers consider safety, a low buying price and consumption, to be extremely important in autonomous vehicles.

Our research also showed that the choice of semi or fully autonomous vehicles depends on time, cost, and safety level relative to traditional vehicles. Other variables include the drivers’ opinion on the importance of support systems in today’s vehicles, such as GPS or parking assistant, and their opinion on the potential impact autonomous vehicles could have on road accidents. Also, driving experience, time spent driving, age, and family income have a strong effect on said choice.

Regarding the binary analysis and the willingness to buy an autonomous vehicle, results show a dependence on the drivers’ opinion on the importance of support systems in today’s vehicles, such as GPS or parking assistant, the safety level of autonomous vehicles in relation to traditional vehicles, and how comfortable they would be with autonomous taxis and public transport on the road. Other factors include the cost of their current car and their age. Secondly, driving experience has a negative effect in choosing semi-autonomous vehicles, which can be explained by the power of habit, which often prohibits people from even considering an alternative means of transportation. On the same level, the positive effect of daily driving frequency on choosing a semi-autonomous vehicle could be attributed to fatigue. Autonomous driving could reduce driving fatigue and stress during traffic congestion for example, thus making them an attractive alternative to those who spend a significant proportion of their time on the road.

Greek drivers are generally positive towards autonomous vehicles, but they are still skeptical on the matter of safety. We believe this is the deciding area that should authorities focus on, would yield the best results in eliminating any hesitation the public might have against autonomous driving.

Another area that should be explored is the pilot operation of autonomous buses or other means of public transportation. Such program was implemented with great success in the city of Trikala with ARTS (Automated Road Transport System), as part of the CityMobil2 initiative. This is proof that a close interaction with autonomous technology can greatly influence the minds of the public in a positive way, as long as the program runs successfully. Dealing with the public’s concerns in a practical manner through the pilot launch of autonomous systems in the public transport sector in select cities, would be the best way to successfully introduce autonomous vehicles to the world in a way that would be beneficial both to car manufacturers and users of the road network.

Autonomous vehicles are an area still at its infancy. The road to fully autonomous vehicles is long, and that gives researchers the chance to be thorough and fully comprehend the scope of their impact on society. It is suggested that a larger survey that includes more scenarios and alternative statistical models (e.g. latent class models) should be carried out, covering various countries. Greece, in particular, presents an interesting case in that it’s geographical particularities could greatly affect how autonomous vehicles are introduced to the public.

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**7. List of figures**

Figure 3. Income distribution.

Figure 4. Responses in the question «would you buy an autonomous vehicle».