A User Acceptance Survey of Pay-How-You-Drive Urban Pricing Schemes

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Abstract. Urban congestion pricing is widely regarded as an effective way of traffic management in order to relief metropolitan centers from heavy traffic, reduce emissions, air pollution and as a means to promote public transport usage. Until recently, pricing strategies were formed mostly by taking into account peak hours and exemption provisions (e.g., for taxis or clean-fuel vehicles). However, recent advancements in smartphone sensing have enabled the monitoring of driving behavior, a practice which can act as an additional parameter for the determination of urban tolls. The aim of this paper is to investigate drivers' perception towards PHYD urban pricing schemes and identify factors that may affect their acceptance in the city of Athens using a questionnaire survey. Our preliminary results have shown that men tend to be more aggressive and exceed speed limits than female drivers do. The findings reveal that women are more likely to accept PHYD urban pricing schemes. In addition, commuters are also more likely to accept such a measure contrary to those travelling for other purposes. Finally, eco-minded drivers are more willing to accept PHYD pricing systems. Such results can be really useful for both researchers and decision and policy makers who are willing to design user friendly and easy acceptable pricing systems.

Keywords: Pay-How-You-Drive · Road pricing · Stated preference survey · Clustering

1 Introduction

The urban transportation system, in an environment with increased population density and economic activity, is a key element of economic growth and equality. Also, due to its impact on traffic congestion and greenhouse gas (GHG) emissions, it constitutes a major issue for urban areas with high dependency on car usage. In order to deal with such problems, urban pricing has been suggested as an improvement solution, which in many cases has faced a hostile environment due to a lack of confidence in what will eventually be implemented [1]. Urban toll schemes are rising again as a prominent measure for managing traffic, reducing emissions and funds for new construction, and promoting public transportation. Urban tolling is not a new concept. The most well-known schemes are found in London and Stockholm, where their impact has been

reflected to reduced volume by 25% and has improved air quality [2]. A flat rate pricing scheme is well known and easy to apply for both policy makers and users. Nowadays, people want different pricing options, especially if they are willing to change some of their driving habits [3].

Most existing pricing schemes can be divided into: Congestion-based, Distance - Based and Pay-As-You-Drive insurance (PAYD). The Congestion-based, is a tax applied to specific areas, the Distance-based, implies a higher price per km travelled and the PAYD, is based on the drivers' mileage. The more you drive, the more you pay, and the less you drive, the more you save. This system is able to achieve goals such as being fair, affordable, improving road safety, reducing various traffic problems and the impact of GHG emissions [4].

A current effective demand management can lead to an efficient future mobility management. Reduced congestion, less emissions and the quality of urban life, benefits all. The technologies of telematics contribute to the introduction of new pricing schemes which serve the needs of authorities worldwide.

Traditionally, pricing schemes are applied in order to promote more sustainable travel modes (such as public transport) and prevent reckless use of private vehicles [5, 6]. Nevertheless, some studies have shown that this measures do not have the anticipated impact on the car use [7] and therefore, in recent years, usage-based pricing schemes arise, which borrow the main aspects of the well-known PHYD and PAYD insurance schemes. Since we cannot prevent drivers from using their own car, we can at least motivate them to drive properly and in a more sustainable way.

The following Fig. 1, illustrates the existing pricing schemes and the innovative concept of PHYD, which encourages drivers to improve their driving behavior in order to pay lower premiums.
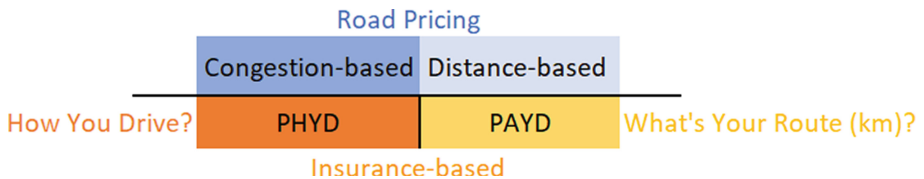

Fig. 1. Pricing schemes.

Taking advantage of this new pricing schemes, urban congestion toll systems can be redefined and become more user-friendly. Previous studies [7], has shown that the success of such services depends on a number of factors ranging from people's characteristics, attitudes, and opinions, but also from the public's perception of the scheme and corresponding benefits, e.g. to reduce car usage, improve air quality and so on. To this end, the aim of this paper is to investigate drivers' perception towards PHYD urban pricing schemes and identify factors that may affect their acceptance. Thus a more user friendly and acceptable pricing system may be designed.

2 Methodology

The acceptance investigation of a new concept, such as the application of PHYD pricing schemes, requires the collection of stated preferences data which are able to capture the perceptions and opinions of the crowd before the measure is actually applied. Therefore, a questionnaire was designed at first and then an online survey was carried out. Once the data was collected, clustering methodology was applied in order to identify groups of potential users of the system which share common characteristics.

2.1 Questionnaire Design and Survey Execution

In order to capture the views of drivers regarding PHYD pricing schemes as well as their perception on the benefits of pricing schemes in general, a questionnaire survey was designed. The stated preferences survey was conducted in from 7/11/2019 until 20/02/2020 and the total number of questionnaires collected is 390.

The questionnaire consists of 5 parts and includes 5 scenarios and 26 questions. In the first part, the respondents were asked which are their preferred means of transport (e.g. car, bicycle or public transport). In the second part, the mobility profile of each driver was captured (e.g., trip purpose, average travel distance, average travel cost, perceived driving behavior).

- Trip purpose: In transport demand analysis, movements are usually characterized by the purpose they serve, leisure, personal affairs, work, etc. [8].
- Average travel distance: this characteristic emerges by the drivers' exposition to traffic accident risk.
- Average travel cost: in the present research the travel cost is defined as the cost of public transport ticket and the fuel cost of private vehicles.
- Perceived driving behavior: refers to the drivers' choices in real time which are linked to the probability of getting involved in a traffic accident, based on their driving way.

In the third part of the questionnaire, questions regarding drivers' perceptions on traffic congestion and its countermeasures were asked. Indicatively, each individual is asked to indicate, between a set sum of answers provided, the impacts of congestion, which are the most appropriate countermeasures, and the benefits of urban road pricing systems. Afterwards the respondent is asked to point out if he would accept the measure of urban tolls, the level of importance, and the benefits that come with such a measure. Finally, the acceptance of an electronic application which can collect personal data with regards to the driving behavior is being investigated, and the extent to whether or not each driver would take advantage of the tips provided in order to improve his driving behavior, drive more eco-friendly and save money. The fourth part, includes scenarios with different cost and travel time values in order to identify whether the drivers will change their mobility patterns or stay firmly at the same behavior. Finally, demographic characteristics were collected as well.

2.2   User Profiling Through Clustering

As mentioned before, we attempted to identify groups of users with common characteristics, who are more likely to accept and get engaged with the proposed system. In order to do so, K-modes clustering technique was applied.

Clustering is a well-known task of dividing a set of observations into a number of groups so that the observations within the same group are similar. The most widely used clustering technique is K-means clustering, where a cluster can be thought as a group of data points whose interpoint distances are small compared with the distances of points outside of the cluster. For each data point X_n, a corresponding set of binary indicator variables $r_{nk} \in \{0,1\}$ are introduced, where $k = 1, ..., K$ describing which of K clusters the data point X_n is assigned to, so that if a data point is assigned to cluster k then $r_{nk} = 1$, and $r_{nj} = 0$ for $j \neq k$. Then, an objective function is defined, given by:

$$J = \sum_{n=1}^{N} \sum_{k=1}^{K} r_{nk} \|x_n - \mu_k\|^2 \tag{1}$$

which represents the sum of squares of the distances of each data point to its assigned vector μ_k, where μ_k represents the center of the kth cluster. The goal is to find values for $\{r_{nk}\}$ and the $\{\mu_k\}$ so as to minimize J [9]. In the case where all data used are categorical, an alternative to k-means technique is the k-modes clustering. The k-modes algorithm tries to minimize the sum of within-cluster distance from the mode of that cluster, summed over all clusters. In the case of k-modes the distance used in the Hamming distance which is mostly used in information theory.

3   Implementation and Findings

3.1   Analysis of Responses

This section provides an overview of the data collected from the questionnaire with the aim to point out the characteristics of the sample. In addition, some of the most interesting findings with regards to users' driving behavior, environmental concerns and their willingness to accept a new road pricing scheme are being discussed. The socio-demographic characteristics of the sample are shown in the following Table 1:

Table 1. Socio-demographics of the sample.

Variable	Example	Percentage of sample
Gender	Male	56.15%
	Female	43.85%
Age	Young (18–34)	59.23%
	Middle-aged (35–54)	33.85%
	Elderly (>55)	6.92%
Income	Low (<10.000)	35.90%
	Medium (10.000–25.000)	53.59%
	High (>25.000)	10.51%

A sample of 390 people is used, which is well distributed among males and females. For the rest of the analysis only respondents who hold a driver's license and use their car at least once or twice a week are taken into consideration (Fig. 2).
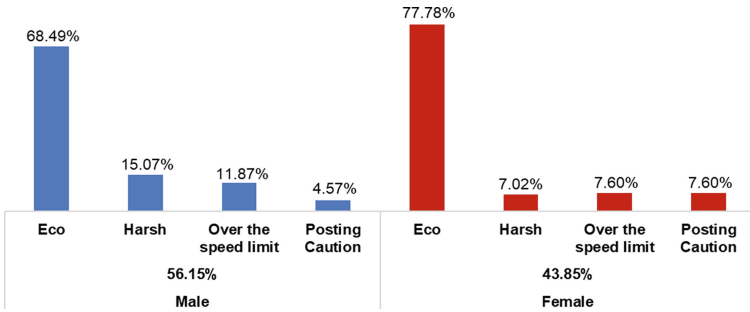

Fig. 2. Male and female drivers' perceived behavior.

In the figure above, it can be clearly seen that there is a significant difference in driving behavior between the two sexes. 15% of the male drivers stated that they drive in an aggressive manner while the responding percentage for females is 7%. Men also stated that they exceed the speed limits more often than women do. Men's driving experience affects their driving skills and reactions by creating a sense of personal safety and confidence as stated in [10].
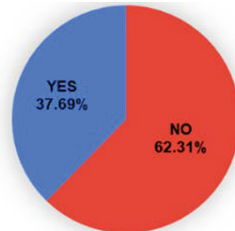

Fig. 3. Urban tolls acceptance.

As it can be seen in Fig. 3, most of the respondents (62.3%) are not willing to accept the urban tolls as a measure of regulating traffic congestion. Studies from several cities, show that the acceptance tends to increase after the implementation [11].

More specifically and according to Fig. 4, drivers with lower income are less likely to accept the measure of urban tolls, while drivers with higher income do not have a clear tendency to accept or reject the measure. Road pricing is expected to receive more support from higher income groups as time is of the essence [12].
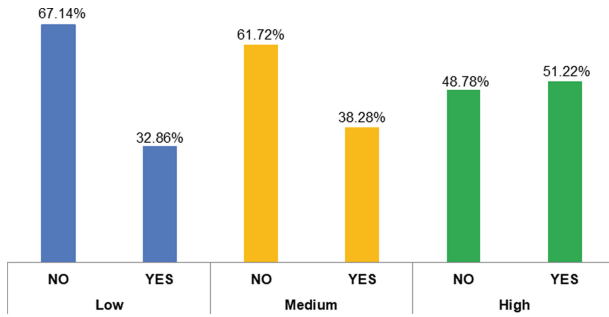
Fig. 4. Relation between urban tolls acceptance and income.

Furthermore, according to main economic theories and in contrast with previous studies [12], the influence of occupation on the acceptability of road pricing seems to be remarkable. Unemployed people and government employees do not accept urban tolls as it can be seen in Fig. 5. This is an expected result, according [5], as the income is an influencing factor for the acceptance in the city of Athens. On the other hand, students and self-employed people, seem to be more progressive and are more likely to accept the measure.
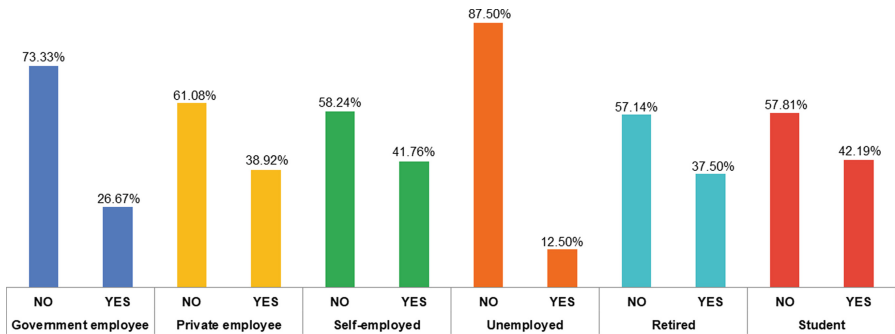

Fig. 5. Relation between urban tolls acceptance and occupation.

[12], in their study mention that urban road pricing is not considered to be an efficient measure of improving ones' driving behavior. Although, with regards to Fig. 6, drivers who perceive that they drive in an eco-friendly manner are more likely to accept the proposed system. This result indicates that people who are eco-minded are more likely to accept measures that lead to reduced air pollution and improved environmental conditions of cities (Fig. 7).
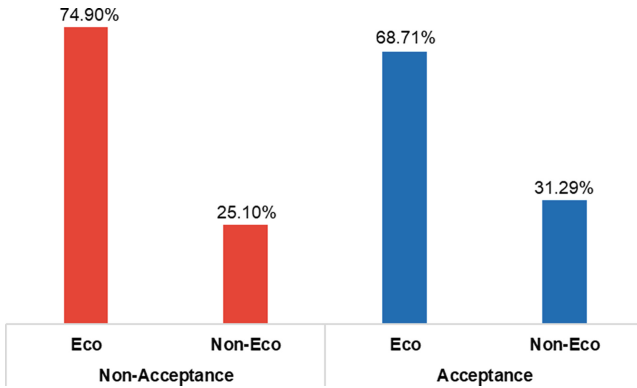
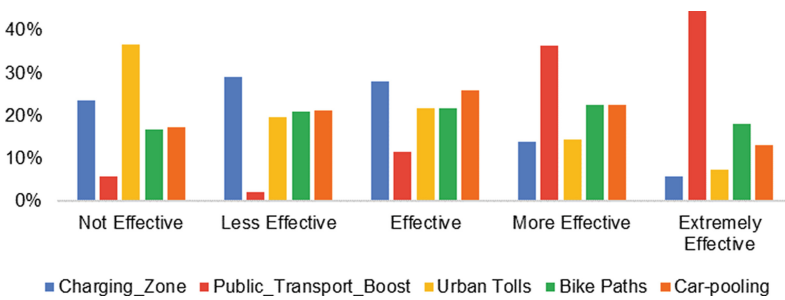**Fig. 6.** Relation between urban tolls acceptance and driving behavior.

Fig. 7. Traffic congestion reduction measures stated efficiency.

All in all, and as displayed in the figure above, urban tolls are not considered to be the most effective measure for the reduction of traffic congestion while the improvement of public transport can be. According to [11], the most popular and efficient measure in order to reduce queues is the improvement of the public transport system with a percentage of those in favour reaching up to 80%.

3.2   Analysis of Responses

In order to identify groups of drivers in the sample who share the same characteristics k-modes clustering was performed. The number of clusters as emerged from the Calinski-Harabasz criterion was set to k = 3. The variables used for the analysis are gender, trip purpose and time travelling. Results indicated that there are three main groups of drivers in the dataset.

- Male commuters who drive to work during peak hours constitute cluster 1.
- Female commuters who drive to work during peak hours constitute cluster 2.
- And finally, female commuters who drive for personal purpose in non-peak hours constitute cluster 3 (Fig. 8).
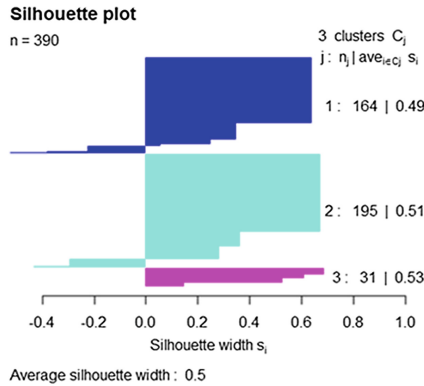
Fig. 8. Silhouette plot.

The average silhouette value is 0.5, which indicates well separated clusters (Fig. 9).
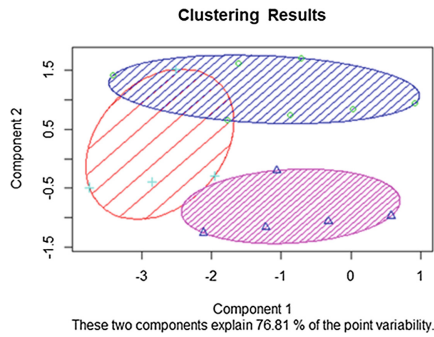

Fig. 9. Clustering results plot in 2d.

Subsequently, the acceptance rates of each of the identified group of drivers is investigated. Finally, 4 scenarios are created:

- Scenario 1: Eco-Driving and Urban Tolls Acceptance
- Scenario 2: Eco-Driving and Non-Urban Tolls Acceptance
- Scenario 3: Non-Eco-Driving and Non-Urban Tolls Acceptance
- Scenario 4: Non-Eco-Driving and Urban Tolls Acceptance

Figure 10 presents the correlation of having knowledge on the concept eco driving and urban tolls acceptance. Results taken from this figure are coming along with those seen earlier in Fig. 3, as in both cases especially high ratios of non-acceptance are noticed. However, when taking a closer look at clusters 1 and 2, for men and women

respectively, where both are being aware of eco driving, it can be noticed that men are less objected in the application of such measure. Whereas, when not taking into consideration the factor of eco-driving, women are more likely to accept.
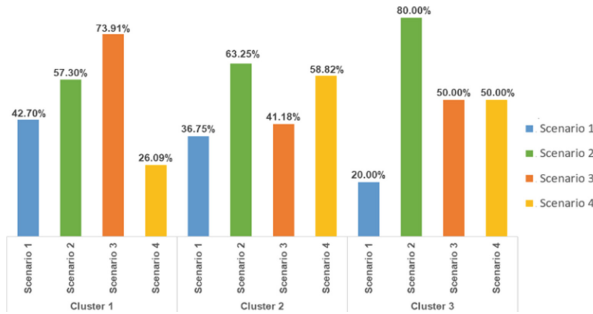

Fig. 10. Relation between clusters and scenarios

In detail, drivers of the first cluster, whether they have knowledge of the eco driving or not, are leaning towards to the non-acceptance of the tolls.

In cluster 2, it is worth noting that, in the specific case where drivers are aware of eco driving, they have almost twice as much higher ratio towards non-acceptance from those who accept such a measure. However, for those who do not know what eco driving is, the urban tolls measure is mostly accepted at a rate of 58.8%.

Finally, in the third cluster, it can be seen that the majority of the drivers are aware of eco driving and at the same time they do not accept the urban tolls. Such result is expected as their travel takes place in non-peak traffic hours and thus some of them may have the possibility to choose a different route or mode of transport. Drivers who do not know what eco driving is, do not have a clear tendency to accept or reject the measure.

Having in mind the analysis conducted above, the result that can be extracted is that the awareness of eco driving cannot act as a factor that drives or either determines the acceptance of urban tolls. It is safe to say that the acceptance of such a measure is mostly connected with factors like as: gender, time and scope of travelling.

Figure 11, reveals that in cluster 1, men drivers do care more about eco driving advices. In cluster 2 women do prefer advices about saving money. In general, in all three clusters people care about eco driving and the improvement of their driving behavior. Privacy issues, such as the abuse of personal data, are viewed as another obstacle to the acceptability of the measures. However, people will allow an application to use the sensors of their mobile phone in order to collect information for their driving behavior. Men tend to trust more the use of such an application.
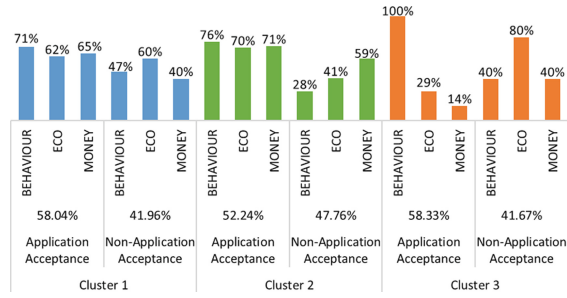
Fig. 11. Relation between clusters – application and application advice.

3.3   Discussion and Conclusions

Studies present that pricing strategies are formed mostly taking into consideration peak hours and exemption provisions. The aim of this paper is to investigate drivers' perception towards PHYD pricing schemes and identify critical characteristics that can lead to their acceptance. Firstly, a questionnaire is designed and distributed to a random but representative sample of 390 participants in Attica region, Greece. This questionnaire, includes both revealed and stated preference questions regarding the acceptance of urban tolls, the effects of congestion and the use of a smartphone application in order to record and collect information about driving behavior.

The conducted survey presents a main finding: this being that people will not easily accept urban tolls. This particular measure is considered not to be an effective way for the reduction of traffic congestion as the improvement of public transport can be.

As far as the two genders are concerned, male are more aggressive drivers and exceed speed limits than female do. Women are more likely to accept PHYD urban pricing schemes. Another important finding is that the income can dictate the acceptance of urban tolls. Drivers with lower incomes or even unemployed do not accept such a measure. Drivers with higher income are equally divided between acceptance and non-acceptance. In this paper, a user profiling took place. From each profile emerged that higher percentages of men tend to trust more the use of an application which collects driving behavior data and do care about eco driving advices. Women do prefer advices about saving money. Finally, the awareness of eco driving cannot act as a factor that drives or either determines the acceptance.

To the best of our knowledge, the present study is one of the very first times that a discrete choice experiment towards the acceptance of urban tolls based on driving behavior is carried out. That is the main contribution of the study.

The present research keeps taking place with the aim of increasing the sample and drawing safer conclusions. The questionnaire can generate various correlations that lead to conclusions about drivers' behavior and characteristics that may influence the acceptance of the urban tolls measure.

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