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Incorporating car owner preferences for the introduction of economic incentives for speed limit enforcement

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Human error including driving misbehavior contributes to over 90 percent of road vehicle accidents, and speeding is considered to be risky. Smart technologies, such as Connected Vehicle System (CVS) are among the interesting technical options to improve driving behavior, and Pay-As-You-Speed (PAYS) is an effective economic incentive to reduce speed violations. We investigated the acceptability of CVS with and without the presence of economic incentives, such as PAYS, in the context of a middle-income country: Iran. We used a Zero-Inflated Ordered Probit model (ZIOP) to estimate drivers' willingness to pay for a CVS, and a hazard-based model for predicting the incentive level needed for accepting CVS via a PAYS scheme. ZIOP model indicated that drivers with the following characteristics were more likely to pay more for CVS: having a comprehensive insurance coverage, being younger than 60 years, owning more than one car, and having older vehicles. The hazard-based model also confirmed that drivers that speed relatively often have a lower tendency to adopt CVS, and drivers who experienced an accident in the past were more inclined to adopt CVS via PAYS. Also, drivers' opinion about CVS, vehicle characteristics, demographics, and driving experience influenced the effect of PAYS characteristics on acceptability of CVS. Finally, we offer recommendations for how to effectively implement CVS, in order to significantly reduce the high fatality and accident rates in middle-income countries such as Iran.

1. Introduction

According to the World Health Organization (WHO) in the year 2018, road accidents were in the top ten of leading causes of death in the world (WHO, 2015). According to the WHO's Global status report on road safety, 1.35 million people die in road accidents and about 20–50 million are injured annually.

Driving behaviour is a contributory factor in over 90 percent of crashes (Petridou & Moustaki, 2000). Its association with traffic accidents have been investigated in several studies (Lajunen, Parker, & Summala, 2004). Speeding is considered to be risky, affecting both the probability of being involved in traffic accidents as well as the severity of injuries caused by

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accidents (Elvik et al., 2004, Mullen, Maxwell, & Bedard, 2015). A decrease of about 40% in the number of road fatalities can be achieved by a 10% reduction in the average speed of the driver (Elvik et al., 2004).

There are several options to improve driving behaviour, such as safer infrastructure, better driving environment, better training and education, proper regulations and smart technologies. Promising examples of smart technologies include Intelligent Speed Assistance (ISA) and Connected Vehicle System (CVS). Compared to most infrastructural changes these are relatively easy and fast to implement.

Presently, smart technologies are an option to reduce drivers' speeding behaviour and because of their potential to impose continual penalties on risky behaviour, it is more effective than conventional alternative measurements, such as speed cameras and manned speeding enforcement (Bolderdijk, Knockaert, Steg, & Verhoef, 2011, Ryeng, 2012).

CVS is a smart technology with the ability of real-time monitoring of vehicle's speed, and comparing it with speed limits. As a result, it is possible to identify speed violations and send the drivers' speeding violations to the police.

According to Risk Homeostasis Theory (RTH), each person has a target level of risk and tries to behave in a way that this level of risk is maintained (Wilde, 1982). Wilde claims that the only way of reducing accidents in the long-term is by implementing road safety interventions that reduce drivers' target level of risk. RHT assumes that the perceived costs and benefits of risky and cautious behavioral options determine the target level of risk.

This target level of risk is decreased by CVS implementation which sends speed violations to police permanently. In fact, penalties followed by CVS implementation add extra costs to risky behavioral options. As a result, according to RTH, it can be expected that stable affect would be achieved on driving down the speed.

CVS has a communication platform for transferring important information and warning messages to passing vehicles via road side units (RSUs) and also for information exchange between vehicles equipped by CVS (On-Board Units – OBUs). The main task of OBUs is collecting vehicle's information such as its speed, location, distance travelled and whether it has stopped, overturned or broken down. OBU sends the data to the other vehicles and RSUs. (Biswas, Tatchikou, & Dion, 2006). RSUs are devices installed on roadside masts which transfer data received from OBUs to the central server or first end users such as police (Biswas et al., 2006).

Moreover, data from sources of road information such as police and highway patrols, is transmitted via RSUs to OBUs. CVS uses Dedicated Short Range Communication (DSRC) as the main platform for data transmission (Biswas et al., 2006, Owens, Antin, Doerzaph, & Willis, 2015).

CVS notifies drivers about near misses, slippery and frozen roads, vehicle failures, abrupt stopping of front vehicles on the road and other possible sources of road danger (Biswas et al., 2006).

The acceptance of CVS as a tool for the enforcement of speed limit might be negatively influenced by the fact that it monitors drivers' speed violations. An important question therefore is: which drivers and under which conditions will buy or use CVS? Despite the advantages of CVS, implementing CVS could be costly and people may refuse to buy or even use it for free. They may have privacy issues with using CVS or they may think it is useless for them, or they may have concerns such as being distracted while driving and, etc. (Owens et al., 2015).

Using economic incentives can help to increase the drivers' motivation to use such systems and may tackle the problem in an effective manner (Warner & Åberg, 2008, Musicant & Lotan, 2016, Wijnands, Thompson, Aschwanden, & Stevenson, 2018). Pay-As-You-Speed (PAYS) is an economic incentive that offers monetary rewards in return for respecting speed limits (Bolderdijk et al., 2011). The core of PAYS is that the insurance premium is calculated based on (in this case) the speeding behaviour of policyholders (Litman, 1997, Zantema, van Amelsfort, Bliemer, & Bovy, 2008, Greenberg, 2009, Hultkrantz, Nilsson, & Arvidsson, 2012, Bian, Yang, Zhao, & Liang, 2018).

Considering the ability of CVS in transferring data based on DSRC, it has a considerable advantage in making a secure network for PAYS compared to other probe devices which use General Packet Radio Service (GPRS) as the main platform for data transmission.

In high-income countries, studies have shown that PAYS is an effective way to reduce speed violations (Hultkrantz & Lindberg, 2011, Bolderdijk et al., 2011, Lahrmann et al., 2012, Stigson, Hagberg, Kullgren, & Krafft, 2014). However, a significant percentage of fatalities caused by road traffic accidents is related to low to middle income countries: low to middle income countries have a share of 93% of the world's road accident fatalities, and 60% of the global number of vehicles (WHO, 2015).

Despite the high fatality rates in low to middle income countries and the effectiveness of the PAYS in reducing these fatalities, to the best of our knowledge, there is very little literature focusing on the PAYS concept in low to middle income countries. In this paper we intend to address this knowledge gap by answering the following questions:

- Which factors have an influence on the acceptance of CVS without any incentives scheme?
- How large should financial incentives be to make CVS acceptable?
- How do economic incentives, such as PAYS, affect public acceptance of CVS?

We have used an empirical approach to answer these research questions. Initially, we collected drivers' opinions about CVS and asked about their concerns about such systems. We also asked them about the most important factors that may influence their decision to adopt such systems. Then we estimated drivers' willingness to pay for CVS system. Secondly, we have used the Hazard-based models for predicting respondent's incentive level for accepting the use of CVS through PAYS scheme.

We have selected Iran as an example of a low to middle income country to conduct this research, mainly because Iran has a disproportionately high number of fatalities and injuries caused by traffic accidents. Although, the population consists of 1.07% of the total world population (Lutz, Butz, & Samir, 2017), about 2.5% of all traffic accidents in the world happen in Iran (Hekmat, Dehnavieh, Norouzi, Bameh, & Poursheikhali, 2016). According to WHO figures released in 2018, it was estimated that Iran had 20.5 road traffic deaths per 100,000 population (WHO, 2015).

In Iran, CVS has been developed and similar to many other countries, it is in the state of solving the challenges of implementation. Projecting and implementing a CVS was suggested in Iran 8 years ago in Iran by ACECR (Academic Center for Education, Culture and Research) – Sharif Branch. This institution in cooperation with IDRO (Industrial Development and Renovation Organization of Iran) has devoted extensive efforts in design and implementation of CVS. Following the primary research, producing software applications and conducting experimental and field tests, the project was successful in its pilot phase (Rostami, Ataeian, Hamzeh, Yousefi, & Karimi, 2013).

Speed violations are common in Iran and around half of the Iranian drivers do not comply with speed limits (Moradi, Motevalian, Mirkoohi, McKay, & Rahimi-Movaghar, 2013). Along with similar studies, Özkan et al. (2006) show a positive relationship between aggressive violations and the number of accidents in Iran. Therefore, reducing speed violations leads to better traffic safety in Iran.

2. Study design

2.1. Survey procedure

We chose to approach passenger car owners in five technical inspection centers and carwashes in Tehran, in March 2016. Tehran is the densely-populated capital of Iran with close to 9 million citizens, and is an important submarket in Iran. There are about 20 million registered road vehicles in Iran, of which approximately 4 million are in Tehran. The survey locations were selected in different parts of the city to draw a random sample.

According to Iranian law, vehicles older than five years should be technically inspected annually and receive a sticker, indicating that their emission levels are within the acceptable levels and that the vehicle fulfills minimum safety requirements. Prior to the Iranian New Year's vacations (20th March to 2nd April), many drivers visit the technical inspection centers to avoid being fined during their New Year's trips. In Tehran, the large number of drivers at most inspection centers during this time leads to queuing vehicles with long waiting times of over half an hour. We used these queues as an opportunity to interview drivers. In addition, to collect data of drivers with newer vehicles (less than five years old), we conducted a number of interviews at carwashes. This approach for data collection recently has been used in another study in Iran (Sahebi, Nassiri, & de Winter, 2019). Twenty volunteers from Sharif University interviewed 258 individuals at both location types. The response rate was about 80%. The experimenters were all students who were trained by the first author.

The survey consisted of questions about drivers' opinions about CVS, acceptance of the PAYS scheme, Willingness to Pay (WTP) for CVS, vehicle-related information, driving risk perception, speeding behaviour, insurance coverage, at-fault accidents, demographic and driving experience, and traffic tickets.

2.2. Data collection

The interview started by showing a 30-second video on a smartphone to participants, introducing CVS. Thereafter, experimenters described the Observing Speed Limit program, which reports drivers' speed-limit violations through OBU to the nearest RSU connected to the police station, after sending three consecutive alerts to the driver when his or her driving speed is above the speed limit.

Then, participants were asked about their concerns toward CVS and to state their opinions about the effectiveness of CVS on accidents reduction. Respondents were asked to rate their concern about CVS effects on driver distraction and privacy issues. For these questions, the participants could choose one of three options, namely low, moderate, and high. These questions were inspired by a study of Schoettle and Sivak (2014) and Bansal et al. (2016) which assessed individuals' perceptions about the benefits and concerns of CVS (Schoettle and Sivak, 2014, Bansal, Kockelman, & Singh, 2016, Bansal & Kockelman, 2017). Next, participants were questioned about the acceptance of the PAYS scheme and participants' WTP for CVS.

Two specific questions were asked about perception of driving risks. Respondents were asked what they think about their probability of having a car accident, and then what they think about the probability of becoming the victim of a fatal accident or an accident resulting in the respondent being severely injured. These two questions which were asked on a five-point Likert scale ranging from very low to very high were inspired by Ullberg and Rundmo's (2003) study (Ulleberg & Rundmo, 2003). Two questions were asked about respondents' speeding behaviour. They were then asked how much slower/faster their usual driving speed is compared to other drivers on a six-point Likert scale from much faster to much slower. And they were asked how often their speeding violations remain unnoticed by the police, on a six-point Likert scale from never to always. Furthermore, we asked the number of out of town trips in the last year, both for long trips (>100 Km) and short trips (<100 Km). Based on distance between provinces of Iran, 100 Km is considered to be the threshold of long distance trip in the context of Iranian drivers.

Participants' acceptance of a PAYS scheme was measured according to a structure shown in Fig. 1. The respondents were asked whether they would like to install CVS in their vehicles. Participants who did not decide on this choice (mainly because they were not the owner of the vehicle) were not included in our survey.

If a participant agreed, we asked them how much they would pay to the annual rent of CVS, 2 Million Iranian Rial (MIRR; 50 Euros) or 1 MIRR[1] (25 Euros). We proposed these amounts based on the description of the manufacturers of this system and its actual implementation costs. If the participants were not inclined to pay 25 euro for the CVS then they were offered a hypothetical discount by the insurer of the third-party insurance scheme, if no speed violations would be observed during a one-year contract. In this scenario, the participants were then asked what the minimum additional discount should at least be in order to receive their third-party insurance to entice them to accept the PAYS: 20% discount on their third-party insurance (20% DTP), 50% DTP, 80% DTP, or free third-party insurance. The average yearly respondents' third-party insurance premium was about 8 MIRR (200 Euros) and the real value of the annual CVS rental is around 3 MIRR. If the driver refused to accept the scheme, s/he was categorized as a driver who has not accepted the proposed new PAYS scheme under any realistic conditions.

As explanatory variables for the acceptance of CVS via PAYS we included the driver's opinions about CVS, vehicle-related information, insurance coverage history, annual average accidents experienced as an at-fault driver, demographic and driving experiences, drivers' speeding behaviour, driver's driving risk perception, and traffic tickets issued for the driver.

Typically, people in Iran are reluctant to tell their income. Assuming a relationship between car ownership levels and income in Iran (Soltani, 2017), we used the number of vehicles owned as a proxy for income.

For assessing the WTP for the CVS program, respondents were also asked how much they would be willing to pay regardless of all plans (Observing Speed Limit program and PAYS) assuming the CVS system would be available on the market by now. Interviewers were reading the answer categories: 0; I will not buy, 1; less than 4 MIRR, 2; 4–8 MIRR, 3; 8–12 MIRR. It should be noted that the CVS user cost in Iran is close to 10 MIRR, so we did not ask respondents' willingness to pay more than 12 MIRR. To put these values in perspective: according to Statistical Centre of Iran the average annual income for a family living in Iran is about 270 MIRR.

3. Modelling procedure

We have used the Zero-inflated Ordered Probit model (ZIOP) for describing respondents' willingness to pay (WTP) for CVS and the Hazard-based model for predicting respondents' incentive level for accepting the use of CVS via the PAYS scheme. As explained above in order to investigate the factors influencing the acceptance of the CVS, we include variables; driver's opinions about CVS, vehicle-related information, insurance coverage history, at-fault accidents experienced by the driver, demographic and driving experiences, driver's speeding behaviour, driver's driving risk perception, and speeding-related traffic tickets issued for the driver.

In order to identify the optimal set of the explanatory variables for the ZIOP and the parametric hazard-based model, at first, the pairwise correlations between potential explanatory variables and the dependent variable were evaluated. In each of the models, variables with a significant correlation with the dependent variable had the first priority to explain the dependent variable. After an elimination process of significant inter-correlated variables with the chosen variables, the remaining explanatory variables that contain weaker correlation with the dependent variable had the next priority to be in the model.

3.1. ZIOP model

The ZIOP model was first introduced by Harris and Zhao (2007). In that study, the ZIOP model is used in a two-level process. The first level determines whether the individual belongs to the participation group by considering a binary variable s_j being 1 if the jth individual belongs to the participation group and 0 otherwise. They modelled participation group membership using a Probit model in which the probability of participation is given by:

$$\Pr(s_j = 1|\mathbf{Z}_j) = \phi(\mathbf{Z}_j\gamma) \quad (1)$$

where belonging to the participation group is defined by $\mathbf{Z}_j$, which is a vector of covariates. $\boldsymbol{\gamma}$ is a vector of coefficients to be calibrated using a Maximum Likelihood Estimation (MLE) procedure, and $\phi(\cdot)$ is the standard normal distribution function. In a case that s_j is equal to 1, participation levels $\tilde{y}_j$ are modeled using an Ordered Probit model; observed values of zero can occur in both groups. The related probabilities are calculated as follows:

$$\Pr(\tilde{y}_j = h|\mathbf{X}_j.s_j = 1) = \phi(k_h - \mathbf{X}_j\boldsymbol{\beta}) - \phi(k_{h-1} - \mathbf{X}_j\boldsymbol{\beta}) \quad h = 0.1.\cdots.H \quad (2)$$

$\mathbf{X}_j$ is a vector of covariates.[2] Considering that two sets of predictors for either groups were needed, $\mathbf{X}_j$ may differ from $\mathbf{Z}_j$. Both the coefficients vector, β, and the boundary parameters, k_h have to be estimated, $k_{-1} = -\infty$, $k_H = +\infty$. Considering Eqs. (1) and (2), the distribution of Y is calculated as follows (Harris & Zhao, 2007):

[1] We propose these amounts based on the description of the manufacturers of this system and its cost.
[2] In Section 2.3 we refer to these covariates as: driver's opinion about CVS, vehicle-related information, insurance coverage history, etc.

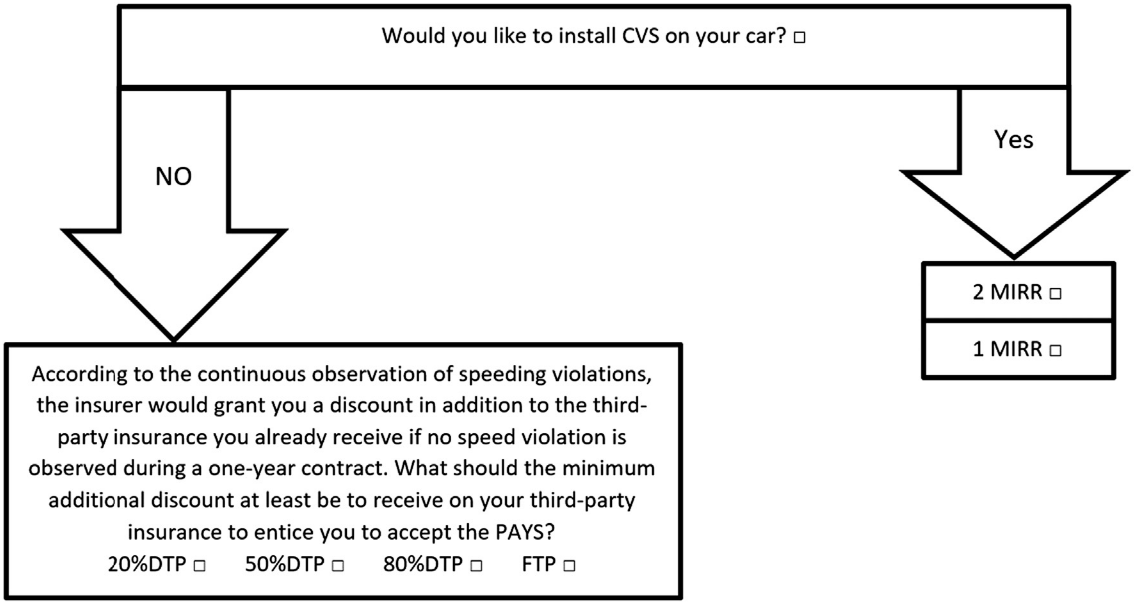

Fig. 1. Acceptance a new PAYS scheme structure.

$$\Pr(Y) = \begin{cases} \Pr(y_j = 0|\mathbf{Z}_j.\mathbf{X}_j) \\ \Pr(y_j = h|\mathbf{Z}_j.\mathbf{X}_j) & h = 1.2.\cdots.H-1 \\ \Pr(y_j = H|\mathbf{Z}_j.\mathbf{X}_j) \end{cases} = \begin{cases} \{1-\phi(\mathbf{Z}_j\gamma)\} + \phi(\mathbf{Z}_j\gamma)\phi(k_0 - \mathbf{X}_j\beta) \\ \phi(\mathbf{Z}_j\gamma)\{\phi(k_h - \mathbf{X}_j\beta) - \phi(k_{h-1} - \mathbf{X}_j\beta)\} & h = 1.2.\cdots.H-1 \\ \phi(\mathbf{Z}_j\gamma)\{1-\phi(k_{H-1} - \mathbf{X}_j\beta)\} \end{cases} \tag{3}$$

Harris and Zhao (2007) explained that estimating an ordered choice model on the whole sample, with the presence of many zeros in response variable, could lead to invalidating results because the zeros in response variable may show two separate data generating processes and WTP behaviours. The ordered Probit model, could not make a distinction between these two different zero types. So, zero observations are not well explained by traditional ordered Probit models (Harris & Zhao, 2007). The WTP is ordered variable which could have a zero value and thus it is suggested to use a ZIOP to investigate the explanatory variables influencing individuals' WTP.

According to Sanbonmatsu and Fazio (1990) attitudes can have a strong effect on peoples' decisions (Sanbonmatsu & Fazio, 1990). In our study, we first used the opinion-related questions to define if respondents belong to the participation group ($\mathbf{Z_j}$). Next we included the remaining variables as explanatory variables in the Ordered Probit part of ZIOP model or $\mathbf{X_j}$.

3.2. Parametric hazard based model

In the literature of statistics, survival analysis consists of a variety of statistical methods for examining positive-valued random variables (Miller, 2011). Typically, the value of the random variable shows a failure time. However, it could show another variable other than time, such as the number of dollars that a health insurance company pays in a particular case (Miller, 2011).

In this study, to investigate the effect of economic incentives (PAYS) on public acceptance of CVS, we used the parametric hazard based model which is defined as follows. Consider the incentive i as a continuous random variable and assume that f(i) and F(i) are the related Probability Density Function and the Cumulative Distribution Function, respectively.

Suppose that the probability of the incentive being greater than some certain incentive i is shown by S(i).

$$F(i) = \Pr(I \le i) = 1 - \Pr(I > i) = 1 - S(i) \tag{4}$$

Consider h(i) a hazard function which gives the probability of acceptance f(i) by knowing that the respondent has not accepted the scheme up to incentive i (Washington, Karlaftis, & Mannering, 2010).

$$h(i) = \frac{f(i)}{1-F(i)} = \frac{f(i)}{S(i)} = \lim_{\Delta i \to 0} \frac{\Pr(i + \Delta i \ge I \ge i | I \ge i)}{\Delta i} \tag{5}$$

A linear relationship between the log of incentive I and a vector of explanatory variables **X** is assumed as follows (Hojati, Ferreira, Washington, Charles, & Shobeirinejad, 2014):

$$\text{Ln}(\text{I}) = \beta\mathbf{X} + \varepsilon \quad (6)$$

where **β** denotes a vector of the estimated coefficient and ε denotes the error term with a given hazard function distribution. To explore the effect of explanatory variables in hazard based models, the following equation, which is written in a general form, needs to be estimated.

$$\text{h}(\text{i}.\text{X}) = \text{e}^{-(\beta\mathbf{X})}\text{h}_0((\text{i})\text{e}^{-(\beta\mathbf{X})}) \quad (7)$$

$h_0(\cdot)$ is the baseline hazard function. In estimating Eq. (7) with fully parametric models, the Weibull and the Exponential distributions were considered for the hazard function and tested to find the best fit to the data using the maximum likelihood method.

Typical hazard-based duration models include a variable which is defined as "the time until an event occurs" (Washington et al., 2010, Vlahogianni, 2013). In our study, this variable was defined as "an incentive to be paid to drivers in order to accept to use of CVS." The incentive was calculated based on CVS rental fee and the third-party insurance premium which the driver had to pay. For instance, the driver who is willing to use the system for an annual fee of 1 MIRR has received 2 MIRR incentives (3 MIRR as the real value of the annual CVS rental fee minus 1 MIRR). Another example: a driver who expressed to be willing to use CVS under the scheme, if s/he receives a 50% discount on his or her third-party insurance receives a 50% third-party premium plus 3 MIRR.

We estimated respondents' third-party insurance premiums based on variables that influence third-party insurance premium in Iran: the history of the at-fault accidents (people get discounts on their insurance premium if they do not claim third party compensation due to any accidents they caused for one or multiple years. For example, after one year they get a 25% discount), vehicle usage (passenger car, van, vehicles for goods transferring), the number of cylinders of the vehicle, and the manufacturing year.

When a Weibull distribution is considered as the hazard function, the Weibull parameter, p, is calibrated. The value of p indicates how an increase in incentives would affect the hazard rate (in this study: the acceptance rate). As indicated in Eq. (8), the value of p indicates the ratio of acceptance rate at incentive levels.

$$\text{ratio of acceptance rate level}_\text{m} \text{ to level}_\text{n} = \left(\frac{\text{incentive}(\text{level}_\text{m})}{\text{incentive}(\text{level}_\text{n})}\right)^{\text{p}-1} \quad (8)$$

4. Results

4.1. Summary of statistics

The participants had an average age of 40.27 years (SD = 12.63) with a minimum and maximum age of 18 and 77 years respectively. The sample mainly consisted of male drivers (90%) having had their driver's license over 3 years (93%) and on average had 17 years active driving experience. The majority of participants were married (72%), 1.5% were widowed or divorced. 65% of participants had a university education (118 bachelors, 37 master degree, and 14 Ph.D.) and 4 respondents were barely literate. Due to a lack of data we cannot compare these figures with those for the population.

Table 1 shows the results of the questions related to respondents' opinions about CVS. It reveals that respondents (somewhat) perceived CVS as an effective technology for reducing accidents and tracking stolen cars (an average score of 2.51 and 2.53 on a scale ranging from 1 to 3). In addition, they were to a lesser extent worried about the effect of CVS on driver distraction and their privacy issues.

The average vehicle age was 4.54 years (SD = 3.98). 63% of the cars had ABS, 21% had ESC, 51% Airbag(s), 8% navigation and 17% had a car kit for hands free phone calls. Summing up all these options the average number of equipment was 1.62 (SD = 1.53). Around half of respondents (52%) indicated that their vehicle was not covered by comprehensive insurance (covering also theft and costs of at fault accidents) at the time of interviewing them. In Iran by law all vehicles must at least have a third-party insurance. When asked whether respondents had a comprehensive insurance for their car in the past years, using a four-point Likert scale ranging from never, via occasionally and often to (almost) always, 42% of participants stated that they had this insurance (almost) always. 39% of them stated that they never had a comprehensive insurance for their vehicle in the past years.

Table 1
Results regarding opinion-based questions on CVS.

Opinion-based question	Low	Moderate	High
Effectiveness of CVS on accidents reduction	9.30%	29.84%	60.85%
Effectiveness of CVS on tracking stolen cars	9.30%	27.13%	63.18%
CVS effect on driver distraction	53.10%	29.84%	14.73%
CVS effect on privacy issues	50%	24.03%	24.42%

The majority of respondents (77%) were not at-fault in any accidents as long as they drove their current car. The respondents' at-fault accident categories are shown in Table 2. In these questions, accidents are accidents as a result of which the respondent paid money or insurance coupons to the other driver/third party.

Respondents on average drove 22099.3 Kilometres per year (SD = 18197.3). Participants usually drove less than two hours per the day (55%). Results of questions about travel behaviour and driving exposure of participants are shown in Table 3.

204 participants (79%) usually drove their own car, 21 participants (8%) usually their spouse's car, 15 participants (6%) their father's car, and the other participants drove the car of their mother, other family members', or an organization/company's car. 185 participants (72%) owned one vehicle and 47 (18%) participants owned two or more vehicles. A large proportion of respondents (76%) were using private parking at night.

When asked what they think about the probability of having a car accident (in general, fatal or causing severe injury), 178 respondents (69%) thought the probability of having a car accident would not be high or very high and 153 respondents (59%) thought the probability of being involved in a fatal or severe injury causing accident would be low or very low. When participants were asked how many times per year they usually get a speeding ticket (categories being never, one to two, three to six, six to twelve, and more than twelve times), the median of their overall estimate was the category of 3–6 times. Furthermore, participants were asked three other questions about their speeding behaviour. Results of these questions are shown in Table 4.

Table 2
Respondents' at-fault accident categories.

Questions	Categories			
	1	2	3	4
Frequency distribution of accidents	72.73%	16.36%	7.27%	3.64%
	Urban area		Country roads	Rural area
Location of accidents	74.35%		19.23%	1.28%
	Minor and damage		Injury	
Severity of accidents	93.42%		6.58%	
	One vehicle	with vulnerable road users	Two-vehicles	Multi-vehicles
Type of accidents	14.66%	4%	80%	1.33%

Table 3
Respondents' driving exposure.

Question	Categories						
Driving days per week	1	2	3	4	5	6	7
%	9.45	10.24	10.24	10.63	7.48	6.69	45.28
Driving takes place on country roads	0–20%		20–40%	40–60%	60–80%	80–100%	
%	52.59		11.55	15.54	9.96	10.36	
Common transportation mode	Private car		Metro	Bus	Walking	Taxi	Motorcycle
Frequency[a]	154		65	46	5	25	10
Usual purpose of driving	Business		Education	Shopping	Excursion	Picking up family members	
Frequency[a]	146		24	51	95	37	

[a] Respondent could select multiple choices.

Table 4
Respondents' speeding behaviour.

Question	Categories					
Traffic ticket for exceeding speed limit during three last years	No tickets	1 ticket	2 tickets	3 or 4 tickets	5–10 tickets	>10 tickets
%	51.41	16.47	13.65	10.04	4.02	4.42
How much faster is your driving speed usually, compared with that of others	Much faster	Faster	A little faster	A little slower	Slower	Much Slower
%	6.72	32.02	28.06	20.16	11.46	1.58
Speeding violations remain unnoticed by the police (on Likert scale)	Never	Rarely	Occasionally	Often	Almost always	
%	46.06	20.47	20.08	8.27	5.12	

Table 5
Results of ZIOP model for WTP.

Explanatory Variables	Coef.	Std. error	Z-stat	P-value	ME
$\mathbf{Pr}\left(\tilde{\mathbf{y}}_{\mathbf{j}} = \mathbf{h} \mid \mathbf{X_j}.\mathbf{s_j} = 1\right)$, $\mathbf{h} = 0.1 \cdots \mathbf{H}$					
Comprehensive insurance coverage in the year of survey (Yes = 1, No = 0)	0.736***	0.241	3.05	0.002	−0.162
Age > 60 (Yes = 1, No = 0)	−0.908**	0.423	−2.14	0.032	0.271
Gender (male = 1, female = 0)	−0.364	0.375	−0.97	0.332	0.071
Car ownership ≥ 2 (Yes = 1, No = 0)	0.568*	0.309	1.84	0.066	−0.105
Vehicle age	0.075**	0.0348	2.16	0.031	−0.017
$\mathbf{Pr}(\mathbf{s_j} = 1 \mid \mathbf{Z_j}) = \phi(\mathbf{Z_j}\gamma)$					
Opinion about the effectiveness of CVS on accidents reduction	0.962***	0.308	3.13	0.002	−0.136
Opinion about the effectiveness of CVS on tracking stolen cars	0.307	0.333	0.92	0.356	−0.044
Worry about CVS effect on driver distraction	−0.522	0.444	−1.18	0.239	0.074
Worry about CVS effect on privacy issues	−0.885***	0.327	−2.71	0.007	0.126
Perceived probability of having a car accident	−0.103	0.263	−0.39	0.697	0.014
Perceived probability of having a fatal or causing severe injury accident	−0.264	0.301	−0.88	0.379	0.037
Constant	1.295	1.629	0.79	0.427	–
Number of observation	163				
Initial Log-likelihood	−208.213				
Log-likelihood at convergence	−151.276				
Cut point[a] 1	−0.554	0.418			
Cut point 2	1.377	0.407			
Cut point 3	1.998	0.428			
Vuong test of ZIOP vs. Ordered Probit	3.42			0.0003	

Where *** significant at 1% level, ** significant at 5% level and * significant at 10% level.
[a] Cut points divides the real line into a series of regions corresponding to the different ordinal classes.

4.2. Willingness to pay for CVS

Assessing the WTP for the CVS program showed that, 15% of the respondents were willing to pay more than 4 MIRR for CVS and 37% of respondents were not willing to buy CVS. Knowing that privacy concern is one of the problems in CVS implementation (Boustead & Stanley, 2015), we asked whether refusal to pay for the technology was due to a privacy related 'protesting reaction'. In fact, the idea behind protesting reaction is that the unwillingness to pay for the use of a CVS is not due to the cost of using the system but rather due to the system disadvantages in the minds of the drivers that they are somehow objected to (such as privacy issues and monitoring of driving violations). It is assumed that people with a protesting reaction will not be willing to use the system even free of charge.

Because 81% of respondents were willing to use CVS if incentives would be provided, the protesting reaction could at max apply to a minority of all respondents. Based on the ZIOP model, we concluded that 'refusal response' is one of two categories of responses, 'financial motives' are the other category.

Table 5 shows the estimation of coefficient, standard deviations, P-values, and Marginal Effect (ME) of the variables used in ZIOP model for WTP. The Binary Probit ZIOP model indicated that respondents who had a more positive opinion toward the effectiveness of CVS on accidents reduction and who had less worry about the effect of CVS on privacy issue were prone to be in the participant group. The driving risk perception, which was measured by perceived probability of having a car accident and perceived probability of having a fatal or causing severe injury accident, had no significant effect on the WTP for CVS.

The Ordered Probit model of ZIOP showed that respondents who used comprehensive insurance coverage for their car, who were younger than 60 years, who owned more than one car, and used older vehicles, were more likely to pay more for CVS. The likelihood of zero WTP changes per one unit increments in independent variables indicated by the marginal effects in the right column of Table 5. The marginal effect calculations assume the mean value for all other variables. According to the Vuong's test,[3] the ZIOP model outperformed the Ordered Probit model.

4.3. Acceptance of PAYS scheme

Measuring the acceptance of PAYS scheme showed that 15% of participants accepted using CVS under the observing speed limit program only if the equipment was free. Approximately half of all respondents were willing to pay an annual rental fee for it (1 MIRR; 18%, 2 MIRR; 31%). Results showed that 16% of participants accepted the PAYS incentives (20% DTP: 6%, 50% DTP: 3%, 80% DTP: 0.4%, FTP: 6%) and 19% of the participants, despite offering the incentives, refused to use CVS. A parametric hazard-based model was used to describe the people's acceptance of CVS under the PAYS scheme and the speed limit observation program. The model results are presented in Table 6.

[3] The Vuong test compares two models based on their average value of the log-likelihood ratio (Vuong, 1989)

Table 6
Results of parametric hazard-based model for PAYS.

	Explanatory variables	Weibull			Exponential		
		Coef.	Hazard ratio	ME	Coef.	Hazard ratio	ME
Opinion about CVS	Opinion about the effectiveness of CVS on accidents reduction	0.479^{***} (3.63)	1.615	−1556	0.431^{***} (3.32)	1.538	−1522
	Opinion about the effectiveness of CVS on tracking stolen cars	0.186^{*} (1.67)	1.205	−605	0.165 (1.49)	1.179	−583
	Worry about CVS effect on driver distraction	−0.029 (−0.27)	0.971	96	−0.047 (−0.43)	0.954	165
	Worry about CVS effect on privacy issues	-0.709^{***} (−6.50)	0.492	2301	-0.625^{***} (−6.14)	0.535	2208
Driving experience	Number of equipment options used in the car	-0.102^{*} (−1.88)	0.903	330	−0.087 (−1.62)	0.917	306
	Out of town trips < 100 km	0.026 (1.62)	1.026	−85	0.023 (1.41)	1.023	−80
	Out of town trips > 100 km	0.042^{**} (1.98)	1.043	−137	0.037^{*} (1.77)	1.038	−132
	Annual average of at-fault accident since driving by the car	0.300^{**} (2.12)	1.349	−972	0.256^{*} (1.84)	1.291	−903
Speeding behaviour	Traffic ticket for exceeding speed limit during last three years > 2 (Yes = 1, No = 0)	-0.598^{**} (−2.51)	0.550	2292	-0.536^{**} (−2.28)	0.585	2255
	Speeding violations remain unnoticed by the police (on Likert scale)	-0.205^{***} (−2.68)	0.815	665	-0.188^{**} (−2.5)	0.829	664
Demographic	Age < 30 (Yes = 1, No = 0)	0.677^{***} 3.68	1.968	−1937	0.601^{***} (3.34)	1.824	−1867
	Age > 60 (Yes = 1, No = 0)	-0.676^{**} (−2.05)	0.509	2855	-0.599^{**} (−1.83)	0.550	2778
Constant		−10.060			−8.651		
P		1.158					
Number of observations		211			211		
Initial log-likelihood		−335.140			−336.389		
Log-likelihood at convergence		−285.219			−288.021		
Log-likelihood ratio statistics		99.84			96.73		
AIC		598.439			602.043		

Where *** significant at 1% level, ** significant at 5% level and * significant at 10% level.
Parameter estimation followed by t-statistics in parentheses.

Likelihood ratio statistics as described in Washington et al. (2010) and Akaike's Information Criteria (AIC) (Akaike, 1981) were used to identify which one of the Weibull and the Exponential model outperforms the other in terms of goodness-of-fit. Higher levels of significance for the likelihood ratio statistic and lower AIC indicate better goodness-of-fit. Based on both Likelihood ratio statistics and AIC the Weibull model yielded a superior fit. The Weibull parameter, p, is between 1 and 2 which suggests that the acceptance rate is increasing if incentives increase, but at a decreasing rate. In other words, the higher the incentives, the higher the acceptance rate, but additional incentives gradually have less effect on the acceptance rate. According to Eq. (8), the ratio of the acceptance rate at incentive 10 MIRR to that at incentive 5 MIRR with value $p = 1.158$ is 1.11 (= $(10/5)^{1.158-1}$). This means by increasing the incentives level from 5 MIRR to 10 MIRR, the acceptance increases by 11%. Another example: the ratio of the acceptance rate at incentive 10 MIRR to that at incentive 2 MIRR is 1.27 which indicates 27% increase in acceptance by offering 10 MIRR instead of 2 MIRR.

Table 6 shows that according to the parametric hazard based model ten variables significantly influence the acceptance of using CVS through PAYS: opinion about the effectiveness of CVS on accidents reduction, opinion about the effectiveness of CVS on tracking stolen cars, worry about CVS effect on privacy issues, the number of equipment used in the car, the level of making out of town long trips during the last year, the average annual number of at-fault accidents since owning the current car, the number of tickets for exceeding speed limits during last three years, the level to which speeding violations remain unnoticed by the police, being younger than 30 years old, and being older than 60 years old. Table 6 shows the estimated coefficients, standard deviations, hazard ratios, and Marginal Effects.

The hazard ratios are defined as an exponent of the estimated coefficients in the hazard-based models which indicate the chance an event occurs as a function of the conditions described by an explanatory variable. To give an example: the hazard ratio for worry about CVS effect on privacy issues equals 0.49, which means that at each incentive level, the acceptance rate decreases 51% (1–0.49) for respondents who have one level more concern about the privacy issues. The coefficient estimate indicates that respondents who had positive opinion about the effectiveness of CVS on accidents reduction and tracking stolen cars and who had less concerns about CVS effect on their privacy issues had higher acceptance rates.

Table 6 shows that respondents' acceptance rate reduces by increasing values for the number of equipment options in the car (ABS, ESC, Airbag, Navigator, and Car kit). Making long trips (>100 km) had a positive relationship with the acceptance of the PAYS scheme (p-value < 0.05). The average number of respondents' at-fault accidents was positively associated with the acceptance of PAYS scheme.

Respondents with more speeding violations, and those reported that their speeding violations frequently remain unnoticed by the police had a lower acceptance rate compared to the other respondents. The Marginal effect estimate shows that if respondents received more than two speeding tickets the incentive needed for PAYS acceptance increases by 2.292 MIRR (ceteris paribus). Respondents younger than 30 years old were significantly more than average included to accept PAYS, those older than 60 years old less than average. The hazard ratio indicates that the acceptance rate is 48% lower than average for respondents older than 60 years old.

5. Discussion

When the participants were asked how often, while driving their speeding violation remains unnoticed by the police, a large proportion of participants (46%) indicated that their speeding violation never remains unnoticed by the police, which might be explained by the high density of speed cameras on roads in Iran. However, speed violations are common in Iran (Moradi et al., 2013) and it can be concluded that the traditional methods of speed management have not been effective in Iran, a middle-income country. This study aims to propose an effective manner to reduce speeding behaviour in middle-income countries.

We proposed using CVS under a speed enforcement scheme, and PAYS as an economic incentive that motivates drivers to use such systems and reduce their speeding behaviours. We used a hazard-based model for predicting the incentive level needed for accepting CVS via a PAYS scheme. The results indicate that accepting CVS is positively influenced when people think it improves road safety. We expect that advertisements and social media attention could support the implementation of CVS, especially if the safety advantages are emphasized. In addition, policymakers could stimulate CVS implementation by reducing privacy concerns.

The results reveal that drivers of more equipped vehicles are less inclined to adopt CVS. A possible explanation might be that (some of) the car options already improve safety, resulting in lower added value of CVS, and consequently lower cost-effectiveness of CVS. People who experienced more accidents showed a higher than average willingness to adopt CVS under a PAYS scheme, a likely explanation being that they clearly see the safety benefits of CVS.

The results show that drivers who frequently make long trips are more inclined to adopt CVS, a possible explanation being that they realize their level of exposure to risks is relatively high. Older people are more than average late adopters of new technologies (Bansal et al., 2016) and in line with this we found that the drivers older than 60 were less inclined to adopt CVS.

We found that people who frequently violate speeds were less than average inclined to accept a PAYS scheme. Furthermore, the results showed that drivers who reported that their speeding violations frequently remained unnoticed by the police were less inclined to accept the proposed PAYS scheme. This finding could be explained by the classical deterrence theory. Based on this, driver speeding behaviour could be related to drivers' abidance by the traffic laws because they are motivated to avoid punishment, especially in a high chance of detection (Wegman & Goldenbeld, 2006). Therefore, drivers who had more speeding tendencies behaviour were less inclined to adopt PAYS which restrict them to violate speed limits.

Reducing speeding via policies can be linked to the perspective of the safe system approach. Based on this approach, the interactions between the main components of the road system (road users, the road environment, and vehicles and travel speeds) are understood. Human error is the most important factor causing road accidents. The safe system approach attempts to design the system in such a way that the impact of human errors on road accidents is as low as possible (Hagenzieker et al. 2014). In a safe system approach, in addition to the main factors affecting road accidents, the role of secondary and other factors must be considered (Hagenzieker et al. 2014). Driving too fast was frequently judged as a secondary contributing factor for road accidents. Under a safe system approach, speed-related interventions may therefore improve safety (Allen, 2017).

In a safe system approach, the occurrence of an accident is the result of a series of alignment of conditions, comparable to light passing holes in a series of Swiss cheese layers (Reason, 1990, Scott-Parker et al., 2015). These layers start with the driver's performance and end with the system design. The recommendation of the safe system approach is to improve road safety via safe system designs. The proposed model of PAYS can be interpreted as an intervention in the system design layer. Policies leading to the adoption of PAYS can reduce speeding levels, and next reduce accidents levels.

As often applies to stated preference studies, our study could be biased by respondents answering in a socially desirable way in which respondents' anonymously participate, could reduce socially desirable responding.

5.1. Future studies

Future research could study the real world effect of the proposed PAYS insurance scheme on reducing drivers' speed limit violations, and next accident levels.

Implementing CVS via PAYS is relatively similar to ISA related studies except in two cases, one that the CVS is able to communicate between cars which can't be done in ISA and the other that CVS could have larger and longer term effect on driver's speed by getting tickets from police, compared to ISA. ISA is a smart system that improves driver compliance with the location specific legal speed limits (Sayed, Delaigue, Blum, Mortazavi, & Eskandarian, 2007, Van der Pas et al., 2014b), and can be considered as a solution to the problem of inappropriate speed (Van der Pas et al., 2014b). Many experimental and field studies show that ISA reduces driving speeds and improves safety (Lahrmann et al., 2012, Van der Pas et al., 2014b, Van der Pas et al., 2014a). In line with these studies, PAYS field tests could be an interesting area of future research in itself, and such studies can also be used to validate our stated preference study.

A next avenue for future research is inspired by the technology acceptance literature. To assess technology acceptance, it is essential to understand factors that affect it. In this context, some researchers have examined the psychological determinants of technology acceptance by proposing and testing models for technology acceptance based on psychological insights. Such theoretical acceptance models describe user attitudes and acceptance based on the behavioral cognitive mechanisms (Zhang et al., 2019). Technology Acceptance Model (TAM) is one of the most widely cited of theoretical acceptance models in the area of new transport technology (Madigan, Louw, Wilbrink, Schieben, & Merat, 2017), which is derived from the Theory of Reasoned Action (TRA, Ajzen, 1985).

Based on TAM's theory, perceived usefulness and perceived ease of use are the main factors that affect people's intention to accept technology. The intent of individuals to adopt technology is prior to the adoption of technology in practice (Davis, 1989).

The UTAUT (Unified Theory of Acceptance and Use of Technology) is a recent extension of TAM theory (Venkatesh, Morris, Davis, & Davis, 2003) which states that behavioral intention towards technology use is affected by the degree of perceived technology performance of an individual, namely Performance Expectancy, the degree of ease of use of technology or Effort Expectancy, and the degree to which an individual perceives that important others believe s/he should use the new system, in other words, Social Influence (Adnan et al., 2018).

While the mentioned research area has focused on the psychological aspect of technology acceptance, others have assessed how individuals' characteristics were related to technology acceptance (Bansal et al., 2016). These studies consider the demand side factors of technology and are very useful in forecasting the adoption of technology. Our study aims to contribute to the second category of technology acceptance studies. Assessing psychological technology acceptance for CVS could be addressed in future studies.

The emphasis of this study was on how individuals were faced with continuous monitoring of violations or detecting violations from the point of view of their acceptance which is related to the first factor of deterrence theory. The severity of punishment is a second factor in conventional deterrence theory. Future research could assess the effect of the level of punishment on acceptance.

5.2. Conclusions

Driving behaviour is a contributory factor in over 90 percent of road vehicle accidents and speeding is considered to be risky, affecting both the probability of being involved in traffic accidents as well as increasing the severity of injuries caused by accidents. Smart technologies, such as Connected Vehicle Systems (CVS) are potentially interesting options to improve driving behaviour. However, assuming voluntary participation, real world use of CSV depends on consumers' acceptance. This acceptance could be influenced by the continuous monitoring of drivers' speed violations. Using economic incentives such as Pay-As-You-Speed (PAYS) can increase acceptance rates. Research suggests that in high-income countries, PAYS is an effective way to reduce speed violations. Our study investigates the effects of PAYS on acceptance of CVS in a low to middle income country, Iran. We investigated the factors which are associated with the acceptance of CVS without any incentives scheme and the role of economic incentives, such as PAYS on public acceptance of CVS.

Results reveal that of the opinion-related variables the expected reduction in accidents and privacy issues were most important for the acceptance of CVS: respondents were critical about the safety issues of CVS and about privacy issues.

The findings of the study show that the majority of drivers are willing to adopt CVS. Some drivers (~50%) are willing to pay an annual rental fee but some (15%) would only adopt it if it was installed free of charge. Both the parametric hazard-based model and ZIOP model showed that respondents' concerns about the effect of CVS on driver's distraction did not influence their decision to adopt the PAYS scheme and their WTP. Assuming a relationship between the number of cars a person owns and the amount of income (Soltani, 2017), we found that, income did not significantly affect CVS acceptance via PAYS, but it did influence the WTP towards CVS.

On the other hand, comparison of the ZIOP model for the WTP for CVS and the parametric hazard-based model for CVS acceptance via PAYS, reveals that drivers' speeding behaviour does not have a significant effect on drivers WTP for CVS. However, by proposing CVS via a PAYS scheme which includes the speeding observation program, results reveal that drivers who drive faster accept CVS via PAYS less than average. It can be concluded that when CVS would be introduced via a PAYS scheme as opposed to a direct launch on market, the effect of the respondents' economic status on their decision will become lower, and their speeding behaviour would become their dominant reason to accept CVS.

Since, we found that car owners in Iran are skeptical on the effectiveness of CVS as a measure to increase road safety, the organizing pilot projects with voluntary participations might be helpful to provide live examples on the effectiveness of such schemes for the rest of the car owners. For instance, in a small town one can implement the CVS scheme as a pilot and measure the impact on reducing accidents levels before and after the scheme, and compare the changes with overall trends in accident levels in comparable towns.

We also found that the privacy issues were one of the major concerns of the drivers regarding the CVS. Therefore, while launching such schemes it is essential to remind the drivers that designated privacy protection measures are implemented, and heavy penalties are set for violations by insurance companies. These privacy measures should be clearly communicated and included in insurance contracts.

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