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Innovative insurance schemes: pay as / how you drive

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Abstract

The objective of this paper is to provide a critical review of the most popular and often implemented methodologies related to Usage-based motor insurance (UBI). UBI schemes, like Pay-as-you-drive (PAUD) and Pay-how-you-drive (PHUD), are a new innovative concept that has recently started to be commercialized around the world. The main idea is that instead of a fixed price, drivers have to pay a premium based on their driving behaviour and degree of exposure. Despite the fact that it has been implemented only for a few years, it is proven to be a very promising practice with a significant potential impact on traffic safety. This is achieved by the financial incentive given to drivers in order to improve their driving behaviour such as reducing the number of harsh braking and acceleration events taking place or reducing their degree of exposure such as their annual mileage, the time of the day travelling etc. and therefore reduces traffic risk. It can also be beneficial towards other social objectives such as traffic congestion and pollution emissions reduction.

To this end, the existing literature on UBI schemes is critically reviewed and research gaps are identified. Findings show that there is a multiplicity and diversity of several research studies accumulated in modern literature examining the correlation between PAUD (based on driver's exposure) and PHUD (based on driving behaviour) schemes and traffic risk in order to determine accident risk. Moreover, it seems that UBI implementation would eliminate the cross-subsidies phenomenon, which implies less insurance costs for goods and less exposed drivers. Moreover, it would also provide a strong motivation for drivers to improve their driving behaviour and reduce their degree of exposure by receiving feedback and monitoring their driving performance and exposure which would result in traffic risk reduction both totally and individually.

Keywords: Pay-as-you-drive; Pay-how-you-drive; Driving behaviour; Driver's exposure; Traffic risk

1. Introduction

Current pricing policy of motor insurance companies around the world which is to charge a lump sum for each user is unfair and inefficient (Butler et al. 1988). Drivers with similar characteristics such as age, gender, location, accident record etc. pay approximately the same premiums no matter if they drive five or fifty thousand kilometres a year. Bordoff and Noel (2008) likened it to a restaurant with an unlimited food policy for a fixed charge per person which encourages people eating more. Respectively, current insurance pricing policy encourages driving more kilometres annually, does not punish aggressive driving behaviour and on the other hand, it does not encourage

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prudent driving behaviour. But above all, this implies increased number of accidents, congestion conditions, carbon emissions, local pollution and oil dependence. Current pricing system is unfair because it literally forces drivers with low mileage per year and safer driving behaviour to subsidize the insurance costs for drivers who drive more annually and more dangerously. It has to be noted that research so far indicates that people with lower income drive fewer kilometres.

In general, each driver could be assigned a probability of accident involvement based on his driving behaviour. Charging all drivers a lump sum, conceptually leads to assume that the accident probability is equal across the entire population of drivers. Evidently, this does not from a user optimum and socially equitable approach, as drivers with lower accident risk are forced to "subsidize" those with higher. In other words, safer drivers are forced to "buy" higher probability of accident risk than actually exists, unlike dangerous drivers who "buy" less.

An innovative insurance policy could have a significant effect on safety depending on its design (Zantema et al. 2008). This can be accomplished by differentiating premiums to reflect safety, more specifically charging higher fees for unsafe road categories and night-time driving, most effectively and apply it to all drivers. The insurance policy based on vehicle use (Usage Based Insurance or otherwise UBI) includes Pay-As-You-Drive Systems (PAUD) and Pay-How-You-Drive (PHUD). PAUD system is charging premiums based on total exposure characteristics such as mileage and road network used while PHUD is based on individual driving behaviour measuring parameters such as speed, harsh acceleration, hard braking etc. The main data source for the aforementioned parameters are the automotive diagnostic systems, OBD (On-Board Diagnostics), installed in the vehicle and / or the Smartphone held by drivers, sending all necessary information in a central database via mobile network.

The main advantages of UBI schemes compared to the conventional solution offered so far are (Sugarman 1994, Litman 2004):

• Each user will pay as and how he drives, not based on other unfair characteristics such as age, type of car, etc., which do not necessarily reflect the chance of being involved in an accident.

• The need for cross-subsidies (cross-subsidies phenomenon) will be lower and result in a lower and more affordable cost of insurance premiums which would lead to a smaller number of uninsured vehicles.

• This method itself is an incentive for users to improve their driving performance and consequently reduce the number of accident in which someone causes or gets involved in. It also enables someone to monitor his behaviour while driving thus eliminating behaviours that increase the likelihood of causing an accident.

• The implementation of this approach will help reduce the total number of accidents leading ultimately to significantly upgraded road safety.

• With regards to the social benefits, this method will assist driving behaviour improvement and thus reduce pollutants emission, saturation, energy consumption and will generally upgrade transportation system.

An additional benefit offered by UBI schemes is user's feedback on driving behaviour by receiving statistical reports, after or while driving, such as the percentage of speeding, number of harsh acceleration/ braking events, time driving during risky hours, fuel consumption etc. (Toledo et al. 2008). In this way, UBI may also serve as a mechanism to raise drivers' awareness and change (improve) their driving behaviour. First, because the economic incentive will be strong for him. The premiums will be very high especially for dangerous drivers so the motivation to drive safer will be very powerful. The same would apply to safe drivers as well since premiums cost will be reduced because of their good performance. Second, the ability to monitor and compare their own performance from now onwards will assist towards their performance improvement. It is generally shown that (Birrell et al. 2014) an in-vehicle smart driving system, e.g. a smartphone application pointing out frequent mistakes a driver makes while driving, which is developed and designed based on drivers' requirements information can lead to significant improvements in driving behaviours.

A study in the Netherlands showed that if PAYD were to be implemented, total crash reduction could be reduced more than 5% leading to 60 less fatalities as well as 1000 less injured each year in the Netherlands (Zantema et al. 2008). Research in other countries outside Europe on differentiating premiums indicates the same percentage of 5% mileage reduction on average although driving during low and medium risk hours was only significantly reduced (Reese and Pash, 2009).

The insurance market was at the starting point of 4.5 million subscribers in 2013, mainly from the United Kingdom, Italy and the US, between 1 billion insured vehicles worldwide. This number is expected to exceed 160 million by 2020 showing that UBI is a very promising sort of insurance. As a result, it is an innovative insurance policy expected to be rapidly adopted worldwide in the future.

Therefore, the future direction is to gradually replace the current homogenized insurance pricing policy with a fairly personalized pricing. As stated above, the development of technology and overcoming impediments that could not be overtaken before make this feasible.

2. Driver exposure and behaviour data collection

Until recently, the high cost of real-time driving data recording systems, data programs, cloud computing services, the inability to accumulate and exploit massive data bases (Big Data) for transport and traffic management purposes (De Romph 2013, Lee2014), as well as the low penetration rate of Smartphones and social networks, made it extremely hard to collect and manage real-time data and, therefore, to study the relation between driving behaviour and exposure and the probability of accident involvement. Research has indicated that barriers like the ones mentioned above can be overcome when consumers are given an incentive such as a monetary prize (Reese and Pash, 2009).

Thus, the main challenge road safety entities and policy-makers are facing at the moment is the wide provision of information on the social benefits that could arise from an implementation of such a policy. As a matter of fact, high level of interest has been observed among users who were given a medium value financial incentive of $88 per 6-months period to reduce their mileage. Consumers stated that lower Insurance premiums is among the strongest incentive for them and that a mileage-based Insurance could probably lead them to ultimately consider car sharing or even using public transportation (Reese and Pash, 2009).

Nowadays, it is feasible to collect high quality real-time data in an efficient way in order to model individual and total traffic risk. In terms of the data collection process, data in most studies are recorded either by the vehicle's OBD or user's smartphone and transmitted to a central database for central processing and analysis (Boquete et al. 2010, Iqbal and Lim, 2006). This allows the development of special indicators for estimating driver's risk exposure (PAYD) and behaviour (PHYD).

In some studies, there exists an on board platform inside the vehicle which acquires and processes data obtained from the GPS, the EOBD system and a mobile-telephone use detection circuit (Boquete et al. 2010). Data are transmitted to a control centre (CC) via a mobile telephone connection, where the risk reflected by each vehicle to the insurance company is estimated. The system uses mobile telephony connection to transmit data between the On-board system (OS) and the CC. Vehicle function data (such as number of seatbelts fastened) are captured from the EOBD system, vehicle position-speed data from the GPS and driver mobile-telephone use data from a detector circuit (RF energy scavenging) are ultimately acquired by the OS. Before transmitting it to the CC, data captured by the OS are processed and stored by a high-performance microcontroller that exists inside the core of the OS.

Other studies also incorporate light or weather sensors that interact via a communications channel (infrared or Bluetooth) with the on-board computing unit reporting a numerical value (Iqbal and Lim, 2006). Position, speed and time are continuously recorded by the GPS receiver and transmitted to the central computing unit.

Finally, Barmpounakis et al. (2016) conclude that, since a few technological obstacles that exist nowadays are overtaken, these systems can also be exploited for real time traffic monitoring. Other methods include extraction of vehicular trajectories from video recordings using a trajectory extraction system to collect vehicle traffic data (Barmpounakis et al., 2015). Although this is also not available for real time traffic monitoring it is very likely to be used for this purpose in the near future.

As shown in Table 1, the method of data transmission to the Control Centre varies and is usually based on the telematics manufacturer. Other transmission methods are via a USB cable connecting the OBD and the CC, via a GPRS/CDMA network, wirelessly from a Bluetooth device built-in the OBD or through a microSD card. The installation cost was also found to be moderate whereas the monthly/yearly fees also varied from a zero cost to $19 a month after the first year of installation.

Table 1. Manufacturers providing Telematic recording devices of driving characteristics.

Manufacturer	**Data recorded: Distance, speed, time**	**Method of transmission**	**Installation cost**	**Monthly/yearly fee**
CarChipFleetPro	Distance, time, acceleration, speed, GPS location, fuel, Engine speed	USB cable/port (customer loaded)	$149 (plus a $395 charge for software, one per fleet) Can also be used wirelessly with a $200 base unit	None
Sky-meter	time, distance, place, speed, acceleration of all driving, and the location and time of all parking	GPRS/CDMA (other protocols available at extra charge)	$50 - $250 activation fee	$5 per month plus 5%–8% of monthly premium (depending on volume)
OnStar	Distance, speed, time, (incl. other features)	Automatic through GPS S	First year free for new GM cars (only available for GM)	$18.95 per month after one year
Freematics	Speed, distance, time, location, acceleration, engine RPM	Built-in Bluetooth Low Energy and SPP module for wireless data communication or via	99$ (Plus $30 for GPS module, plus $10 for MEMS MPU-9150 (9-axis) module, plus $10	None

		microSD card (32GB)	for DUO BLE-BT 2.1 and plus 5$ for 32GB microSD)	
Progressive (MyRate Device)	Distance, speed, time, location, acceleration, trip frequency	Wirelessly	None but $75 fee if not timely returned at end of policy	Varies

3. Driver exposure and behaviour risk indicators

The indicators that are recorded by each device refer to exposure and behavioural characteristics, such as distance, time, location and speed, acceleration/deceleration, seatbelt use (www.skymetercorp.com, www.carchip.com etc.). There are a few manufacturers that measure additional information, such as the location and parking duration (www.skymetercorp.com). This information is then processed, based on rating information provided by the insurer, to generate the risk factors of interest for each driver.

Some insurers so far are charging for driving per minute or mile (or km) travelled, or modify charges based on driver's driving record, vehicle type owned, the class of road, time of the day driving, the riskiness of the historical behaviour or the riskiness of the current behaviour. Some others also charge for parking (www.skymetercorp.com) per hour parked at high risk locations (e.g., on street, in mall) but this is beyond the scope of this research.

Generally, the main driving indicators mostly used so far in literature for calculating the driving risk of an individual are shown below in Table 2:

Table 2. Risk indicators classification.

PAYD	PHYD
Total distance driven by the user (the higher the mileage the higher the risk)	Speeding expressed either as a percentage of kilometres/time driving over the speed limit or a percentage of speeding
Road network type (increased accident frequency in the cities, increased accident severity outside)	Harsh braking/ acceleration
Risky hours driving (increased accident frequency during a particular hours range).	Driver's accident history (severity of accidents, the circumstances of the accident)
Trip frequency (a driver is more likely to cause an accident during an infrequent trip)	Seatbelt use
Vehicle type	Mobile phone use

The PHYD concept is not thoroughly examined and much less implemented. Nevertheless it should be highlighted that only a handful of studies have included behavioural characteristics in their models. So far, there is only one insurance company exploiting behavioural information to assess drivers and estimate their charges (https://www.progressive.com/auto/snapshot/).

Even on a research level, there exist many indicators both behavioural (harsh cornering, alcohol use, Ecological driving etc.) and exposure (vehicle maintenance condition, safety rating of the vehicle from the IIHS (Insurance Institute for Highway Safety)) that also affect traffic risk but are not incorporated in risk modelling until now. For instance, eco-driving is a factor considered to be significantly related to accident risk (Haworth and Symmons, 2001). If fuel consumption according to the manufacturer's specifications is compared to the real consumption, conclusions can be drawn about how a user is driving (aggressive driving, speeding etc.). Moreover, the simultaneous existence of two driving characteristics, such as speeding during risky hours or braking harshly in an urban network may affect accident risk excessively. All the above should be further investigated to conclude on their significance to crash risk modelling.

However, it should be mentioned that some of these indicators e.g. alcohol use cannot be easily taken into account yet in driving behaviour models as they cannot be captured efficiently. Nevertheless, it is very likely for scientists to be able to monitor these factors in an easy and reliable manner in the near future.

4. Exposure-based Insurance (PAYD)

Few studies focus on the correlation of vehicle-kilometres travelled to the hazards of traffic and therefore the determination of likelihood of a driver being involved in an accident. In the primary form of PAYD, mileage as an exposure characteristic was only incorporated in the models. This was derived from the fact that mileage and accident risk are close related. Indeed, there are many studies (Litman 2005, Bordoff and Noel 2008) that indicate a relationship between the reduction of VMT (vehicle miles travelled) and the reduction of crash risk. For example, Edlin (2003) finds that the elasticity of the number of accidents occurring with respect to VMT is approximately 1.7 which means that if mileage was reduced by 10%, accidents would be reduced by 17%. Other researchers have found the elasticity of accident risk to be around 1.2 (ICBC Research Services Data, 1998). More specifically the authors claim that the 1981-1982 recession led to a 10% VMT and 12% insurance claims reduction in British Columbia. In support of the above, Ferreira and Minikel (2010) found that there is a high statistical significance between mileage and risk and that they are positively correlated.

Many researchers on the other hand, focused on the type of relationship between mileage and accidents with a number of them indicating that there are serious grounds to believe that it is neither linear nor proportional for an individual vehicle (Janke 1991, Litman 2008). Consequently, the number of accidents divided by the number of mileage driven for a group of users should not be expected to remain constant. Ferreira and Minikel (2010) conclude that the relationship between risk and mileage is less-than-proportional when all vehicles are considered together with class or territory differentiation and less-than-linear when these factors are not taken into consideration.

It was also found that most groups of lower mileage drivers (such as young and older drivers) tend to have higher crash rates compared to higher mileage drivers (Janke 1991), Langford et al. 2013). As a general fact, per mile crashes tend to decrease as annual mileage increases which is attributed (Litman 2008) to several factors such as that low mileage drivers are usually driving more miles in congested urban areas where traffic risk is higher, lack of driving practice etc.

Based on the above it is clear why first studies concentrated on developing models that take into account mileage as the most (and sometimes the only) influential factor for traffic risk, the mostly used of which are described below. It should be mentioned that the risk prediction increases, when mileage is incorporated along with other rating factors in the model and not alone (Litman 1997, Ferreira and Minikel 2010). It is shown that mileage provides a great explanatory power, when combined with space and behavioural information of the miles driven (Ferreira and Minikel, 2010). It is, thus, a powerful supplement to traditional insurance rating factors (e.g. experience and territory). This would increase fairness among motorists even more as not all drivers would be expected to pay a flat-rate premium per mile but it would be differentiated based on other driving characteristics as well.

Moreover, it has been found that, when annual mileage is taken into consideration, the influence of variables sex and education for accident prediction is minimized (Lourens et al. 1999). On the other hand, a well-documented age influence (young drivers' age group) is proved and a strong positive correlation between traffic violation commitment and accident involvement (which is independent of the annual mileage driven) is seen in literature (Rajalin 1994, Massie et al. 1997, Lourens et al. 1999).

4.1 Pay-at-the-Pump (PATP)

Other studies in the past presented the Pay-at-the-Pump (PATP) method which was the early stage of the mileage-based insurance policy that appeared later. Considering that fuel consumption and mileage are somehow correlated these two methods share many similar characteristics and the same basis. Wenzel (1995) argued why insurance premiums should be estimated based on use. Claiming that VMT is a good predictor of accident costs, he proposed an exposure-based system which was actually a per-gallon surcharge for consumers, a method similar to the PATP method. Wenzel also suggested that premiums should be the sum of a fixed amount based on location, vehicle safety characteristics and driving record, most of which are exposure characteristics, plus a variable amount based on fuel consumption (per-gallon surcharge).

In other forms of PATP (Sugarman, 1994), the foundation of a governmental or county organization is introduced that will collect the funds at the pump in the form of fuel surcharges. Sugarman suggested that apart from the fuel surcharge, additional charges should be imposed based on drivers' driving record and experience as well as on vehicle ownership. The latter amount was proposed to be defrayed either as a once-off fee or as an annual instalment. It should be highlighted that this method would substitute lawsuit system or tort liability only for bodily injuries and not for material damages. The author concludes that this new system will provide fairer funding, greater safety and better compensation for most users. On top of the benefits presented above by Litman (2004), Sugarman (1994) claimed that the new vehicle injury plan (VIP) would assist in overcoming many problems that appear in today's insurance policy such as the fact that a large percentage of premiums goes to claims administration, duplicate other sources of compensation, for pain and suffering awards or is lost to fraud, the enormous number of seriously injured victims that are vastly undercompensated, , the unsatisfying claims process the long payment delays of many bodily injury claims and finally the fact that safer driving and safer vehicles are insufficiently encouraged.

Khazzoom (2000) calculated the marginal exposure risk of the average driver to be around 2c/mile and suggested that the fuel surcharge could be set to 50c/gallon. He also argued for PATP over VMT-based insurance stating that the latter does not remove uninsured motorists from the road or encourage them to switch to more fuel efficient vehicles burdening this way the environment as well as it does not have any implementation problems.

Generally, research indicates that PATP results to welfare benefits with both a direct and an indirect manner (Kavalec and Woods 1999, Khazzoom 1999, Khazzoom 2000). An average driver can be benefitted either individually by paying lower insurance premiums and have enhanced road safety or indirectly by societal benefits such as reduced external costs such as reduced energy consumption, congestion, greenhouse gases, emissions etc.

However, due to the drawbacks of the PATP method referred below, PATP was not extensively implemented. Kavalec and Woods (1999) claimed that introducing a surcharge for gasoline is an incentive for consumers to drive vehicles that are more energy efficient in order to reduce their exposure to tax and not reduce their annual mileage significantly. Khazzoom (2000) raised the issue that differences in vehicle fuel efficiency are probably leading to a discrepancy between drivers which is nevertheless fairer than today's lump sum policy. According to the author, PATP might also cause a slight shift to energy efficient vehicles, a fact that will increase the above mentioned discrepancy. Previously (Khazzoom, 1999), criticism against PATP was classified into two categories i.e. criticism of PATP design such as state bureaucracy, uncertainty of insurers' income and long-distance motorists penalization and the consequences of adopting this new method such as the burden on lower income insurers and the shift to fuel efficient vehicles.

4.2 Mileage-based Insurance

Because of the drawbacks of the PATP method, efforts were focused on distance-based methods that are directly "penalizing" driving. For example, Weaver (1970) examined the potential of paying premiums proportionally to vehicle use (pay-as-you-drive - PAYD) as a possible solution for the economic asymmetry that currently exists in the vehicle insurance market. Survey results indicated that the new insurance method would reduce transaction costs, lead to more cost-efficient consumer behaviour, reduce premiums and benefit insurance companies, allowing them to create policies that better represent actual risk corresponding to each consumer. Other social benefits of PAYD insurance were also examined as well as the obstacles to the development of such a policy is likely to result from the implementation of such a program such as reducing GHG emissions and CO2, dependence on oil, lowest number of accidents, the reduced need for maintenance of the infrastructure etc.

Bordoff and Noel (2008) developed and evaluated a mileage-based model (PAYD) resulting that each household can reduce up to $ 270 per vehicle insurance contributions to be paid. The authors pointed out that if users were charged per kilometre, they would have an extra incentive to drive less, which would result in accidents reduction. They also consider that the reduction of vehicle would be around 8%, a figure which is equivalent to $ 50-60 million due to reduced harmful effects on driving. The above reduction would also reduce carbon dioxide emissions by 2% and oil consumption by about 4%. Nichols and Kockelman (2014) showed that the average vehicle will be driven less by 2.7% (237 mileage reduction per year), with benefits for average consumers only $ 2.00 per vehicle with a premium that is partly fixed and partly based on mileage. Drivers with lower vehicle kilometres per year are expected to receive the greatest social benefits, thanks to the convex relationship between vehicle mileage and accident probability. This analysis supports the findings of the existing literature, namely that the PAYD policy can reduce vehicle kilometres travelled annually and leads to a fairer premiums system.

5. Behaviour-based Insurance (PHYD)

Current Pay As You Drive systems are said to have many weaknesses and shortcomings, because they are focused only on the number of driven kilometres and not on driving behaviour (Kantor and Stárek, 2014). Evaluating how a user is driving is most times more crucial to accident risk estimation than counting how much he is being driving. Modelling the driving pattern of each driver efficiently is a matter of significant importance for crash risk modelling, as it gives the opportunity not only to sufficiently understand differences between driving behaviours but take them into consideration as well.

Most researchers used a linear modelling approach to model PHYD insurance (Iqbal and Lim 2006, Boquete et al. 2010). For instance, Boquete et al. (2010) implemented a UBI model that takes into account driving behaviour attributes. The on-board system was installed in vehicles and data were transmitted using mobile data service to the control Centre. The basic concept was to build a premium cost model based on how much (mileage), where (Zones used), when (Day/night) and how (overspeeding, harsh accelerations, number of vehicle passengers, mobile phone use) a vehicle is driven. Premiums were calculated as a sum of a fixed charge imposed to each driver plus a linear combination of the above mentioned indicators and their coefficients. In other recent studies (Iqbal and Lim (2006)) driving behavioural attributes are also included in cost calculation and apart from exposure characteristics such as weather and light conditions risk, rush hour risk and road network risk terms, they also incorporate speeding risk terms which stands for the percentage of driving over the speed limit after detecting the road network type the driver is using. Premium cost in this study was computed as the product of a base rate for each driver by all risk factors calculated for each indicator (road network type, overspeeding etc.) (Iqbal and Lim 2006).

On the other hand, there have been studies where the alternative method proposed is a fuzzy-linguistic approximation apparatus which according to the authors is a suitable tool taking into consideration the insufficient exact knowledge and the large possible combinations of the parameters used as model's input (Kantor and Stárek, 2014). A comprehensive algorithmic procedure successfully integrated the process of the driving pattern assessment and a projection of that evaluation into the insurance premium was produced. The algorithm consisted of six algorithmic steps namely data collection, meteorological conditions evaluation, vehicle dynamic qualities determination, manoeuvre type determination, manoeuvre style evaluation and finally number of penalty points assignment and determination of driving style sanctions. As for the types of manoeuvres, driving straight, turning, overtaking, speeding, aggressive deceleration, non-fluent driving (frequent acceleration and deceleration) were taken into account but the manoeuvre style is being evaluated for driving straight, turning, overtaking and aggressive braking. Finally, the parameters used as input for the fuzzy model were visibility, deteriorated road conditions, sufficient vehicle performance, acceleration in x and y axes, speeding, motorways and roads (directions separated or not separated).

According to performed research on PHYD schemes so far, this new method presents many potentials and appears to have many benefits. However, although PHYD is undoubtedly the best way to rate a user's driving and estimate his crash risk, it still remains a sharp shift from today's lump sum policy; an alteration that probably needs some effort in order to be adopted by society. Moreover, PAYD methodologies implemented so far seems to be very persistent and unilateral as to the parameters considered. With regards to exposure-based modelling, mileage is not the only factor influencing traffic risk and therefore multivariate exposure-based insurance models should be developed taking into account parameters such as the road network used, time-of-the-day driving etc. (on the top of mileage driven).

6. Issues to Consider

The aim of studying UBI is the development of a premium calculation system based on the exposure and/or the behavioural characteristics during driving and ultimately to create reliable models able to associate driving risk with driving exposure (for PAYD models) and/or driving behaviour (for PHYD models) and charge road users based on that risk. PAYD premium calculation method is based only on driving exposure characteristics. Risk is only correlated with vehicle's exposure, assuming that the probability of an accident occurrence increases as some indicators referred below, such as driven kilometres, increase. Traditional insurance approach does not consider the exposure of a vehicle or the behaviour of a user and assigns to a specific vehicle and driver an "average premium" that corresponds to the "average driver" and consequently to an "average accident probability". On the other hand, PHYD is based on users driving behaviour evaluation and degree of exposure leading to a realistic estimation of the corresponding risk. The PHYD model incorporates a large number of parameters allowing the accurate estimation of the driving risk. The final outcome of the PHYD model can be an individual risk indicator that will depict the risk associated with the driving behaviour of a user. Since premium calculation in PHUD is based on the evaluation of driving behaviour of the user, it leads to a more realistic assessment of the risk than PAYD approach does.

It is evident that the PAYD model is a more simplistic approach using fewer parameters as risk indicators. However, it has also significant advantages since (a) it is easier to implement (b) the period for the development and the verification of the model is significantly smaller, as less data are required and, also, significant information may be found in literature and reports of relevant organizations (c) it is targeted to the vehicles that are not often used. On the other hand, PHYD is a more sophisticated approach aiming to (a) associate the driving risk with a large number of indicators quantifying - in a realistic manner- the driving behaviour (b) raise driving awareness and motivate the driver to evaluate and improve their own driving behaviour and (c) increase the profit of the Insurance Companies via this self-improvement of the drivers.

Ranking insurance pricing schemes based on how well marginal vehicle costs are represented by different fees (Litman 1999), models taking into account time and location information (PHYD) were the best performing, followed by mileage-based models (PAYD), PATP models (PAYD), fixed vehicle charges models (current insurance policy) and external costs (not charged to drivers) models respectively.

Finally, as shown above, although the contribution of past research on PAYD pricing is important, only a small percentage to date has dealt with PHUD systems. As previously mentioned, this method objectively calculates traffic risk since it takes into account several important factors such as sudden braking / acceleration, driving over the speed limits, etc. which makes it a more reliable tool for calculating the probability of accident involvement. This is where future research should mainly focus on as well as on developing and evaluating PAYD and PHYD models and compare their efficiency.

In terms of the indicators exploited so far in PAYD/ PHYD literature, it should be mentioned that there are a few such as alcohol use, vehicle maintenance condition, vehicle safety rating etc. that affect accident risk and are not yet included in UBI modelling. Furthermore, the effect of two different driving characteristics such as harsh acceleration on a highway should also be examined. Although some of these factors cannot be currently monitored in an easy and reliable manner, most of these can or will be able to be efficiently captured in the near future.

The above literature review reveals a trend in PAYD related literature which are mainly focusing on the effects, externalities and potentials that UBI offers. Although the potential that arises from the implementation of PAYD schemes both on insurance companies and drivers has been examined thoroughly (Husnjak et al. 2015), PAYD appears not to be exhaustively modelled till now.

7. Discussion

This paper constitutes a systematic effort to gather, group and present the most scientifically strong studies in literature relevant to PAYD and PHYD methodologies. Unlike the past, there is an obvious trend for motorized insurance to become even more personalized. This means that instead of calculating insurance premiums based only on demographic characteristics such as age, number of years holding a driving licence etc., personal driving characteristics either exposure and/or behavioural are slowly incorporated into insurance models.

As seen from the above literature review there has been an extensive effort of analysis and evaluation of PAYD methods. The small extent of implementation thus far has demonstrated that it has a great influence on all levels, economic, social, environmental, etc. This is a ground-breaking first attempt to change the established insurance billing system that is currently anachronistic and unfair to many users and also proved not to contribute in any way in accident reduction which is the goal of road safety.

In the future, a gradual global transition towards PAYD/PHYD insurance could be envisaged. Low-risk drivers (low-mileage, safer drivers etc.) will receive gain many incentives to opt out of traditional insurance in favour of alternative insurance policies such as mileage-based insurance (Parry 2004); this is becoming increasingly feasible as telematics systems are gradually incorporated in newer vehicles. Governments are also likely to encourage this trend in the future through policies and political decisions such as subsidies, tax waivers for insurance companies offering alternative policies like these.

Annual crash risk can be calculated as the product of per-mile crash risk times annual mileage (Litman, 2008). Although imposing drivers to reduce their annual mileage would probably lead to reduced traffic risk, two factors are not taken into consideration. Firstly, a driver that is penalized based only on mileage is not incentivized at all for improving his driving behaviour. Therefore, per-mile risk remains an unspecified factor which can fluctuate over time. This means that despite the fact that mileage is reducing, total crash risk can still be increased. Secondly, insurance system still remains unfair and the cross-subsidies phenomenon is not eliminated since per-mile crash risk is considered to be the same for all drivers and is not individually calculated. Consequently, behavioural aspects of driving should be incorporated in insurance models in order to contribute towards current trends of personalized vehicle insurance.

In support of the above, even if it is assumed that per-mile crash risk remains constant, while annual mileage is reducing throughout the year, total individual crash risk reduction cannot be calculated since it depends on other behavioural characteristics that are not currently recorded and therefore not taken into consideration in today’s usage-based insurance. Driving information such as number of harsh brakings and accelerations, percentage of overspeeding, road network category etc. should be included in driver’s evaluation so as a per-mile risk factor could be assigned to each individual driver. In other words, risk factor is risk’s increase rate which indicates how total individual risk is increased as mileage raises. Calculating this factor is the only way to accurately predict individual crash risk and consequently, fairly charge each driver based on the risk he reflects. Since technological solutions can be given nowadays and conditions to efficiently record and manage real-time big data are finally met, science should move towards that direction.

From a road safety perspective, eliminating the cross-subsidies phenomenon would award good drivers for driving safely. It would also provide a strong motivation for risky drivers to improve their driving behaviour and reduce their degree of exposure by being charged higher insurance premiums and receiving feedback and monitoring their driving performance and exposure. As a result, an insurance model incorporating individual driving characteristics would enhance safety by reducing traffic risk both totally and individually, since it would provide drivers with both positive and negative incentives to decrease their exposure and improve their behaviour.

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