Usage-based INSURANCE

Pay-As-You-Drive (PAYD) automobile insurance is now marketed in several countries, and has become a basic benchmark for a new insurance concept: usage-based insurance. This document includes an analysis of available literature and an empirical study. Based on this information, it describes the link between use and the claims ratio, and considers how usage-based products can go beyond automobile insurance, i.e. their application in general insurance.

MANUELA ALCAÑIZ ZANÓN
MERCEDES AYUSO GUTIÉRREZ
ANA M. PÉREZ-MARÍN
RISKCENTER
UNIVERSITY OF BARCELONA

Pay-As-You-Drive (PAYD) automobile insurance is a new concept marketed in several countries. It is also known as Usage-Based Insurance, since the premium is determined depending on the vehicle's mileage, in addition to the traditional risk categories used in premium rating. Premium calculation also takes into account other variables that describe the policyholder's driving pattern, such as speeding, type of road or time of day he or she most frequently drives.

It is thus possible to offer each driver a more tailored automobile insurance. In short, people who use their vehicle more pay a higher premium because their exposure to the risk of an accident is higher. Undoubtedly, designing this type of product is a complex process, and there is little relevant literature and very little statistical information.

Consequently, this paper has three main aims. Firstly, we carry out a wide review of literature about this topic; secondly, we consider how to extend the concept of usage-based insurance to insurance products other than automobile insurance; thirdly, our empirical study shows how usage-associated factors are important to explain accidents rates among PAYD policyholders.

This paper is divided as follows: section 1 contains a description of driving behavior, and its connection with a higher accident risk. In section 2 we describe how PAYD premium rating systems work. In section 3 we consider how to transfer this new insurance concept to products other than automobile insurance. Section 4 contains the results of the empirical application, and the last section lists the conclusions of this study.

1. Driving behavior and accident risk

Several authors, including Rice *et al*. (2003), Jun *et al*. (2007), Laurie (2011), Litman (2005; 2011) and Williams *et al*. (2012) show how usage-associated factors have an impact on accident rates. Specifically, it becomes clear that mileage is directly connected with exposure to risk and probability of an accident. Also, authors such as Litman (2005) and Langford *et al*. (2008) state that this is not a proportional relationship: drivers who use their vehicle more often tend to have fewer accidents by unit of distance than drivers who use it less often.

In terms of speed, its link with accident severity is clear (WHO, 2004; Jun *et al*. 2007, 2011). Specifically, Elvik *et al*. (2004) have concluded that there is a strong statistical link between speed and road accidents: if average traffic speed is reduced by 10 per cent, the number of fatalities decreases by 37.8 per cent (based on data from Sweden and Norway).

Similarly, it is shown that the most frequently-used road type is linked to the risk of being in an accident. Several studies have identified urban roads as the most dangerous. For example, Laurie (2011)

determined that the accident rate in Great Britain is 8.26 times higher on urban roads than on highways.

Additionally, Akerstedt *et al*. (2001) researched the probability of an accident occurring depending on the time of day (based on data from Sweden). For accidents with no excess blood alcohol content, the biggest risk is at around 4am – you are 5.7 times more likely to be injured in an accident and 11.4 more times likely to die. Accident risk is also influenced by the days when drivers most frequently use their vehicles. For example, there is higher danger among young drivers on weekend nights; all the more so if they drive a powerful vehicle (as shown by Doherty et al. 1998 and Williams *et al*. 2012).

Accident rates are also linked to the reason for using a vehicle. Specifically, Elias *et al*. (2010) studied the type of daily activity and the travel patterns of drivers (based on data from Israel), and concluded that people who use their vehicles to go to work (even if they do other tasks along the way) are less likely to be in an accident than people who use their vehicle for activities other than work or school/university. Therefore, it is demonstrated that there is higher accident risk on travel without a specific purpose.

Driving patterns are also described by the number of sudden braking or slowing down maneuvers. According to Jun *et al*. (2007), this is another underlying factor in accident rates. This is especially relevant during morning travel on any road, and during nighttime travel on local roads. In these cases, there is not usually traffic congestion, which may mean that the safety distance is not complied with, or the driver is distracted due to cell phone use, etc. (according to Farmer *et al*., 2010).

Furthermore, it has been shown that PAYD policy underwriting results in changes in the policyholders' driving habits, so as to reduce their exposure to risk and, consequently, benefit from a lower premium (Bolderdijk *et al*., 2011). Additionally, insurance becomes more affordable

thanks to this premium rating system, and this helps to reduce the number of uninsured vehicles on the road. But the positive effects of PAYD policies go beyond this specific issue (Peña, 2007): by encouraging less vehicle usage, it is possible to reduce mileage, accident rates, traffic congestion, public expenditure on road maintenance, and even contamination issues (Parry, 2004 and 2005).

2. Premium rating systems for PAYD insurance

Litman (2011) divided premium rating systems for PAYD policies into three types. The first type, Mileage Rate Factor (MRF) uses the insured party's annual mileage as another premium rating variable, and offers discounts to policyholders who drive less than a given number of miles per year. However, since the annual mileage is estimated by the policyholder, this value may be underestimated.

The second type of systems is Per-Mile Premium (PMP): policyholders are allocated a rate by unit of distance driven, based on traditional actuarial variables for automobile insurance premium rating. The main disadvantage of this type of system has to do with how to measure and control the distance driven by each vehicle (Guensler *et al.*, 2003). In most cases, this is measured by means of the odometer (which could lead to user fraud if tampered with).

Finally, current technological developments make it possible to objectively control vehicle usage and driving habits. And so we talk about the third type of systems: based on GPS, it offers the option of setting a rate by mile driven, also taking into account the type of road, driving time, speeding percentage by type of road, and even sudden slowing down maneuvers. This is the most commonly used system; it is provided as an option subject to whether the policyholder agrees with the installation of a GPS system.

3. Usage-based insurance beyond PAYD insurance

After reviewing existing literature, it becomes clear that PAYD insurance is the basic application of usage-based insurance, without consideration for possible uses in other insurance products. This is the second objective of this paper. In this section, we consider how to design usage-based products in general insurance.

In this context, the first instance of usage-based factors in general insurance (other than PAYD) is home insurance. For this type of insurance, a distinction is made between usual address and second home while setting premiums, a clear example of usage-associated factors.

And this can be applied to other insurance products. Specifically, in occupational accident insurance there are factors related to the job that can be considered while setting the premium. Consequently, incentives to reduce workplace accident rates[1] may be reflected on the premium rating of any type of occupational accident insurance (including insurance taken out by self-employed individuals). This is the *bonus-malus* in workplace accident insurance (FUNDACIÓN MAPFRE, 2010).

For occupational accident insurance, there is a series of traditional factors linked to the following: professional activity divided into major groups (agriculture, construction, etc.), characteristics of work done in the context of said profession (e.g. in the case of construction, tiler for work under 5 meters, or in the case of agriculture, farmer who drives machines), and the person's age. We could also add factors directly connected with the way work is done, which can have a direct impact on the accidents reported.

[1] Spanish Royal Decree 404/2010, dated March 31, regulating the creation of a reduction system for work-related quotations for companies with a particularly important role in reducing and preventing workplace accidents.

AFTER REVIEWING EXISTING LITERATURE, IT BECOMES CLEAR THAT PAYD INSURANCE IS THE BASIC APPLICATION OF USAGE-BASED INSURANCE, WITHOUT CONSIDERATION FOR POSSIBLE USES IN OTHER INSURANCE PRODUCTS

Knowing individual work habits and behaviors may be important to calculate fair premiums for occupational accident insurance. There are behavioral factors directly connected with risk but they are often difficult to measure. Risk prevention measures can place significant focus on accident risk. Accident insurance premium rating should include validation systems for these measures, which are often disregarded.

The question is: how can an insurance company analyze exposure to risk in occupational accident insurance? While policyholders agree to installing a GPS system for PAYD insurance, occupational accident policyholders may agree to checks on their work activities without there having to be an accident. In other words, these are preventive checks. On taking out their occupational accident insurance, policyholders could agree to have the insurance company randomly check compliance with certain workplace safety rules while their policy is valid. Consent to voluntary auditing (no legal obligation) is an option allowed for in Spanish RD 404/2010. Exposure to the risk of having a workplace accident will be reduced by complying with any or several of the technical requirements listed in the above-mentioned Royal Decree: for instance, increase in own preventive resources, implementation of road safety plans related to professional activities, reduction in the number of workers exposed to professional activities, and close monitoring of workplace accident rates (based on the number of workplace accident reports and accident severity). Finally, in relation to coverage of *en route* accident risk, usage-based automobile insurance clearly makes sense.

4. Empirical Analysis

In the opposite page, we describe the results of an empirical analysis of a sample of 25,014 young insured parties who took out a PAYD policy with a Spanish insurance company, effective throughout 2011. 17.6 per cent of policies were linked to an accident, while 82.4 per cent were linked to no accident.

We show the results of a descriptive analysis of both traditional premium rating variables, and factors associated with vehicle usage. For each case, we distinguish between drivers with and without accidents.

FOR OCCUPATIONAL ACCIDENT INSURANCE, THERE IS A SERIES OF TRADITIONAL FACTORS LINKED TO PROFESSIONAL ACTIVITY, CHARACTERISTICS OF WORK DONE AND THE PERSON'S AGE. WE COULD ALSO ADD FACTORS DIRECTLY CONNECTED WITH THE WAY WORK IS DONE, WHICH CAN HAVE A DIRECT IMPACT ON THE ACCIDENT REPORTED.

Table 1. Average values for drivers with and without accidents

Variable	Accidents		No accidents	
	Mean	(Est. dev.)	Mean	(Est. dev.)
Driver's age (years)	27.18	(3.10)	27.65	(3.09)
Years driving license	6.73	(2.94)	7.27	(3.07)
Vehicle's age (years)	8.69	(4.11)	8.76	(4.19)
Vehicle's power (hp)	98.36	(27.46)	96.98	(27.83)

Descriptive analysis

In terms of gender, the percentage of men is slightly higher in the group of policyholders involved in accidents (50.32 per cent) vs. groups not involved in accidents (48.61 per cent). Additionally, the number of drivers who park their vehicle in a garage is slightly higher among drivers involved in accidents (78.17 per cent) vs. drivers with no accident (77.21 per cent).

Table 1 shows average results of the applicable numerical variables. Specifically, we can see that drivers involved in accidents are on average slightly younger and more inexperienced than drivers who had no accident. Furthermore, the vehicle's age is on average almost the same both for drivers who were involved in accidents, and drivers who had no accident. Finally, average vehicle power is higher among policyholders involved in accidents vs. insured with no accident.

Additionally, average annual mileage is higher for drivers involved in accidents (7,962.36 km) vs. drivers with no accidents (6,987.86 km). Similarly, average nighttime mileage is also higher for policyholders involved in accidents (609.94 km) than for drivers with no accidents (513.41 km).

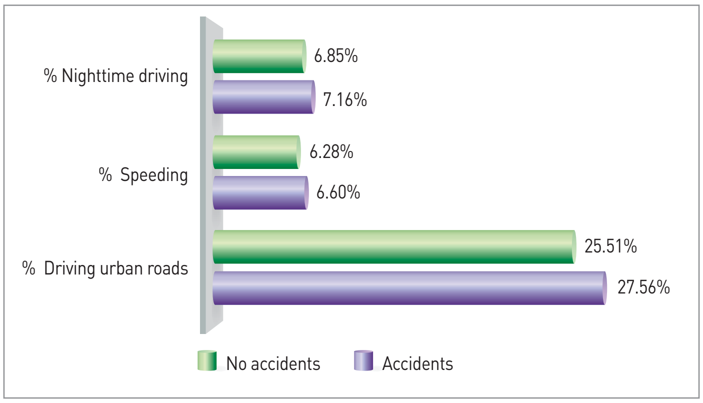
Figure 1 shows the driving profile of drivers with and without accidents. Average driving on urban roads is higher among drivers involved in accidents vs. drivers with no accidents (27.56 per cent vs. 25.51 per cent). We can also see how, on average, drivers involved in accidents exceed speed limits to a greater extent than drivers with no accidents (6.60 per cent vs. 6.28 per cent). Lastly, on average nighttime driving (nighttime km over total km driven) is higher among drivers involved in accidents (7.16 per cent) vs. drivers with no accidents (6.85 per cent).

Modeling results

We have adjusted a logistic regression model to predict the probability of an accident based on traditional variables used for premium rating, and on new factors linked to vehicle usage. Table 2 shows the results of the model's estimate. Below we analyze the effect of each variable on the probability of an accident.

We can see how the more experienced the driver, the lower the probability of an accident. Also, the coefficients associated to the applicable age groups are not significant; this is likely due to the high correlation between the driver's age and the

Figure 1. Driving profile for drivers with and without accidents



number of years they have had their driving license. In terms of vehicle power, our results point to an increase in the probability of an accident if there is an increase in power. Additionally, neither gender nor parking location nor the vehicle's age have a significant impact on the probability of an accident.

Regarding the variables associated with vehicle usage, we can see that the higher the total mileage, the higher the probability of an accident. Similarly, more frequent use of urban roads is significantly linked to higher probability of an accident.

In terms of the time of driving, the probability of an accident for people driving between 11 per cent and 20 per cent of km during the night is lower than the probability of an accident for people driving less at night. Similarly, driving more than 20 per cent of km at night is not significantly linked to a higher accident rate. This is possibly due to a higher accident rate among people who do not drive often at night, only on specific occasions.

Finally, regarding speed, we can see that policyholders who exceed speed limits by up to 2 per cent are less likely to have an accident. When speeding is over this limit, there are no significant differences in accident rates as compared to the benchmark category (speeding higher than 11 per cent).

Table 2. Estimated results of the logistic regression model

	Coeff.	S.E.	*p*-value	Odds ratio
Constant	-2.487	0.128	0.000[a]	0.083
Age 25-28	-0.037	0.047	0.436	0.964
Age ≥ 29	-0.034	0.059	0.563	0.967
Male	-0.035	0.036	0.329	0.966
Years insured driver has had driving license	-0.060	0.008	0.000[a]	0.941
Insured vehicle's age	0.005	0.004	0.205	1.005
Insured vehicle's power	0.003	0.001	0.000[a]	1.003
Parking: garage	0.031	0.041	0.451	1.032
Number of km driven	$7.8e^{-5}$	$5.7e^{-6}$	0.000[a]	1.0001
Number of km driven at night in year	$5.5e^{-5}$	$4.4e^{-5}$	0.212	1.0001
Nighttime km: 11%-20% of total	-0.115	0.057	0.042[b]	0.891
Nighttime km: 21%-30% of total	-0.189	0.123	0.123	0.828
Nighttime km: more than 30% of total	0.088	0.227	0.699	1.092
Speeding percentage: 0%-2%	-0.150	0.056	0.007[a]	0.861
Speeding percentage: 3%-5%	-0.004	0.054	0.943	0.996
Speeding percentage: 6%-11%	0.049	0.054	0.368	1.050
Driving percentage on urban roads	0.020	0,001	0.000[a]	1.020

Benchmark categories: age (≤ 24 years old); gender (female); parking (road); percentage of nighttime km of total (0-10%); speeding percentage over permissible limit (≥ 12%). Chi-Squared: 608.932 (p-value=0.000); -2log-likelihood: 22677.913; degrees of freedom: 16.

[a] a significance at 1%; [b] b significance at 5%.

Conclusions

To conclude, it can be said that PAYD automobile insurance represents a change toward a new concept of insurance product: usage-based insurance. Based on an analysis of available literature and an empirical study, we can see that there is evidence of a link between usage and accident rates. In this paper we also expand the concept of usage-based insurance to policy types other than automobile insurance, e.g. home insurance (there is already a distinction between usual address and second home) or even occupational accident insurance (knowledge about individual daily work habits may be taken into account when calculating premiums; also if *en route* accident coverage is included, usage-based automobile insurance would be applicable).

We believe that the concept of tailored insurance may consolidate in the next few years as a new premium rating trend, with usage-based insurance as the basic application. Papers such as this can be relevant to face the new challenges for the insurance sector and actuarial science.

THE CONCEPT OF TAILORED INSURANCE MAY CONSOLIDATE IN THE NEXT YEARS AS A NEW PREMIUM RATING TREND, WITH USAGE-BASED INSURANCE AS THE BASIC APPLICATION

REFERENCES

—Akersted, T., Kecklund, G., Hörte, L.G. (2001): *Night Driving, Season, and the Risk of Highway Accidents*. Sleep, 24, 4.

—Bolderdijk, J.W., Knockaert, J. Steg, E. M., Verhoef, E.T. (2011): *Effects of Pay-As-You-Drive vehicle insurance on young drivers' speed choice: results of a Dutch field experiment*. Accident Analysis and Prevention, 43, 1181-1186.

—Doherty, S.T., Andrey, J.C., MacGregor, C. (1998): *The situational risks of young drivers: The influence of passengers, time of day and day of week on accident rates*. Accident Analysis and Prevention, 30, 1, 45-52.

—Elias, W., Toledo, T., Shiftan, Y. (2010): *The effect of daily-activity patterns on crash involvement*. Accident Analysis and Prevention. 42, 6, 1682-1688.

—Elvik, R., Christensen, P., Amundsen, A. (2004): *Speed and road accidents. An evaluation of the Power Model*. TØI report 740/2004. Institute of Transport Economics TOI, Oslo.

—Farmer, C.M., Braitman, K.A., Lund, A.K. (2010): *Cell Phone Use While Driving and Attributable Crash Risk*. Traffic Injury Prevention, 11, 5, 466-470.

—FUNDACIÓN MAPFRE (2010): *Incentivos por reducción de la siniestralidad en accidentes de trabajo. Bonus-Malus en el seguro de accidentes de trabajo*. Gerencia de Riesgos y Seguros, 107.

—Guensler, R., Amekudzi, A., Williams, J., Mergelsberg, S., Ogle, J. (2003): *Current State Regulatory Support for Pay-as-You-Drive Automobile Insurance Options*. Journal of Insurance Regulation, National Association of Insurance Commissioners, 21, 3, Spring 2003.

—Jun, J., Guensler, R., Ogle, J. (2011): *Differences in observed speed patterns between crash-involved and crash-not-involved drivers: Application of in-vehicle monitoring technology*. Transportation Research Part C, 19, 569–578.

—Jun, J., Ogle, J., Guensler, R. (2007): *Relationships between Crash Involvement and Temporal-Spatial Driving Behavior Activity Patterns: Use of Data for Vehicles with Global Positioning Systems*. Transportation Research Record, 2019, 246-255.

—Langford, J., Koppel, S., McCarthy, D, Srinivasan, S. (2008): *In defence of the 'low-mileage bias'*. Accident Analysis and Prevention, 40, 1996–1999.

—Laurie, A. (2011): *Telematics: the new auto insurance*. In: Emphasis. - New York: Towers Watson. Issue 1, 20-25.

—Litman, T. (2005): *Pay-As-You-Drive Pricing and Insurance Regulatory Objectives*. Journal of Insurance Regulation, National Association of Insurance Commissioners, 23, 3, Spring 2005.

—Litman, T. (2011): *Pay-As-You-Drive Insurance: Recommendations for Implementation*. Victoria Transport Policy Institute.

—World Health Organization (2004): *World Report on Road Traffic Injury Prevention*. Washington, D.C.: OPS.

—Parry, I.W.H. (2004): *Comparing alternative policies to reduce traffic accidents*. Journal of Urban Economics, 56, 346-368.

—Parry, I.W.H. (2005): *Is Pay As You Drive insurance a better way to reduce gasoline than gasoline taxes?* American Economic Review, 95, 2, 288?293.

—Peña, L. (2007): *Nuevos modelos de gestión de seguros: MAPFRE y su proyecto Generación Y*, Carreteras, 54, 156/Nov-Dec.

—Spanish Royal Decree 404/2010, dated March 31, regulating the creation of a reduction system for work-related quotations for companies with a particularly important role in reducing and preventing workplace accidents, Spanish Ministry of Labor and Immigration, Official State Gazette, April 1, 2010.

—Rice, T.M., Peek-Asa, C., Kraus, J.F. (2003): *Nighttime driving, passenger transport, and injury crash rates of young drivers*. Injury Prevention, 9, 3, 245-250.

—Williams, A.F., West, B.A., Shults, R.A. (2012): *Fatal crashes of 16- to 17-year-old drivers involving alcohol, nighttime driving, and passengers*. Traffic Injury Prevention, 13, 1, 1-6.