ŁUKASZ KURYŁOWICZ

Usage-Based Insurance: the concept and study of available analyses

Although insurance telematics may be a source of competitive advantage, the Usage-Based Insurance (UBI) is still an insufficiently explored area, especially in the context of the Polish insurance market. Accordingly, the main purpose of this paper is to facilitate a better understanding of the topic through a review and summary of selected literature and research achievements, which may prove useful in a discussion about domestic UBI.

The paper presents both the historical perspective of UBI development and a summary of the research carried out over the last decade. It discusses the advancement of UBI tariffs and the successful modification of the applicable pricing schemes as well as points to issues that may hinder the market launch of Usage-Based Insurance. Finally, it attempts to present a structured view of definitions of various terms associated with telematics-based insurance.

Keywords: insurance telematics, motor insurance, Pay-As-You-Drive (PAYD), Usage-Based Insurance (UBI), Distance-Based Insurance (DBI).

Introduction

Fierce competition on the motor insurance market and stifling diversification have led to a significant decline in margin and, consequently, a decrease in the insurers' profits. The trend is particularly apparent in less developed markets, including Poland, where MTPL and Motor Own Damage Insurance is a major (if not the major) section of auto insurers' portfolios. These problems can be potentially avoided by the introduction of UBI tariffs. The tariffs are a relatively new concept based on the assumption that the premium should be adopted, as far as possible, to risks associated with the usage of a given vehicle.

In traditional pricing schemes, premiums depend on a set of variables describing a vehicle, its usage and drivers. Such variables include, for example, the age and experience of the driver, vehicle type, engine power, etc. Most of the variables are purely declarative which leads to a situation where, for instance, the planned annual mileage is often underestimated by the policyholder. Such

variables no longer present reliable characteristics of the vehicle usage, and impede a correct differentiation of premiums for high- and low-risk drivers. Ultimately, this may lead to *adverse selection*.

On the other hand, the UBI model of premium calculation factors in more accurate and personalised information on the actual vehicle usage. In consequence, premiums for drivers who use vehicles safely or cover less distances may be lowered.

The implementation of the UBI model, which is likely to change the paradigm of insurance as a market innovation, will probably take a considerable effort but the stakes are high. For example, Ptolemus Consulting Group estimates that by 2020 the number of UBI policies will increase to 100 million[1] while in 2012 there were nearly 2 million of such policies (with over one billion of insured vehicles[2]). Although the forecast seems to be overestimated, the rate at which new UBI insureds arrive is still impressive.

1. Terms and definitions found in the literature

The literature has developed a plethora of terms and definitions related to telematics-based tariffs. Such terms are often erroneously used interchangeably. Noteworthy is the fact that some, such as PAYD, are registered trademarks of insurance companies. Given the above, a structured presentation of terminology should be a starting point for further considerations.

So, what exactly is *telematics*? The term, originally used in the Nora-Minc Report[3] to describe the combination of telecommunications and data processing, is defined by Wydro as "telecommunication and IT services as well as automatic control solutions tailored to the needs of the physical systems they support (…). The term 'physical systems' refers to the systems created for specific activities and their administration, operators, users and environmental considerations, including the natural, economic as well as formal and legal environment". According to Wydro, the key function of telematics systems is the manipulation of information, i.e. the collection, processing, distribution (including transmission) and use of information in different decision-making processes[4]. Therefore, telematics is not an independent technological standard but a concept that nowadays often refers to the information and communication devices installed in vehicles.

The telematics solutions that are currently used by insurers are known as *insurance telematics*. Insurance telematics is principally applied in pricing schemes of motor insurance[5]. Such schemes can be divided into the following categories based on the scope of use of telematics solutions and the impact of a vehicle's usage on the pricing process:

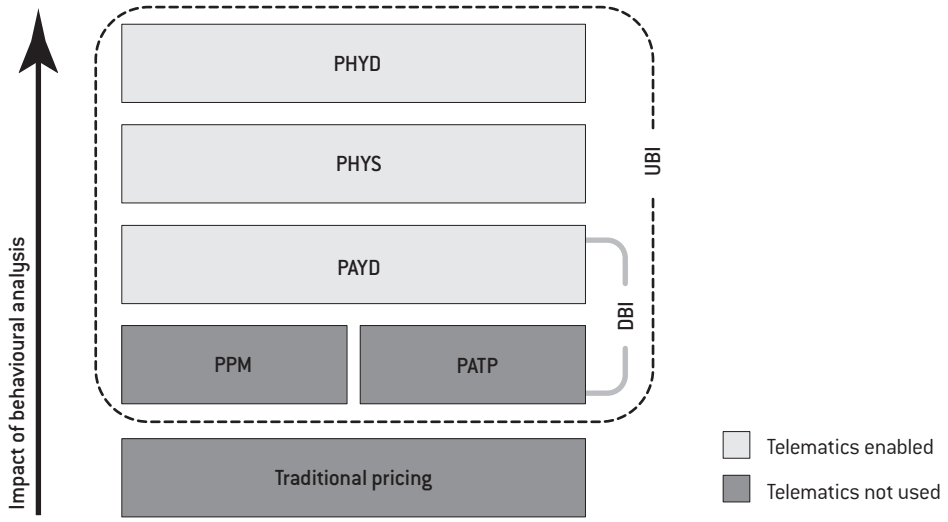
1. **Traditional pricing** – these schemes do not use telematics and the pricing is not dependent on the actual vehicle usage.

1. Ptolemus Consulting Group, *Usage based insurance, Global study – Free abstract*, 2016 Edition, January 2016, p. 14.
2. D. I. Tselentis, G. Yannis,, E. I. Vlahogianni, *Innovative insurance schemes: pay as / how you drive*, "Transportation Research Procedia", 2016 Volume 14, p. 364.
3. S. Nora, A. Minc, *L'Informatisation de la societe, Rapport a M. le President de la Republique, La Documentation Francaise*, Paris, 1978.
4. K. B. Wydro, *Telematyka – znaczenie i definicje terminu*, "Telekomunikacja i techniki informacyjne", 2005 nr 1–2, p. 117.
5. There are other examples of telematics-enabled insurance such as travel insurance.

2. **Pay-At-The-Pump (PATP)** – the premium is a component of the fuel price thus it depends on fuel consumption.
3. **Pay-Per-Mile (PPM)** – PPM systems do not use telematics but the premium is wholly or partially based on the distances travelled by a vehicle (self-reported by the insured).
4. **Pay-As-You-Drive (PAYD)** or **Pay-As-You-Go (PAYG)** – here, the tariff takes into account a relationship between the premium and a vehicle's mileage. Nevertheless, telematics solutions are used to collect, store and transmit the data on the covered distances.
5. **Pay-How-You-Drive (PHYD)** – this model of insurance incorporates telematic analyses of the mileage and also a driving style which is characterised by variables such as speed, types of roads or time-frames of the most frequent daily use of a vehicle.
6. **Pay-As-You-Speed (PAYS)** – this pricing scheme includes a system of financial penalties for speeding, which take the form of decreases in previously granted discounts.

All the systems, excluding traditional pricing, are collectively referred to as "UBI". Additionally, PATP, PPM and PAYD(G) schemes form the Distance-Based Insurance (DBI) group.

Picture 1. Categorisation of insurance pricing schemes based on the impact of telematics and analysis of the insured's behaviour.



Source: Own elaboration.

2. The origins and history of insurance telematics

The concept of UBI is a direct consequence of the discussion that took place in the United States in the late 1960s and early 1970s. Vickrey was one of the first to criticise the idea of pricing schemes based on lump-sum premiums, which were commonly used. At the same time, he proposed to implement tariffs based on the distance covered by the insured vehicle over a particular period of time. Vickrey's PATP system and the *Insured tires* coverage were innovative proposals. In the case of the former, the idea was to include premiums in fuel prices paid by drivers at petrol stations. Under the latter scheme, an insurer, in some way associated with a tyre manufacturer, would cover claims related to vehicles with specific brand

of tyres[6]. However, these solutions had a weakness: they did not satisfy the conditions of the horizontal equity principle. Consequently, an insured who caused damage in the past would be charged the same premium as those who did not[7]. In addition, the usage of a vehicle would be characterised solely by fuel consumption or a type of the tyres used rather than by the covered distances.

The periodic examination of odometers turned out to be the easiest way to measure a vehicle's mileage. Thus the idea of PPM was born from reflection on the inadequacies of the systems proposed by Vickrey. However, the PPM solution proved to be vulnerable to fraud (e.g. a deliberate rolling back of odometers). Although some researchers, such as Litman, argue that with odometers becoming more resistant to tampering their "audits" should be a sufficient solution to this problem[8], the idea of PPM ultimately has not found its way to the market. However, modern technology facilitates vehicle usage measurements thanks to the employment of more accurate systems such as the GPS. This enabled the introduction of more complex tariff schemes, in which prices are associated not only with the actual distance travelled but also with factors such as speed, the time of day when a vehicle is used, and geographical areas. All these factors have an impact on the probability of an accident[9].

In 1999, American insurer Progressive launched in Texas the pilot project *Autograph*. About 1,000 vehicles were covered by innovative insurance with premiums based on data obtained from GPS devices. Although the policyholders were charged a fixed monthly fee for the use of the device, the solution proved to be effective (considering the potential benefits in the context of incurred expenses), especially for those drivers who used their vehicles less frequently than the average or seldom travelled in high-risk areas. A 13% drop in the average mileage and a reduction of premiums by about 25% was reported by the project participants. Both the pilot project and its follow-up *TripSense* (renamed into *MyRate*) brought the insurer significant publicity and resulted in telematic solutions' reach expanding on other US states[10].

In Europe, UBI solutions have been greeted with far less optimism. In 2006, the Aviva Group, operating under the Norwich Union brand, introduced an innovative UBI product in the UK but was forced to cancel the project after about two years of operation. The official justification was the insufficient interest of prospective policyholders. Despite that, other insurers have later launched certain telematics solutions in their home markets such as the Netherlands, Italy, Switzerland, Spain, Germany or Japan. For instance, about 15% of the vehicles in Israel (200,000) are covered by PAYD insurance provided by the local carrier Aryeh Insurance.

Currently, electronics experts predict the development of more sophisticated devices that will be able to collect and process data on the condition of a vehicle, drivers' compliance with traffic signs

6. W. Vickrey, *Automobile accidents, tort law, externalities, and insurance: An economist's critique*, "Law and Contemporary Problems", 1968 Vol. 33, pp. 464–487.
7. J. D. Khazzoom., *Pay-at-the-Pump auto Insurance: Review of criticisms and proposed modifications*, "Journal of Insurance Regulation", 2000 Vol. 18, pp. 448–496 and R. Guensler, *Current state regulatory support for Pay-As-You-Drive automobile insurance options*, "Journal of Insurance Regulation", 2003 Vol. 21 Issue 3, p. 31.
8. T. Litman, *Distance-Based Vehicle Insurance: Feasibility, Costs and Benefits – Comprehensive Technical Report*, Victoria Transport Policy Institute, 2011, p. 46.
9. M. Ayuso, M. Guillén, M. Alcañiz, *The impact of traffic violations on the estimated cost of traffic accidents with victims*, "Accident Analysis & Prevention", 2010 Vol. 42, pp. 709–717 and J. Jun, J. Y. Ogle, R. Guensler,, *Relationships between Crash Involvement and Temporal-Spatial Driving Behavior Activity Patterns: Use of Data for Vehicles with Global Positioning Systems*, "Transportation Research Record: Journal of the Transportation Research Board", 2007 Vol. 2019, pp. 246–255.
10. I. Carnahan, *Insurance by The Minute*, "Forbes", 2009 Vol. 166 Issue 15, pp. 86–88.

and regulations as well as a detailed record of their manoeuvres[11]. New pricing schemes, based on such data and safety-improving add-on services, are expected to create an entirely new class of insurance and, at the same time, deliver an unprecedented level of activity innovation in motor insurance.

After the initial period of considerable interest in the subject, insurers have started expressing disappointment in UBI as they realised they needed to deal with several challenges presented by this type of insurance[12]:

1. Telematics-based tariffs generate high implementation costs related to corporate infrastructure and on-board devices installed in vehicles.
2. Costs associated with the transmission of data from the device to the insurer are still considerable and represent a significant share of an UBI project's budget.
3. Prospective policyholders present a cautious approach to UBI products; they expect only minor savings which are not a sufficient incentive to change an insurer. Moreover, policyholders fear of the invasion of their privacy and are concerned about surcharges applicable in the case of dangerous driving.
4. Intermediaries tend to more frequently offer traditional insurance than UBI because in the former they have real influence on the final value of the premium.

Nowadays, many insurers attempt to find appropriate solutions that would enable them to tackle these challenges.

3. Development of UBI tariffs

According to the conventional approach, net insurance premiums are calculated based on the best estimate of the number and cost of random claims that may occur during a reported period. A premium is usually calculated for an individual insurance portfolio as the former is determined through the assessment and measurement of risk, which usually is described by the collective risk model. The final amount of the gross premium (the sum of money the policyholder pays to the insurer) includes an allowance designed to cover the insurance company's operating expenses and risk loadings[13]. Within this calculations framework, the insured disregards the marginal cost of insurance when making decisions about the frequency of a vehicle's use and travel distances (whereas such decisions are influenced by factors such as fuel costs). This results in the insured using their vehicles more frequently[14], which in turn has an impact on the higher risk and the average premium. The remainder of the chapter will summarise approaches to UBI tariffs that address the above shortcomings related to the calculation of premiums through relying on the actual usage of a vehicle.

Todd Litman of the Victoria Transport Policy Institute in Canada was a precursor of the idea of using GPS data in premium calculation schemes. In initial analyses, the author focused exclusively

11. R. Herrtwich, *Fahrzeuge am Netz, in: Total vernetzt: Szenarien einer informatisierten Welt,* ed. F. Mattern, Springer, Berlin 2003, p. 71; V. Coroamă, N. Höckl, *Pervasive Insurance Markets and their Consequences*, research presented at the Pervasive 2004 conference, Vienna 2004, p. 2 and L. Filipova, P. Welzel, *Reducing Asymmetric Information in Insurance Markets: Cars with Black Boxes*, "Volkswirtschaftliche Diskussionsreihe", 2005 No. 270, pp. 1–29.
12. T. Ippisch, *Telematics Data in Motor Insurance: Creating Value by Understanding the Impact of Accidents on Vehicle Use* (doctoral thesis), Universität St.Gallen, 2010, p. 1.
13. *Ubezpieczenia. Rynek i ryzyko*, red. W. Ronka-Chmielowiec, PWE, 2002, pp. 199–202.
14. T. Litman, *Distance-based Vehicle Insurance as a TDM strategy*, Victoria Transport Policy Institute, 2012, pp. 1–34.

on the discussion on PATP[15], and only in later works did he also consider the possibilities afforded by telematics. He compared different tariff schemes referring to twelve evaluation criteria (e.g. implementation costs, road safety, energy and emissions), and argued that a premium depending on the number of kilometres covered[16] would be superior to other schemes, as it significantly improves actuarial accuracy and provides the insured with noticeable savings. According to Litman, the greatest benefit would be enjoyed by low-income households. At the same time, the author assumed that, the introduction of tariffs based on GPS data in mandatory insurance would not be feasible due to the high costs associated with technology and privacy restrictions[17].

Oberholzer suggested that such problems might be solved by further development of UBI business models. He pointed to low-risk and low-mileage drivers as potential target groups for telematics-based insurance. As regards the tariff scheme, the author suggested a premium based on factors such as types of roads and travel hours, calculating different rates per kilometre for different combinations of location and time. Oberholzer also argued that insurers should cooperate with vehicle manufacturers, which might translate into a wider availability of UBI for prospective insureds[18]. However, his proposals have several disadvantages. For instance, the assumed costs of GPS devices (including installation and data transmission costs) do not reflect actual market costs. Also, Oberholzer failed to fully consider psychological factors related to clients' approach to UBI solutions: he neither discussed the privacy aspect nor the fear of premium surcharges.

Coroamă proposed yet another iteration of UBI, introducing the *Smart Tachograph*, a prototype platform for the calculation of premiums based on individual drivers' behaviour. The system collects GPS data and data on the engine operation so the premium calculated in Coroamă's platform would reflect not only the mileage but also any rapid accelerations or decelerations. An insured may monitor all data via a dedicated application. The application would show the premium and the values used for its calculation. The feedback is designed to make drivers aware of their negative behaviours and encourage them to change them[19].

A team led by Lindberg further developed the concept of distance-based tariffs by introducing the monitoring of driving styles (e.g. speed) via electronic data recorders and GPS. They relied upon a well-documented series of studies conducted among drivers of the Swedish town of Borlänge[20]. These telematics-enable studies were to answer a set of questions related to road travels and driving styles. The researchers' argument was that if pre-determined discounts for drivers are, to some extent, forfeited in the case of speeding, drivers will ultimately be deterred from braking traffic laws[21]. The very prospect of suffering financial consequences results in insureds assuming lower risk, which, consequently, leads to a decrease in their average premiums.

15. Idem, *Distance-Based Vehicle Insurance as a TDM Strategy*, "Transportation Quarterly", 1997 Vol. 51 No. 3, pp. 119–137.
16. The covered distance would be determined on the basis of periodic odometer inspections.
17. T. Litman, *Distance-Based Vehicle Insurance: Feasibility, Costs and Benefits – Comprehensive Technical Report*, Victoria Transport Policy Institute, 2008, pp. 1–89.
18. M. Oberholzer, *Geschäftsmodell einer nutzungsbasierten Motorfahrzeugversicherung in der Schweiz*, "Leipziger Arbeitspapiere zur Versicherungswissenschaft", 2003, No. 2, pp. 1–42.
19. V. Coroamă, *The Smart Tachograph – Individual Accounting of Traffic Costs and its Implications* in: Pervasive Computing, eds. K.P. Fishkin et al., Berlin Heidelberg, 2006, pp. 135–152.
20. The "Borlänge experiment".
21. G. Lindberg et al., *Pay-as-you-speed: Two Field Experiments on Controlling Adverse Selection and Moral Hazard in Traffic Insurance*, "Swedish National Road and Transport Research Institute", 2007, pp. 1–26.

The role of a regulatory authority and the goal that an insurer wants to achieve have the major impact on the choice of an appropriate pricing scheme that may effectively be applied across a domestic market. Zantema et al. examined seven different models of pricing schemes, including compulsory insurance with a fixed premium, voluntary insurance with diverse premiums reflecting factors such as road types and compulsory insurance for young drivers. Zantema's team showed that when the goal is to improve road safety, the best results can be brought by the differentiation of premiums for all insured persons, which should reflect the type of roads on which a vehicle is mostly used (with motorways being "less costly" than local roads) and the driving hours (with night hours resulting in higher premium costs due to the increased risk)[22].

The above outline attempts at illustrating how extensively UBI have been studied. Such studies are performed in the field of actuarial science and refer to economic and social development and applied technology. With a significant increase in the number of relevant research attempts, insurance telematics is gradually becoming a better-known area. A simultaneous decrease in technology costs creates favourable conditions for more economically and practically feasible market implementation of UBI.

At the same time, there are new expectations about the implementation of UBI: not only insurance practitioners perceive Usage-Based Insurance as an opportunity to gain a market advantage under conditions of strict competition, but also politicians and academics consider UBI as a promising approach to deal with social and environmental problems[23].

4. Expectations regarding UBI and opportunities from its implementation

Telematics-based insurance had been arousing high expectations even before it was technically possible to implement UBI solutions in practice. From the insured's perspective, UBI benefits are quite straightforward – a lower premium is paid for a vehicle travelling shorter distances or used in a more responsible and safer manner. Moreover, UBI policies provide access to add-on safety services such as remote diagnostics, emergency assistance or vehicle recovery after theft[24].

The insurance industry's perspective on UBI is multidimensional. According to Hagerbaumer, the insurers who implement UBI tariffs will be seen as customer-oriented, proactive and environmentally responsible, for example due to the effect of mileage reduction[25]. UBI may also help organizations to improve their corporate image and potentially increase the market share. These are the externalities resulting from the implemented solutions. The opportunities related to UBI can also be categorised based on particular aspects of the internal impact of Usage-Based Insurance on an insurer's business, namely:

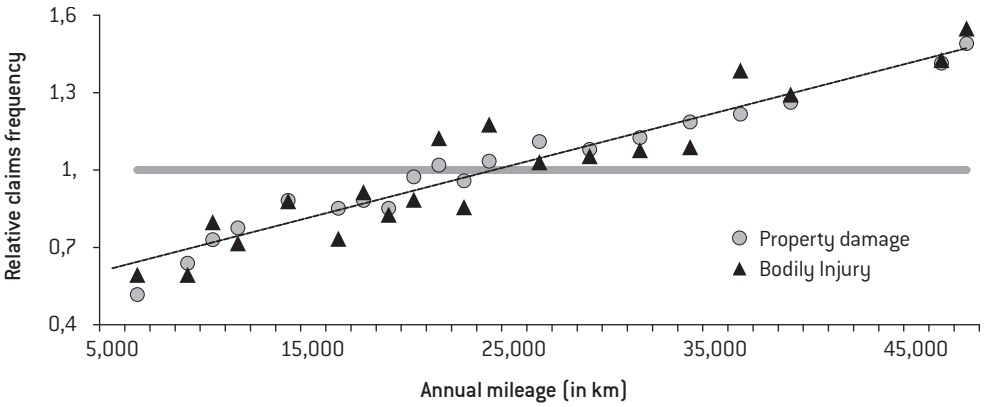
1. Claims frequency reduction;
2. Adherence to the horizontal equity principle;
3. Market share increase accompanying the improvement of insurance portfolios.

22. J. Zantema et al., *Pay-as-You-Drive Strategies: Case Study of Safety and Accessibility Effects*, "Transportation Research Record: Journal of the Transportation Research Board", 2008 No. 2078, pp. 8–16.
23. T. Ippisch, *Telematics Data in Motor Insurance* …, op. cit., p. 7.
24. S. Husnjak, D. Peraković, I. Forenbacher, M. Mumdziev, *Telematics System in Usage Based Motor Insurance*, "Procedia Engineering" 2015 Vol. 100, p. 820 and R. Tooth, *An insurance based approach to safer road use*, Australasian Road Safety Research, Policing and Education Conference 2012, Wellington, New Zealand.
25. C. Hagerbaumer, *Drive-By Rates: Can Pay-As-You-Drive Insurance Attract Good Risks And Gain Insurers An Environmentally Responsible Image?*, "Best's Review", April 2004, pp. 68–69.

4.1. Claims frequency reduction caused by reduced annual mileage and a change of driving behaviour

The introduction of insurance premiums that reflect actual mileage of insured vehicles may lead to a significant reduction of the mileage, estimated at the level of 8%[26] or even 10%[27]. This reduction is a consequence of insureds having actual impact on the amount of insurance premiums and their readiness to modify their habits. A driver, aware of the relationship between the mileage and the premium, is willing to reduce covered kilometres in order to lower insurance costs (*mileage-reduction effect*). Principally, this results in a reduction in claims frequency. The empirical evidence of such reduction was provided by a study of Progressive Insurance. The study covered more than 200,000 vehicles insured between 2002 and 2005 (the equivalent of more than 160,000 of earned vehicle years), divided into groups of equal numbers of earned vehicles years. The relative claims frequency in these groups ranged from approximately 0.5 to 1.5, which means that the claims frequency observed in the group with the lowest annual mileage was lower by nearly 50% than that recorded in the total sample. By contrast, the claims frequency in the group with the highest mileage was 50% higher than the frequency of the total sample[28].

Picture 2. Relative claims frequency depending on annual mileage.



Source: Own study based on data of Progressive Insurance

26. J. Buxbaum, *Mileage-Based User Fee Demonstration Project: Potential Public Policy Implications of Pay-As-You-Drive Leasing and Insurance Products*, Cambridge Systematics Inc., 2006, p. 2–2; A. Calafat et al., *Relación del consumo de alcohol y drogas de los jóvenes españoles con la seguridad vial durante la vida recreativa nocturna en tres Comunidades Autónomas en 2007*, "Revista Española de Salud Pública", 2008 nr 82, pp. 323–331 and J. E. Bordoff, P.J. Noel, *Pay-As-You-Drive Auto Insurance: A Simple Way to Reduce Drive-Related Harms and Increase Equity*, Discussion Paper, The Brookings Institution, 2008, p. 25.
27. C. Hagerbaumer, *Drive-By Rates*…, op. cit., pp. 68–69; Nichols and Kockelman's studies produced lower but still observable results cf. B. G. Nichols, K. M. Kockelman, *Pay-As-You-Drive Insurance: It's impact on household driving and welfare*, "Journal of the Transportation Research Board", 2014 Vol. 2450, pp. 76–82.
28. *Texas Mileage Study: Relationship Between Annual Mileage and Insurance Losses Progressive Insurance*, Progressive Insurance, 2005, p. 2.

The reasons for this reduction can be explained by two factors: a lower vehicle risk exposure and the fact that a vehicle not used in traffic is not a potential "target" for other drivers, which prevents it from being damaged[29].

Moreover, drivers with UBI policies tend not only to drive less often, which alone can reduce the claims frequency, but also have the tendency to drive more safely, which has a significant impact on the overall improvement of road safety (*driving-behaviour-change effect*). A study of the Dutch market indicates that a significant relationship exists between PHYD premiums and a tendency to avoid speeding, mainly among young drivers[30]. Unfortunately, there are still certain factors that are not implemented in pricing schemes (e.g. eco-driving). According to Haworth and Symmon[31], such factors materially influence the risk of accident as speeding or sudden accelerations or decelerations affect fuel consumption, which starts to differ from manufacturer's specifications[32].

However, it should be noted that the relationship between a vehicle's annual mileage and the number of claims per a vehicle is not linear. There are risk factors that do not decline with a mileage reduction. The ratio of the number of claims per one kilometre decreases as the annual mileage rises. This dependence results from a plethora of causes, including the following:

1. High-risk drivers (e.g. those belonging to certain age groups) tend to travel shorter distances in a year.
2. High-mileage drivers are likely to have greater driving experience.
3. Newer (and safer) cars are used more frequently than older (and less safe) vehicles.
4. Drivers travelling mostly in urban areas are involved in more accidents even if they cover shorter distances.
5. High-mileage drivers use mainly "safer" roads such as motorways[33].

The impact of driving experience on the probability of claim occurrence is also shown by Boucher, Pérez-Marín and Santolino. The researchers observed a large angle of slope of frequency curve for low mileages, which marginally decreases with the rise in the number of kilometres covered by an insured per year. Although the slope is always positive, it reaches its lowest values in the range between 15,000–20,000 kilometres and from that point it is almost constant. The relationship between the frequency of claims and the annual mileage can be linear in the higher ranges of the mileage. Thus, the higher risk associated with covering a greater number of kilometres is partially balanced by the combination of the five aforementioned factors. The positive effect of greater driving

29. A.S. Edlin, *Per-mile premiums for auto insurance, in: Economics for an imperfect world: essays in honor of Joseph E. Stiglitz*, ed. R. Arnott et al., MIT Press, Cambridge 2003, pp. 53–82.
30. J. W. Bolderdijk *et al.*, *Effects of Pay-As-You-Drive vehicle insurance on young drivers' speed choice: results of a Dutch field experiment*, "Accident Analysis and Prevention", 2011 Vol. 43, pp. 1181–1186 and Hultkrantz, L., Lindberg, G., *Pay-as-you-speed: An economic field-experiment*, "Journal of Transport Economics and Policy", 2011 Vol. 45 No. 3, pp. 415–436.
31. N. Haworth, M. Symmons, *The relationship between fuel economy and safety outcomes*, Monash University Accident Research Centre, 2001 Report No. 188.
32. D. I. Tselentis, G. Yannis, E.I. Vlahogianni, *Innovative motor insurance schemes: A review of current practices and emerging challenges*, "Accident Analysis & Prevention", 2017 Vol. 98, p. 142.
33. M. Janke, *Accidents, Mileage, and the Exaggeration of Risk*, "Accident Analysis and Prevention", 1991 Vol. 23 No. 3, pp. 183–188, R. Dougher, T. Hogarty, *Paying for Automobile Insurance at the Pump: A Critical Review*, American Petroleum Institute, 1994, pp. 1–55 and J. Langford *et al.*, *Findings from the Candrive/Ozcandrive study: low mileage older drivers, crash risk and reduced fitness to drive*, "Accident Analysis & Prevention", 2013 Vo. 61, pp. 304–310.

experience and other safety-related aspects leads to a reduction in claims frequency; however, that does not seem to be the case with drivers who travel 15,000–20,000 kilometres per year[34].

4.2. Adherence to the horizontal equity principle

Another positive effect of the establishment of a fair level of premiums in relation to a specific owner of a vehicle is attained through better qualification of risk attributable to drivers. An insurer that does not have reliable data on the annual mileage of a vehicle before the conclusion of a given contract is forced to quote the "average" premium (adjusted by the predicted vehicle's mileage declared by an insured) for all insured persons named in the contract, regardless whether their actual mileage is high or low. This approach is particularly disadvantageous for drivers with low annual mileage, who are charged an extra premium to compensate for claims made by high-mileage insureds (good risk is penalised with a higher premium), which can be the reason for adverse selection[35]. Here, the use of telematics seems to be the best solution to mitigate the problem. As it was mentioned earlier, Litman argues that these solutions are superior to other forms of including mileage in tariff schemes such as insureds' declarations[36]. What is more, the individualisation of premiums most rewards low-income drivers, for whom insurance will become more affordable[37]. Consequently, this may be conducive to a reduction in the number of uninsured drivers.

Furthermore, telematics allows for the replacement of other traditional risk factors. An example of that would be the sex[38] or age of drivers. Here, the properly obtained and analysed data on an insured's driving style can explain different levels of risk associated with those characteristics[39].

4.3. Market share increase accompanying the improvement of insurance portfolios

The above-discussed aspects are inextricably interlinked with the quality of insurance portfolios. Most researchers agree that telematics-based insurance can have a strong and positive impact on both the size of an insurance portfolio and the level of risk that the portfolio presents. Since UBI tariffs enable insureds to exercise some degree of control over their premiums (and savings), UBI may encourage drivers to change their insurer[40] with fair premium quotations attracting mainly

34. J.-P.Boucher, A.M. Pérez-Marín, M. Santolino, *Pay-As-You-Drive Insurance: The effect of the kilometers on the risk of accident*, "Anales del Instituto de Actuarios Españoles", 2013 3ª época, nr. 19, pp. 135–154.
35. M. Rothschild, J. E. Stiglitz, *Equilibrium in Competitive Insurance Markets: An Essay on the Economics of Imperfect Information*, "The Quarterly Journal of Economics", 1976 Vol. 90 No.4, pp. 629–649.
36. T. Litman, *Distance-Based Vehicle* …, op. cit., 2011, p. 68.
37. Idem, *Distance-Based Vehicle* …, op. cit., 1997, pp. 119–138.
38. According to Directive 2004/113/EC sex of an insured cannot serve as grounds for differentiating insurance premiums or benefits.
39. M. Ayuso, M. Guillén, A.M. Pérez-Marín, *Telematics and Gender Discrimination: Some Usage-Based Evidence on Whether Men's Risk of Accidents Differs from Women's*, "Risks", 2016 Vol. 4 No. 2, 10 and Idem, *Time and distance to first accident and driving patterns of young drivers with pay-as-you-drive insurance*, "Accident Analysis & Prevention", 2014 Vol. 73, pp.125–131.
40. T. Litman, *Distance-Based Vehicle* …, op. cit., 1997, pp. 119–138.

good-risk insureds[41]. At the same time, those of the insured drivers who will be asked to pay higher, less attractive premiums are likely to leave the portfolio. Furthermore, there is the driving-behaviour-change effect: some insureds will review their driving styles in an attempt to reduce annual insurance expenses[42]. All the above factors taken collectively facilitate insurers' ability to obtain a desired size, structure and sustainability of a portfolio.

There is another aspect impacting an insurer's underwriting profit: the effect of lowering the average claim value that is a consequence of the claim settlement process based on reliable data about the accident collected by vehicle's on-board recorders.

The described benefits, available for customers and insurers alike, are quite significant. However, attention should also be given to the positive social and economic effects of UBI, such as reduced traffic congestion, lower road upkeep and CO_2 emissions, resulting from the decreased usage time of a vehicle[43]. Buxbaum estimates that an 8% drop in annual mileage (and the resulting decrease in fuel consumption) translates into a 2% reduction in CO_2 emissions and a 4% decrease in motor oil consumption[44]. Additionally, Parry concludes that UBI products can substantially contribute to a reduction in fuel consumption, surpassing the similar effect of fuel taxes[45].

Although both the insurance industry and domestic authorities in various jurisdictions are aware of the beneficial aspects of UBI's application, attempts to implement this type of insurance are often faced with failure, mainly due to insureds' reluctance and concerns.

5. Possible sources of insureds' resistance

The fear of violation of insureds' privacy is a key reason for their conservative approach to telematics-based insurance. Data-collecting technology is capable of violating insureds' privacy because it provides comprehensive information about driving times and locations and, first and foremost, about a person's driving style or the number of kilometres driven. However, it seems that insureds are willing to relinquish their privacy to motor insurers in consideration for a minor financial compensation[46].

Several papers describe methods which should protect the privacy of insureds under UBI policies. For example, Iqbal and Lim developed a solution that involves the calculation of premiums

41. G. Lindberg et al., *Pay-as-you-speed: Two Field Experiments on Controlling Adverse Selection and Moral Hazard in Traffic Insurance*, Swedish National Road and Transport Research Institute", 2007, pp. 1–26.
42. It should be noted that the described processes may be triggered by factors other than tariffs based on a driving style or covered mileage. W.F. Fincham observed in his study similar effects in those insured persons who had installed a type of on-board "black box", an Event Data Recorder (EDR), a device gathering data on a vehicle's parameters at the time of a loss occurrence.
43. L. Peña Pérez, *Nuevos modelos de gestión de seguros: MAPFRE y su proyecto Generación Y*, "Revista Carreteras", 2007 nr 156, pp. 54–68.
44. J. E. Bordoff, P. J. Noel, *Pay-As-You-Drive* …, op. cit., p. 36.
45. I. W. H. Parry, *Comparing alternative policies to reduce traffic accidents*, "Journal of Urban Economics", 2004 Vol. 56, p. 346–368 and Idem, *Is Pay-As-You-Drive insurance a better way to reduce gasoline than gasoline taxes?*, "American Economic Review", 2005 Vol. 95 No. 2, pp. 288–293.
46. S. Derikx, M. de Reuver, M. Kroesen, *Can privacy concerns for insurance of connected cars be compensated?*, "Electronic Markets", 2016 Vol. 26 Issue 1, p. 73.

directly in the vehicle. According to Iqbal and Lim's proposal, neither positioning data nor driving behaviour would be disclosed, and an insurer would receive only the aggregated and anonymised data necessary for the correct calculation of the premium. The payment would be made on-line with "Anonymous Digital Currency". However, this approach was impractical and failed to factor in the costs associated with the implementation of dedicated infrastructure. In another study, Iqbal and Lin examined the possibility of profiling insureds with the use of GPS data. They proved that the spatial and temporal monitoring provides a good measure of personality traits but technical limitations can produce erroneous results[47].

A similar approach can be found in the work of Troncoso et al., which describe the PriPAYD model. In this model, collected data are stored in an on-board device, which is also used to calculate the premium. However, the proposed system does not utilise electronic currency and the final calculation of premiums is made after all the necessary data are transferred to the insurer. End users of this system also have instant (e.g. on-line) access to collected data, which enables them to review the rates quoted by the insurer[48].

Stigler showed that individuals are willing to accept the invasion of their privacy only if they consider this move effective[49] (for example, a person can allow access to their data stored by a credit reference agency to receive a lower mortgage rate). Nevertheless, we should be aware that different individuals value privacy differently; in other words, some people value and protect their privacy more than others.

Given the above, the studies of privacy conducted by Hollis and Strauss and Filipova- Neumann employed an economic perspective. The researchers observed that those insureds who are less concerned about the invasion of their privacy tend to receive greater benefits under UBI as compared to those who value their privacy more. Under the conditions of perfect competition, after the latter leave the portfolio, the average premium will increase for the remaining insureds. This, in consequence, will persuade the privacy-sensitive insureds to switch to UBI. Although they will be disadvantaged in terms of utility loss, for them choosing an UBI policy will still be a better option than staying with an insurer offering a traditional tariff scheme. Finally, the researchers concluded that some policyholders would find themselves at a disadvantage no matter their choice of insurance type: these are the high-risk insureds or those with a very high valuation of their own privacy[50].

Contemporary studies show that policyholders are likely to be persuaded to switch to UBI if offered technological privacy-protecting solutions *and* appropriate financial incentives. With adjustment processes taking place at the portfolio level, such incentives may be smaller than the subjective privacy valuation of particularly privacy-sensitive insureds. Besides, not only the value but also the form of an incentive has a major impact on its effectiveness. When designing a new UBI

47. M. U. Iqbal, S. Lim, *Privacy implications of automated GPS tracking and profiling*, "IEEE Technology and Society Magazine", 2010 Vol. 29 Issue 2, pp. 39–46.

48. C. Troncoso *et al.*, *PriPAYD: Privacy Friendly Pay-As-You-Drive Insurance*, "IEEE Transactions on Dependable and Secure Computing", 2011 Vol. 8 Issue 5, pp. 742–755.

49. G. Stigler, *An Introduction to Privacy in Economics and Politics*, "Journal of Legal Studies", 1980, Vol. 9 No. 4, pp. 623–644.

50. A. Hollis, J. Strauss, *Privacy, Driving Data and Automobile Insurance: An Economic Analysis* (working paper), Department of Economics, University of Calgary, 2007, pp. 1–18 and L. Filipova, *Monitoring and Privacy in Automobile Insurance Markets with Moral Hazard*, "Volkswirtschaftliche Diskussionsreihe", 2007 no. 293, pp. 1–38.

tariff, one cannot ignore the consequences resulting from the concerns an insured can voice over the prospects of premiums increasing in the case of unsafe driving. Why? Because a tariff based primarily on penalties could not produce the desired results.

Summary

The interest in UBI dates back to the times when the criticism of motor insurance tariffs based on lump-sum premiums was first expressed. Several decades of research in the areas of technology, actuarial science and psychology have provided a solid foundation for exploring UBI as an alternative to traditional tariff schemes. The implementation of UBI solutions can not only generate the competitive advantage necessary on a saturated market but also bring about positive social and environmental consequences. The obstacles faced by insurers introducing UBI are tackled with increasing efficiency and new ideas for telematics insurance emerge on a daily basis, making its implementation easier to apply.

References

Archer, R. L., *Self-Disclosure* in: *The Self in Social Psychology*, ed. D.M. Wegner and R. R. Vallacher, Oxford University Press, New York 1980

Ayuso, M., Guillén M., Alcañiz, M., *The impact of traffic violations on the estimated cost of traffic accidents with victims*, "Accident Analysis & Prevention", 2010 Vol. 42

Ayuso, M., Guillén, M., Pérez-Marín, A. M., *Telematics and Gender Discrimination: Some Usage-Based Evidence on Whether Men's Risk of Accidents Differs from Women's*, "Risks", 2016 Vol. 4 No. 2, 10

Ayuso, M., Guillén, M., Pérez-Marín, A. M., *Time and distance to first accident and driving patterns of young drivers with pay-as-you-drive insurance,* "Accident Analysis & Prevention", 2014 Vol. 73

Birrell, S., Fowkes, M., Jennings, P., *Effect of using an in-vehicle smart driving aid on real-world driver performance*, "IEEE Transactions on Intelligent Transportation Systems", 2014 Vol. 15 Issue 4

Buxbaum, J., *Mileage-Based User Fee Demonstration Project: Potential Public Policy Implications of Pay-As-You-Drive Leasing and Insurance Products*, Cambridge Systematics Inc., 2006

Bolderdijk, J. W. et al., *Effects of Pay-As-You-Drive vehicle insurance on young drivers' speed choice: results of a Dutch field experiment*, "Accident Analysis and Prevention", 2011 Vol. 43

Bordoff, J. E., Noel, P. J., *Pay-As-You-Drive Auto Insurance: A Simple Way to Reduce Drive-Related Harms and Increase Equity*, Discussion Paper, The Brookings Institution, 2008

Boucher, J.-P., Pérez-Marín, A. M., Santolino, M., *Pay-As-You-Drive Insurance: The effect of the kilometers on the risk of accident*, "Anales del Instituto de Actuarios Españoles", 2013 3ª época, nr. 19

Calafat, A. et al., *Relación del consumo de alcohol y drogas de los jóvenes españoles con la seguridad vial durante la vida recreativa nocturna en tres Comunidades Autónomas en 2007*, "Revista Española de Salud Pública", 2008 nr 82

Carnahan, I., *Insurance by The Minute*, "Forbes", 2009 Vol. 166 Issue 15

Coroamă, V., Höckl, N., *Pervasive Insurance Markets and their Consequences*, research presented at the Pervasive 2004 conference, Vienna 2004

Coroamă, V., *The Smart Tachograph – Individual Accounting of Traffic Costs and its Implications* in: *Pervasive Computing*, ed. K.P. Fishkin et al., Berlin Heidelberg 2006

Derikx, S., de Reuver, M., Kroesen, M., *Can privacy concerns for insurance of connected cars be compensated?*, "Electronic Markets", 2016 Vol. 26 Issue 1

Dougher, R., Hogarty, T., *Paying for Automobile Insurance at the Pump: A Critical Review*, American Petroleum Institute, 1994

Edlin, A.S., *Per-mile premiums for auto insurance*, in: *Economics for an imperfect world: essays in honor of Joseph E. Stiglitz*, ed. R. Arnott et al., MIT Press, Cambridge 2003.

Filipova, L., *Monitoring and Privacy in Automobile Insurance Markets with Moral Hazard*, "Volkswirtschaftliche Diskussionsreihe", 2007 no. 293

Filipova, L., Welzel, P., *Reducing Asymmetric Information in Insurance Markets: Cars with Black Boxes*, "Volkswirtschaftliche Diskussionsreihe", 2005 No. 270

Fincham, W. F., *Watching how you drive*, "IEE Review", 1996 Vol. 42 No. 3

Gonder, J., Earleywine, M., Sparks, W., *Analyzing Vehicle Fuel Saving Opportunities through Intelligent Driver Feedback*, "SAE International Journal of Passenger Cars – Electronic and Electrical Systems", 2012 Vol. 5 Issue 2

Goyal, M., *Insurance Telematics*, "International Journal of Innovative Research & Development", 2014 Vol. 3 Issue 6

Guensler, R. et al., *Current state regulatory support for Pay-As-You-Drive automobile insurance options*, "Journal of Insurance Regulation", 2003 Vol. 21 Issue 3

Hagerbaumer, C., *Drive-By Rates: Can Pay-As-You-Drive Insurance Attract Good Risks And Gain Insurers An Environmentally Responsible Image?*, "Best's Review", April 2004

Haworth, N., Symmons, M., *The relationship between fuel economy and safety outcomes*, Monash University Accident Research Centre, 2001 Report No. 188

Herrtwich, R., *Fahrzeuge am Netz*, in: *Total vernetzt: Szenarien einer informatisierten Welt*, ed. F. Mattern, Springer, Berlin 2003

Händel, P. et. al., *Insurance telematics: opportunities and challenges with the smartphone solution*, "IEEE Intelligent Transportation Systems Magazine", 2014 Vol. 6 Issue: 4

Hollis, A., Strauss, J., *Privacy, Driving Data and Automobile Insurance: An Economic Analysis* (working paper), Department of Economics, University of Calgary, 2007

Hultkrantz, L., Lindberg G., *Pay-as-you-speed: An economic field-experiment*, "Journal of Transport Economics and Policy", 2011 Vol. 45 No. 3

Husnjak, S., Peraković, D., Forenbacher, I., Mumdziev M., *Telematics System in Usage Based Motor Insurance*, "Procedia Engineering" 2015 Vol.100

Ippisch, T., *Telematics Data in Motor Insurance: Creating Value by Understanding the Impact of Accidents on Vehicle Use* (doctoral thesis), Universität St.Gallen, 2010

Iqbal, M. U., Lim, S., *A Privacy Preserving GPS-based Pay-as-You-Drive Insurance Scheme*, Conference materials from symposium organized by the International Global Navigation Satellite Systems Society, Surfers Paradise 2006

Iqbal, M. U., Lim, S., *Privacy implications of automated GPS tracking and profiling*, "IEEE Technology and Society Magazine", 2010 Vol. 29 Issue 2

Janke, M., *Accidents, Mileage, and the Exaggeration of Risk*, "Accident Analysis and Prevention", 1991 Vol. 23 No. 3

Jun, J., Ogle, J.Y., Guensler, R., *Relationships between Crash Involvement and Temporal-Spatial Driving Behavior Activity Patterns: Use of Data for Vehicles with Global Positioning Systems*, "Transportation Research Record: Journal of the Transportation Research Board", 2007 Vol. 2019

Khazzoom, J. D., *Pay-at-the-Pump auto Insurance: Review of criticisms and proposed modifications*, "Journal of Insurance Regulation", 2000 Vol. 18

Langford, J. et al., *Findings from the Candrive/Ozcandrive study: low mileage older drivers, crash risk and reduced fitness to drive*, "Accident Analysis & Prevention", 2013 Vol. 61

Lindberg, G. et al., *Pay-as-you-speed: Two Field Experiments on Controlling Adverse Selection and Moral Hazard in Traffic Insurance*, "Swedish National Road and Transport Research Institute", 2007

Litman, T., *Distance-Based Vehicle Insurance: Feasibility, Costs and Benefits – Comprehensive Technical Report*, Victoria Transport Policy Institute, 2008

Litman, T., *Distance-Based Vehicle Insurance: Feasibility, Costs and Benefits - Comprehensive Technical Report*, Victoria Transport Policy Institute, 2011

Litman, T., *Distance-based Vehicle Insurance as a TDM Strategy*, "Transportation Quarterly", 1997 Vol. 51 No. 3

Litman, T., *Distance-based Vehicle Insurance as a TDM strategy*, Victoria Transport Policy Institute, 2012

Market Intelligence: 89 Million insurance telematics subscribers globally by 2017, says ABI Research, "Latin America Telecom", 2012 Vol. 17 Issue 2

Nijkamp, P., Pepping, G., Banister, D. *Telematics and Transport Behavior*, Springer, New York 1996

Nichols, B. G., Kockelman, K. M., *Pay-As-You-Drive Insurance: It's impact on household driving and welfare*, "Journal of the Transportation Research Board", 2014 Vol. 2450

Nora, S., Minc, A., *L'Informatisation de la societe, Rapport a M. le President de la Republique, La Documentation Francaise*, Paris, 1978

Oberholzer, M., *Geschäftsmodell einer nutzungsbasierten Motorfahrzeugversicherung in der Schweiz*, "Leipziger Arbeitspapiere zur Versicherungswissenschaft", 2003 No. 2

Peña Pérez, L., *Nuevos modelos de gestión de seguros: MAPFRE y su proyecto Generación Y*, "Revista Carreteras", 2007 nr 156

Parry, I. W. H., *Comparing alternative policies to reduce traffic accidents*, "Journal of Urban Economics", 2004 Vol. 56

Parry, I. W. H., *Is Pay-As-You-Drive insurance a better way to reduce gasoline than gasoline taxes?*, "American Economic Review", 2005 Vol. 95 No. 2

Ptolemus Consulting Group, *Usage based insurance, Global study – Free abstract*, 2016 Edition, January 2016

Rothschild, M., Stiglitz, J. E., *Equilibrium in Competitive Insurance Markets: An Essay on the Economics of Imperfect Information*, "The Quarterly Journal of Economics", 1976 Vol. 90 No. 4

Stigler, G., *An Introduction to Privacy in Economics and Politics*, "Journal of Legal Studies", 1980, Vol. 9 No. 4

Texas Mileage Study: Relationship Between Annual Mileage and Insurance Losses Progressive Insurance, Progressive Insurance, 2005

Tooth, R., *An insurance based approach to safer road use*, Australasian Road Safety Research, Policing and Education Conference 2012, Wellington, New Zealand

Troncoso, C. *et al.*, *PriPAYD: Privacy Friendly Pay-As-You-Drive Insurance*, "IEEE Transactions on Dependable and Secure Computing", 2011 Vol. 8 Issue 5

Tselentis, D. I., Yannis, G., Vlahogianni, E. I., *Innovative insurance schemes: pay as / how you drive*, "Transportation Research Procedia", 2016 Vol. 14

Tselentis, D. I., Yannis, G., Vlahogianni, E. I., *Innovative motor insurance schemes: A review of current practices and emerging challenges*, "Accident Analysis & Prevention", 2017 Vol. 98

Ubezpieczenia. Rynek i ryzyko, W. Ronka-Chmielowiec [ed.], PWE, 2002

Van Der Laan, J. D., Heino, A., De Waard, D., *A simple procedure for the assessment of acceptance of advanced transport telematics*, "Transportation Research Part C: Emerging Technologies",1997 Vol. 5 No. 1

Vickrey, W., *Automobile accidents, tort law, externalities, and insurance: An economist's critique*, "Law and Contemporary Problems", 1968 Vol. 33

Wahlström, J., Skog, I., Händе, P., *Driving Behavior Analysis for Smartphone-based Insurance Telematics*, Proceedings of the 2nd workshop on Workshop on Physical Analytics, 2015

Wydro, K. B., *Telematyka – znaczenie i definicje terminu*, "Telekomunikacja i techniki informacyjne", 2005 nr 1–2

Zantema, D. H. et al., *Pay-as-You-Drive Strategies: Case Study of Safety and Accessibility Effects*, "Transportation Research Record: Journal of the Transportation Research Board", 2008, No. 2078

Usage-Based Insurance. Koncepcja i studium dotychczasowych analiz

Pomimo, że ubezpieczenia wykorzystujące rozwiązania telematyczne mogą stanowić potencjalne źródło przewagi konkurencyjnej, tematyka Usage-Based Insurance (UBI) jest wciąż mało poznana szczególnie w kontekście realiów krajowych. Z tego powodu głównym celem artykułu jest umożliwienie lepszego zrozumienia tematu poprzez przegląd i podsumowanie dotychczasowych osiągnięć badawczych oraz dostępnej literatury.

Praca porusza zarówno historyczny aspekt rozważań jak i podsumowanie badań prowadzonych w ciągu ostatniej dekady. Obejmuje swoim zakresem aspekty związane z rozwojem koncepcji taryf typu UBI, szansami wynikającymi z modyfikacji dotychczasowego podejścia do taryfikacji jak i potencjalnymi przeszkodami mogącymi utrudnić rynkowe wdrożenie UBI. Dokonuje również próby usystematyzowania definicji poszczególnych terminów powiązanych z ubezpieczeniami wykorzystującymi rozwiązania oparte o telematykę.

Słowa kluczowe: telematyka ubezpieczeniowa, ubezpieczenia komunikacyjne, Pay-As-You-Drive (PAYD), Usage-Based Insurance (UBI), Distance-Based Insurance (DBI).

ŁUKASZ KURYŁOWICZ – WARTA S.A. Insurance and Reinsurance Company.