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Technology Risk Model Development and Application to Green Vehicle Purchases

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Abstract

This study proposed a technology risk model for assessing environmentally-friendly vehicles. It analyzes risk factors to explore what may hinder vehicle purchases and subsequent market diffusion. A preliminary study has been conducted to test the model's validity and future research is suggested to examine the factors for encouraging environmentally-friendly vehicle purchases such as hydrogen-based automobiles.

Keywords

Technology Adoption, Risk Model, Green Vehicle

1. Introduction

R&D investment in green vehicle technologies has increased as interest grows in ways to minimize greenhouse gas (GHG) emissions, particularly through innovation in transportation, which has been shown to the major contributing sector to global GHG emissions. Studies have shown that electrically powered vehicles emit less GHG gases than conventional vehicles driven by gasoline. It is estimated that if the share of green vehicles in the entire automotive market increases, GHG emissions will be reduced significantly.

Green vehicles are typically seen as synonymous with electric vehicles (EVs). EVs require no petrol to run as they are powered by electric energy generated through batteries and an electric motor and, as a consequence, they emit no GHG gas. In fact, the electric vehicle was built in 1873, 12 years before the first gasoline vehicle appeared in 1885. Yet, for a variety of political, economic and technical reasons, EVs were not commercialized. A century later and, with the energy crisis and oil shocks in the 1970s, the world's attention returned to the electric vehicle, which seemed to allay growing concerns over environmental pollution. However, it wasn't until the 1990s that R&D into EVs began to really take off. General Motors released the EV1, the world's first mass-production electric vehicle, in 1996 and many automotive manufacturers have since joined in with the development of green vehicles.

In terms of market development, the green vehicle market is still very much in its formation stage and the dissemination of electric vehicles has a long way to go. The relatively short history of green vehicles means consumers largely remain wary of them. To grow, the electric vehicle market has to answer the perceived concerns and risks present in the purchase decision. To expand the market, then, it is necessary to analyze what risks hinder the purchase of electric vehicles and how these risks affect the purchase of electric vehicles.

Technology Acceptance Model (TAM) is widely used to analyze consumer behavior in regards to the acceptance of products featuring new technology. TAM is particularly prevalent in the IT sector as electronic auto parts and software become an increasingly central part of the modern car. Of course, ICT plays a crucial role in electric vehicles and its importance is anticipated to increase further. TAM is thus seen with a limit to analyze consumer behavior from the standpoint of electric vehicle adoption, and this study has conducted empirical analysis of factors that affect consumers' electric vehicle purchase through a Technology Risk Model (TRM), which has been upgraded and expanded with the application of perceived risk theory.

With the growing concern over environmental pollution and global warming, automotive manufacturers around the world have actively engaged in the R&D of green vehicles that are environmentally friendly and highly sustainable. The full-scale commercialization of green vehicles is currently ongoing and this trend is expected to reduce environmental pollutant emissions caused by transport and increase vehicle performance and fuel efficiency. Depleting oil resources and the rise in oil prices are also triggers for the development of green vehicles using alternative energy sources.

The major examples of green vehicles are: electric vehicles (EV), hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), and fuel-cell electrical vehicles (FCEV). A hybrid electric vehicle (HEV) combines an electric motor and an engine. HEVs were developed to remedy the traditional weaknesses of EVs. As HEVs are driven by an electric motor at low speeds and by an internal combustion engine at high speeds, they have a further effective range than EVs. This perhaps explains why HEVs are the most popular type of green vehicle when judged on sales and, in the U.S. at least, HEVs are seen as having entered the mainstream market.

A plug-in hybrid electric vehicle (PHEV) is a type of vehicle that combines the features of an EV and a HEV. PHEVs are driven solely by electric energy over short distances and by an engine over longer distances. PHEVs contain rechargeable batteries that can be restored to full charge by connecting a plug into an electric socket. One drawback to both HEVs and PHEVs is that they both generate pollution, impacting their environmental friendliness.

A fuel-cell electrical vehicle (FCEV) is a type of vehicle that powers an electric motor using hydrogen and oxygen from the air. FCEVs are highly environmentally-friendly because they emit only water vapor, meaning zero GHG emissions. Despite its high potential, FCEV technology is still in its early commercialization stage. An EV is a zero pollution vehicle driven only by batteries and an electric motor, without using an internal combustion engine, and does not use petrol nor emit GHGs. However, EVs are limited in their marketability by a high price, short driving range and long charging time.

2. Research Method

The Technology Acceptance Model (TAM) is a theory introduced by Davis (1989) that was devised to predict consumer behavior regarding the acceptance of information technology based on the Theory of Reasoned Action (TRA) used in social psychology. TAM has various advantages, particularly that it can be easily used with only a small number of variables, yet still provide good explanatory power. It is specific to analysis in the IT sector and able to explain user adoption behavior with regard to new technologies. The most important two variables in TAM are: perceived utility (PU) and perceived ease of use (PEOU). PU refers to the degree to which a person believes that using a the system in question would enhance his or her job performance, while PEOU refers to the degree to which a person believes that using the system in question would be effortless. TAM suggests that these two variables, PU and PEOU, affect users' receptivity toward using the technology in question, which in turn affects actual system use through the interface with behavioral intention. In other words, the more a user rates the utility or ease of use of a new technology, the more he or she is likely to accept it. In addition, PEOU affects PU, and PU directly affects both the attitude and the intention to use. **Figure 1** shows a model schematizing this.

To more accurately predict and explain user behavior, Davis (1989) modified TAM to have only three variables: the intention to use, PU, and PEOU. He excluded attitude due to its insignificance as an intervening variable. Since then, many studies exclude the "attitude" variable, and use a model where PU and PEOU directly affect behavioral intention.

To analyze consumer behavior surrounding the adoption of electric vehicles, various research models have been applied, including prospect theory, the theory of planned behavior, and social comparison theory. TAM has limitations; however, Dudenhöffer (2013) validated behavioral intention regarding the use of plug-in hybrid electric vehicle by applying TAM, but their hypothesis that PU and PEOU have a positive effect on behavioral intention was disproved in the study.

First introduced by Bauer (1960), perceived risk is a concept that refers to the psychological risk perceived by a consumer when he or she makes a purchase decision. The psychological risks perceived by the consumer have a negative effect on the outcome of the purchase decision. Perceived risk has been defined in

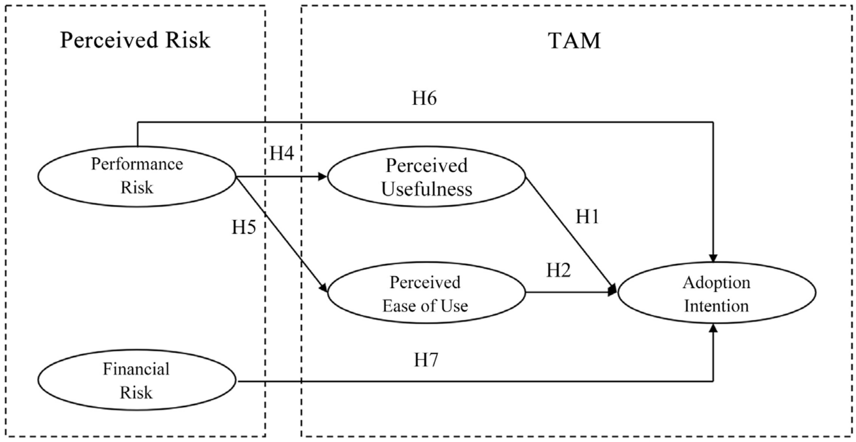

Figure 1. Research model to consider technology risk factors.

various ways in the wider literature, including as an anticipated or potential loss in purchase. Using the classification criteria by Bauer (1960), perceived risk has been classified into various factors, including performance risk, financial risk, time-loss risk, physical risk and social risk. **Table 1** shows the definition of these perceived risks.

There is considerable ongoing research integrating perceived risk and TAM to suggest new models. Featherman & Pavlou (2003) used TAM to analyze the behavior of adopting e-service from the perspective of perceived risk. Their study found that perceived risk consists of performance risk, finance risk, time risk, psychological risk, privacy risk and overall risk, and that perceived risk decreases PU and adoption intention. Lu et al. (2005) analyzed the effect of perceived risk on the behavioral intention to use online applications by utilizing the expanded TAM. They found that perceived risk has a negative (−) effect on PU and attitude toward use and PU. By contrast, behavior has a positive (+) effect on the behavioral intention to use. They concluded that perceived risk has a negative effect on the behavioral intention to use online applications through indirect paths. It was also found that PU and PEOU have a negative effect on senior consumers deciding to adopt self-service banking technologies. Crespo et al. (2009) conducted an empirical study applying TAM to analyze the effect of perceived risk on internet shopping behavior and found that the perceived risk, which consists of financial risk, performance risk, social risk, time risk, psychological risk, and security risk, has a direct negative effect on PU and the behavioral intention to use online shopping.

This study analyzed factors affecting electric vehicle adoption intention by using TRM, a new approach to Davis (1989), and perceived risk factors as external variables. According to the initial TAM, when a consumer adopts information technology, PEOU affects PU and attitude, and PU affects attitude and adoption intention. These days, many studies consider attitude as an insignificant intervening variable and remove variables related to attitude to emphasize user behavior. Three variables are typically used: PU, PEOU and behavioral intention. In line with this, this study has excluded the attitude variable in an effort

Table 1. Perceived risks factors in technology adoption (Bauer, 1960).

Risk types	Description
Financial risk	Possibility of losing money in the course of purchasing or using the product.
Physical risk	Possibility of the purchase or use of the product threatening the safety or health of the user.
Performance risk	Possibility of performance defects arising in the purchased product, such as a failure or malfunction.
Social risk	Decline in social status due to unfavorable opinions by others due to the use of the product.
Time risk	Loss of time that could occur before the purchase of the product or in its use after purchase.

to emphasize adoption intention and formed a basic model by using three variables: PU, PEOU and adoption intention.

TAM has been generally used to analyze user adoption intention for cutting-edge information systems and technologies. Although there are not many studies that have applied TAM to vehicle adoption intention, it is nevertheless useful to apply TAM partially to electric vehicles because they feature a growing proportion of electrical components befitting a new state-of-the-art product using ICT as a core technology. There have been many studies in recent years that have examined the factors affecting the behavioral intention to use a smartphone by applying TAM. Smartphone technology is similar to electronic vehicle technology in that it uses ICT as a core technology and has only been developed comparatively recently.

Perceived risk consists of various factors, including performance risk, financial risk, time-loss risk, physical risk and social risk. Previous studies have shown that perceived risk has a negative effect on PU, PEOU, and adoption intention with regard to the use of information systems. Perceived risk also affects decisions on vehicle purchase. Yee & San (2011) analyzed factors affecting the purchase decision for a vehicle, and found that perceived risk is closely related to a purchase decision when a consumer purchases a vehicle.

As an electric vehicle is a product made based on new technologies that have not yet been completely proven, there are concerns about the purchase of EVs, including short range, performance, higher prices, and safety accidents such as battery explosion. Wiedmann et al. (2011) saw various perceived risk factors as barriers hindering the adoption of natural gas vehicles and suggested that these factors affect innovation resistance. On the basis of this previous literature, this study has selected three risk factors: performance risk, physical risk and financial risk, as external variables of TAM for electric vehicle adoption intention.

Kim & Park (2006) selected performance risk and financial risk as external variables and applied them to TAM and, based on the outcome of this research, analyzed the effect of perceived risk on WiBro adoption intention. Kim et al. formulated a hypothesis that there is a negative effect on PEOU and PU and found that performance risk has a negative effect directly on PU, PEOU and usage intention, while financial risk has a direct negative effect only on usage intention. With regard to this outcome, performance risk has been shown to affect not only usage intention, but also PU and PEOU because it is embedded in the technology itself. By contrast, as financial risk is not derived from the nature of the technology itself, but occurs externally when the technology is purchased or used, it directly affects only usage intention. The performance risk and physical risk of EVs are risks that are embedded in the technology itself, while financial risk is a risk that occurs externally when the technology is purchased or used.

On the basis of the afore-mentioned hypotheses, we designed a research model through a structural equation model (SEM) for investigating the causal relationship and paths between the variables. **Figure 1** shows the research model. To test these hypotheses and validate the research model suggested in this study, the SEM was run with survey responses described below.

3. Results and Discussion

We developed survey questions based on the findings of previous studies and conducted a survey with 231 Korean adults aged 20 or above (Hwang & Lee, 2020). Reliability can be validated by evaluating the internal consistency of each item. For this, this Study measured the Cronbach's alpha value for each item for evaluating internal consistency and used the outcome to determine the reliability. According to the outcome of the analysis, Cronbach's alpha value for each item was 0.790 or above, in which case reliability was confirmed in this study. Validity is the criterion used to determine how accurate the measurement is. As summarized in **Table 2**, Hwang & Lee (2020) conducted a confirmatory factor analysis (CFA), and also underwent a validity analysis process. Convergent validity was tested by assessing the factor loading, average variance extracted (AVE) and construct reliability (C.R.), and discriminant validity was tested by comparing the AVE value with the square of correlation coefficient. In this study, convergent validity has been validated with all the factor loading values being between 0.735 and 0.957, and AVE values between 0.55 and 0.66, and C.R. values between 0.757 and 0.836.

This study set hypotheses with regard to the paths for the effect between the three variables of TAM (PU, PEOU, and adoption intention) and the two variables as a perceived risk factor (performance risk and financial risk). These were then validated using AMOS20, a structural equation modeling analysis tool. To test the fit of the research model, we measured the values for χ^2/df, GFI, AGFI, NFI, RMSEA, CFI, and IFI.

Table 3 shows the outcomes of the analysis of the paths for the model, with H1, H2, H3, and H4 having been confirmed and adopted, while H4 and H5 having been disproved as being invalid. According to the validation of the H1, it indicates that it has a positive (+) effect on electric vehicle adoption intention. For the effect to be regarded as significant, the absolute value for C.R. (critical ratio) should be 1.96 or higher based on $p < 0.05$, where it has been confirmed that PU has a significant effect on the adoption intention. The outcome of the

Table 2. Confirmatory factor analysis results (Hwang & Lee, 2020).

Factors	Factor Loading	AVE	Construct Reliability (C.R.)
Performance Risk → Performance Risk 1	0.896	0.660	0.795
Performance Risk → Performance Risk 2	0.873		
Financial Risk → Financial Risk 1	0.855	0.510	0.757
Financial Risk → Financial Risk 2	0.834		
Financial Risk → Financial Risk 3	0.735		
Perceived Usefulness → Perceived Usefulness 1	0.868	0.549	0.784
Perceived Usefulness → Perceived Usefulness 2	0.904		
Perceived Usefulness → Perceived Usefulness 3	0.796		
Perceived Ease of Use → Perceived Ease of Use 1	0.833	0.631	0.773
Perceived Ease of Use → Perceived Ease of Use 2	0.897		
Adoption Intention → Adoption Intention 1	0.872	0.630	0.836
Adoption Intention → Adoption Intention 2	0.957		
Adoption Intention → Adoption Intention 3	0.826		

Table 3. Results of hypothesis testing.

Hypothesis	Path	Coeff.	C.R.	*P*	Result
H1	Perceived Usefulness → Adoption Intention	0.680	8.283	0.000	Adopt
H2	Perceived Ease of Use → Adoption Intention	0.396	4.463	0.000	Adopt
H3	Perceived Ease of Use → Perceived Usefulness	0.478	4.531	0.000	Adopt
H4	Performance Risk → Perceived Usefulness	−0.330	−2.981	0.037	Adopt
H5	Performance Risk → Perceived Ease of Use	0.297	2.720	0.068	Reject
H6	Performance Risk → Adoption Intention	−0.140	−1.317	0.675	Reject
H7	Financial Risk → Adoption Intention	−0.268	−3.126	0.026	Adopt

validation of H2 shows that PEOU has a positive (+) effect on the adoption intention. The outcome has been confirmed as significant, as the path coefficient. According to the outcome of the validation of H3, PEOU has a positive (+) effect on PU. The outcome of the validation of H4 shows that performance risk has a negative (−) effect on PU. The outcome of the validation of H5 shows that performance risk does not effect PEOU. The outcome of the validation of H6 shows that performance risk does not directly affect adoption intention. According to the outcome of validating H4, H5 and H6, performance risk does not directly affect PU and adoption intention, although it has a negative (−) effect on PU. The outcome of the validation of H7 shows that financial risk has a direct negative (−) effect on adoption intention. Note that the relations between physical risks to PU, PEOU, and Adoption Intention have been also tested by Hwang & Lee (2020) but there were no significant effects, suggesting that TRM mainly consists of performance risk and financial risk factors.

This study was designed to identify factors affecting consumers' adoption intention when they adopt the new technologies and products in EVs. For this, we designed a new research model in which perceived risk factors (i.e. performance risk and financial risk) were added to propose a risk model for new technology adoption that also uses as variables PEOU, PU and adoption intention. Our validation of the research model has produced the following outcomes:

These findings of this study provide several implications for electric vehicle manufacturers, government policy advisors and researchers. First, there are several business implications of this study for actors such as electric vehicle manufacturers: The outcome of our validation of H1, H2 and H3 regarding the positive effect given by PU and PEOU on consumers' adoption intention of electric vehicle implies an increase the sales of electric vehicles. Given this, electric vehicle manufacturers should improve the utility and ease of use of their products in the development and production stages. In addition, the outcome of our validation of the H4 about the negative effect of perceived performance risk on electric vehicle adoption intention implies that it is necessary to eliminate the socio-technical risk factors surrounding green technologies (Yun & Lee, 2015). For the manufacturers of electric vehicles, it is necessary to eliminate any risk factor perceivable by consumers in the stage of developing products and technologies. For governments that intend to increase the dissemination of electric vehicles in response to environmental pollution, it is important to eliminate the risk factors perceived by consumers regarding electric vehicles by expanding charging infrastructure and providing institutional support, such as incentive programs. It is also necessary to reduce perceived risk factors and improve the utility and ease of use by providing knowledge and information regarding electric vehicles at the government level. Lee et al. (2006) suggested that providing appropriate knowledge and information on issues such as global warming would lead to environmental innovation such as the development of low-pollution vehicles. In terms of utility and ease of use, it is important to provide timely knowledge and information to consumers so that they can learn about innovations that reduce risk factors and improve utility and ease of use. This is because reduced risk factors and upgraded utility and ease of use are unlikely in themselves to lead to an increase in the purchase of electric vehicles, unless consumers are first aware of such changes.

4. Conclusion

This study contributes to knowledge by suggesting an expanded model of risk factors in technology adoption, which uses perceived risk as an external variable in the analysis of consumers' electric vehicle adoption intention. This study suggests TRM for the analysis of consumers' adoption behavior of electric vehicles. By setting perceived risk factors as external variables, this study has identified factors that have a direct or indirect effect on electric vehicle adoption intention. Notably, this study has analyzed factors that hinder the adoption of electric vehicles by using perceived risk as a variable, which is an innovation in the research methodology.

In terms of the limitations of this study, it has made little allowance for the characteristics of individuals. While the relatively short history of electric vehicle commercialization would imply that there would be wide variations in the level of knowledge and information possessed by individual consumers, the research model did not take into account such individual characteristics. Therefore, a study that designs and validates an expanded TRM incorporating knowledge and information on electric vehicles as a moderating variable will likely offer more significant results. Lastly, this study conducted empirical analysis with Korean consumers. If empirical analysis is conducted with consumers in Norway or California in the U.S., where the electric vehicle market has already grown substantially, then it would provide significant opportunity for comparison with the purchase behavior of Korean consumers.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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