Are Consumers Ready to Adopt Highly Automated Passenger Vehicles? Results from a Cross-national Survey in Europe

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Abstract: Automated vehicles are currently being developed by major car manufacturers planning to be available in market diffusion the next years. This disruptive technology is expected to provide an alternative type of transportation services by positively affecting road safety, traffic congestion, more individual comfort and convenience for drivers/users. However, besides the aforementioned societal benefits, researches on the predictors influencing individuals' attitudes and willingness to adopt automated vehicles in the future are crucial requirements for their successful diffusion in international market. In this way, the current study aims to investigate the factors that may hinder or facilitate consumers' acceptance and adoption of Highly Automated Passenger Vehicles (HAPVs). A research model through extending the original Unified Theory of Acceptance and Use of Technology (UTAUT) was developed and accordingly an online survey was conducted among the general public in Europe; 811 valid answers were collected and analyzed. The results indicate that the constructs of perceived driving enjoyment, perceived financial cost, perceived reliability/trust, social influence and performance expectancy were all useful predictors of behavioural intentions to drive/use HAPVs. The findings derived from this study will contribute to car manufacturers towards HAPVs in order not only to develop better driving automation technology systems for them, but also to develop proper implementation strategies that will lead to widespread deployment in international market.

1 INTRODUCTION

Many innovations in vehicle technology and driver assistance systems have been developed rapidly by automotive and other related companies. The individual and social demands for a safe, convenient, efficient, and eco-friendly transportation are pushing to fundamental changes in the transportation field like the introduction of Automated Vehicles (AVs). AVs hold much promise to significantly reduce road fatalities as over 90% of road accidents come from human errors, as well as social costs by positively affecting road safety, traffic congestion, energy consumption, people's mobility, more individual comfort and convenience for drivers (Piao et al., 2016). Furthermore, new disruptive business models, such as car sharing mobility services, could also be developed resulting to a strong decrease of car vehicles on the roads (Fagnant and Kockelman, 2015).

Besides the numerous advantages with regard to vehicle automation technologies, AVs may also face numerous challenges before being introduced to the market, ranging from vehicle performance degradation due to unexpected situations (e.g., bad weather conditions, driving automation system failure, etc) to security breaches against malicious attacks by cyber criminals (hackers), and legal liability issues (Van Brummelen et al., 2018). These concerns can be critical obstacles to the market adoption and diffusion of AVs influencing consumers' intention to drive/use them (Kyriakidis et al., 2017).

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Therefore, forecasting technology usage and acceptance by the end users becomes fundamental in order to understand aspects that are likely to minimize consumer resistance and maximize adoption of driving/using AVs. In this respect, the automotive industry still lacks a widely accepted and used framework to assess technology acceptance towards AVs. As such, the goal of this study was twofold:

- First, to design and introduce an adapted version of the original Unified Theory of Acceptance and Use of Technology (UTAUT) social-psychological model in predicting consumers' intension to drive/use Highly Automated Passenger Vehicles (HAPVs).
- Second, to investigate in what extent European consumers intend to drive/use HAPVs in the future, by identifying the factors that affect the uptake of such vehicles.

It should be stated that the term HAPVs refers to road passenger vehicles with a high level of automation within their driving system, being capable to execute all the elements of the dynamic driving task in certain roadway and environmental conditions (SAE International, 2018).

The remainder of the paper is structured as follows. Section 2 takes a look at the relative research works on user acceptance of vehicle automation. Section 3 describes our motivation for using UTAUT model in this study and the hypotheses from a proposed UTAUT-extended model concerning the acceptance and use of HAPVs. In Section 4 the research approach for empirically testing the hypotheses is presented. In section 5 we report on the findings from a questionnaire survey that investigates the extent to which the constructs of the proposed UTAUT model explain the acceptance and driving/usage of HAPVs. Section 6 discusses the research findings, in line with literature, whereas in section 7 the concluding part reflects on the outcomes of the entire study and recommendations for further research.

2 RELATED WORK

With the advanced and dynamic growth of technologies, how fast the consumers are accepting these technologies depends on a number of factors such as availability of technology, convenience, consumers' need, trust, etc. A variety of well-known theories and technology acceptance models have been widely used to assess and gauge consumers' behavioral intentions and determine the factors which most positively influence potential users' likelihood to adopt new vehicle technologies (Park and Kim, 2014).

In addition, some studies in the existing literature have applied various models into understanding of user acceptance towards vehicle technology and autonomous driving. Cho et al. (2017) applied an expanded UTAUT acceptance model about the advanced driver assistance systems (ADAS), where the determinants anxiety, self-efficacy, perceived safety, trust and affective satisfaction were included as direct predictors of behavioral intention to use ADAS, in addition to the basic factors of the original UTAUT model. In addition, Madigan et al. (2016) assessed user acceptance of automated road transport systems (ARTS) using the original UTAUT framework. They found that performance expectancy had the strongest impact on consumers' behavioral intentions to use ARTS. Furthermore, Madigan et al. (2017) investigated consumers' intension to use ARTS by extending UTAUT model to include the effects of facilitating conditions and hedonic motivation. The results of this study indicated that hedonic motivation was the strongest predictor on consumers' intention to use ARTS. Moreover, Nordhoff et al. (2017) investigated user acceptance of driverless shuttles in public transport in an open and mixed traffic environment by using the original UTAUT framework. Results show that the acceptance and use of such shuttles is predominantly influenced by their performance expectancy, effort expectancy and social influence.

3 CONCEPTUAL MODEL

Although the aforementioned studies in the existing literature have investigated and replicated the original UTAUT model and agreed that it is valid in predicting end users' acceptance towards vehicle technology and autonomous driving, further extensions are needed, in most of cases, to fully explore the predictors influencing consumers' attitudes and willingness to use/accept innovative vehicle technologies.

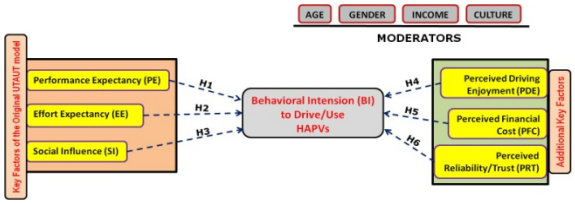

Figure 1: The proposed theoretical UTAUT-extended model.

In this direction, the present analysis takes the initial UTAUT model with the main three

determinants, Performance Expectancy (PE), Effort Expectancy (EE), and Social Influence (SI), as a starting point, by incorporating three further direct determinants, namely "Perceived Driving Enjoyment (PDE)", "Perceived Financial Cost (PFC)" and "Perceived Reliability/Trust (PRT)" (see Figure 1).

3.1 Perceived Driving Enjoyment

With the expected widespread availability of vehicles with advanced driving automation technology becoming ever-closer, the way we travel is set to be revolutionized. In this context, driving pleasure is also likely to play a role in such a new and innovative environment. This specific kind of hedonic motivation is called as Perceived Driving Enjoyment (PDE), and is defined as "*the degree to which individuals perceive enjoyment and pleasure derived from driving/using HAPVs*".

As found in the literature, hedonic motivation has been shown to be one of the most important factors influencing consumers' acceptance of technology across a variety of sectors (Venkatesh et al., 2012). In the context of automation in vehicles, according to the study of Madigan et al. (2017), hedonic motivation, or users' enjoyment of the system, was the strongest predictor on consumers' behavioral intensions to use ARTS.

3.2 Perceived Financial Cost

AVs adoption is highly encouraged by economic factors such as operating costs, maintenance costs, insurance costs, fuel costs, etc. (Zmud and Sener, 2017). Due to the fact that the present study focus on HAPVs, perceived financial cost is also likely to play an important role in consumers' willingness to adopt and purchase/use such vehicles in the future. In this way, the factor Perceived Financial Cost (PFC) is defined as "*the degree to which individuals perceive financial costs derived from purchasing and driving/using HAPVs*".

Previous studies have shown that PFC is one of the most important concerns influencing consumers' acceptance of autonomous and self-driving technology. More in detail, according to the study of Howard and Dai (2015), which public perceptions towards self-driving cars were explored, the cost factor was one of the least attractive features. Furthermore, Ahmed (2018) investigated automotive engineers' perspectives on the awareness, demand and trust on AVs in the current sharing infrastructure with conventional vehicles. Results show that the cost factor was one of the most important customer requirements for the successful deployment of AVs.

3.3 Perceived Reliability/Trust

Several previous studies shown that trust is a crucial contributor to an individual's acceptability in the context of e-services and e-government applications (Mou et al., 2017) as well as in consumers' intentions towards driving automation technology and AVs (Choi and Ji, 2015; Körber et al., 2018). In the present study, PRT is defined as "*the degree to which individuals believe that HAPVs will ensure safe and reliable travels by protecting them from potential misuse and problems*".

As found in the literature, according to the study of Zmud and Sener (2017), most of the people surveyed (82%) are not at all or only somewhat concerned that their data would not be kept private when using self-driving cars. Furthermore, the study by Choi and Ji (2015) supports the claim that trust is a major determinant to predicting the reliance on and adoption of AVs. In addition, the study of Kaur and Rampersad (2018) found that the ability of the driverless cars to meet performance expectations and their reliability were important adoption determinants.

3.4 Moderating Effects and Hypotheses

In the above extended UTAUT-model, as depicted in Fig. 1, the moderating effects of age, gender, income and culture were also considered. It must be noted that while the original UTAUT model also included voluntariness of use and experience as moderators, these variables were not included in the present analysis, in light of the fact that the vast majority of potential consumers in Europe have no concrete and real experience with HAPVs.

In addition, six hypotheses have been totally formulated to better reflect the potentials of the proposed theoretical UTAUT-extended model, as follows:

- H1:"PE significantly affects individual BI to accept and drive/use HAPVs"
- H2: "EE significantly affects individual BI to accept and drive/use HAPVs"
- H3: "SI significantly affects individual BI to accept and drive/use HAPVs"
- H4 "PDE significantly affects individual BI to accept and drive/use HAPVs"
- H5: "PFC significantly affects individual BI to accept and drive/use HAPVs"
- H6: "PRT significantly affects individual BI to accept and drive/use HAPVs".

4 METHOD OF ANALYSIS

4.1 Questionnaire and Measures

Similar to previous research in technology acceptance towards autonomous and self-driving vehicles, the present study employed a quantitative research approach to test the proposed UTAUT-extended model. In this direction, a questionnaire survey was developed with three main parts.

The first part aimed to identify the socio-demographic characteristics of the data sample, as well as the general attributes of the respondents about car vehicles and transportation mobility. The second part of the questionnaire assessed the general experience and concerns of the participants towards automation technologies with multiple choice questions. In the third part of the questionnaire a 26-item measurement scale was administrated with appropriate measures for each construct of the proposed research model (PE, EE, SI, PDE, PFC, PRT) to assess consumers' BI in driving/using HAPVs. All items measured using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

Items selection was based on relative statements in the existing literature (Venkatesh et al., 2012; Choi and Ji, 2015; Madigan et al., 2017) on each of the aforementioned constructs. These items were modified in a suitable manner due to the fact that the present paper focus on HAPVs, which can perform and control all critical driving functions in certain traffic and environmental conditions.

4.2 Participants

The assessment towards HAPVs, which are expected to be utilized in transportation activities the next years, was conducted among adults in Europe currently more than 18 years old. The research was advertised via online means of communication (i.e. websites, social media) inviting European people to take part in a questionnaire survey, in order to explore the knowledge, attitudes, perceptions and behaviours in relation to HAPVs. The questionnaire was disseminated between February and May 2018. All respondents responded in English language.

Participation in the survey was completely voluntary and no compensation was offered to complete the relative questionnaire survey. To ensure survey respondents had a clear understanding of the different levels of driving automation technology, respondents were required to read the simplified definitions of vehicle automation, as defined in (SAE International, 2018). Participants were not able to continue to the next questions of the survey without confirming a relative control question that they have read and understood the definition regarding passenger vehicles with a high level of automation within their driving system, where the present study focus.

Out of the 847 on-line collected responses, 829 valid answers were used for final analysis, indicating a 97.8 per cent acceptance rate. 18 respondents, who had answered only the first four questions, as they expressed their wish not to participate in the present survey, were eliminated from the final sample. This left a total number of 811 responses for final analysis.

5 RESULTS

5.1 Descriptive Statistics

Characteristics and background information of the participants who filled out the questionnaire are provided. 811 participants answered the survey. More in detail, 353 respondents reside in Northern Europe (43.5%) and 458 in Southern Europe (56.5%). The gender split for the whole sample was 57.5% males and 41.4% females, whereas 1.1% responded "I prefer not to answer". With respect to age, 47.8% of the respondents were between 18 and 30 years old, 29.1% between 31 and 40 years old, 22.7% more than 40 years old, whereas 0.4% responded "I prefer not to answer". Regarding the educational level option, most respondents were M.Sc. or/and Ph.D. holders (53.9%), whereas 32.6% were university/college diploma holders, 12.8% had secondary education or less, and 0.7% responded "I prefer not to answer". Moreover, among the respondents, 41.8% had a net average monthly personal income below 1000€, 27.1% between 1000€ and 2000€, and 20.7% more than 2000€, whereas 10.4% responded "I prefer not to answer".

With respect to the respondents' transportation profile, 83.5% of them stated that they own a passenger car, 49.4% indicated that they use passenger cars as a daily commute transportation mode, 54.5% responded that they are driving less than 5 hours per week (on average), and 49.8% stated that the usual purpose of their travels with passenger cars is professional (work, education, etc). Furthermore, almost six to ten respondents (56.8%) stated that they feel quite safe or extremely safe when they are driving/using passenger vehicles today, whereas the vast majority of respondents (79.2%) believe that technology progress, until now, has extremely improved (31.6%) or quite improved (47.6%) the safety of their travels with passenger cars.

Moreover, the vast majority of European respondents (87.2%) had heard of AVs before their participation in the present survey, whereas 9.7% answered "No" and 3.1% responded "I do not know – I'm not sure". Moreover, many respondents (almost 70%) had not any previous experience on driving/using AVs before participating in this survey. Regarding the respondents' level of interest in AVs before their participation in the survey, 52.7% answered that they strongly interested (24.2%) or somewhat interested (28.5%). In addition, 67.6% of the people surveyed answered that they are strongly interested or somewhat interested with the trends of the global automotive community towards vehicle automation. Finally, almost 65% of the total sample had a positive general opinion regarding AVs whereas only 7.9% had a negative general opinion and 6.9% responded "I do not know – I'm not sure".

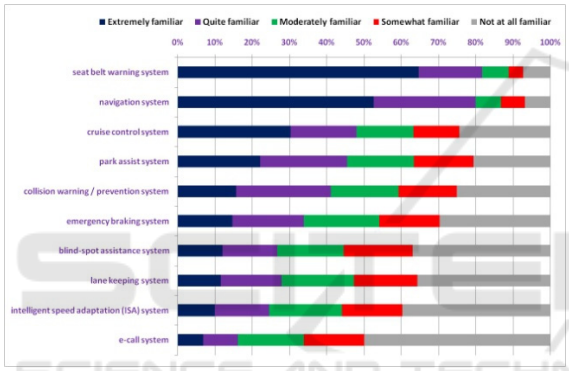

Figure 2: Responses on level of familiarity with ADAS.

5.2 Experiences with Automation Technologies and ADAS

In this section, the experience of consumers towards automation technologies and ADAS, is investigated. Based on the survey results, almost three-to-four respondents considered themselves, late adopters on the technology adoption curve (e.g., they wait before adopting a new automation technology).

Additionally, almost 40% of the respondents stated that they are keeping up with the latest trends in ADAS, and 60% indicated that they are strongly agreed or somewhat agreed with the statement "ADAS make easier my driving". Moreover, the majority of the respondents (almost 70%) stated that it is easy for them to use and apply ADAS in driving and they do not waste too much time in driving with their use.

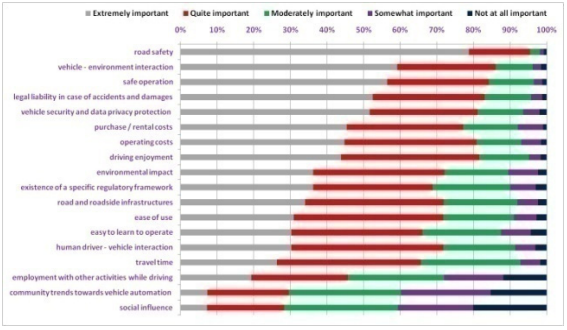

Figure 3: Responses on "How important are the following features for you regarding HAPVs?"

Furthermore, as depicted in Figure 2, the majority of respondents indicated that only "seat belt warning system" (81.6%) and "navigation system" (80.0%), respectively, are the most quite/very familiar ADAS, which are offered today on human-driven passenger cars. On the other hand, it should be stated that the level of respondents' familiarity towards the other available ADAS (e.g., cruise control system, park assist system, etc) being offered by the automotive industry is not exceed the threshold of 35%.

5.3 Intention to Drive/Use and Accept HAPVs

In this section, the respondents' intention to drive/use and accept HAPVs is explored. The majority of respondents indicated that "road safety" (78.8%), "vehicle-environment interaction (59.2%), "safe operation" (56.5%), "legal liability in case of accidents and damages" (52.5%), and "vehicle security and data privacy" (51.7%) were the most extremely important features for the respondents towards the driving/usage of a HAPV, as depicted in Figure 3. On the other hand, a small portion of respondents indicated that "employment with other activities while driving" (19.4%), "community's trends towards vehicle automation" (7.4%) and "social influence" (7.3%) were the most attractive features regarding the driving/usage of a HAPV.

Additionally, a multiple linear regression analysis was conducted for predicting behavioral intentions towards HAPVs taking into account the predictors of PE, EE, SI, PDE, PFC and PRT. To test these effects, the moderators (age, gender, income and culture) with the aforementioned six independent predictors were added to the model.

As demonstrated in Table 1, an examination of the standardized beta weights (β) indicate that the moderating variable "Culture" had a high significant

positive effect influencing consumers' BI to drive/use HAPVs.

Table 1: Summary results of the regression analysis with the presence of the four moderating effects.

H#	Path	Modified UTAUT-model *(standardized path coefficients β)*	Decision
H1	PE→BI	0.121**	Supported
H2	EE→BI	-0.008#	Rejected
H3	SI→BI	0.107***	Supported
H4	PDE→BI	0.215***	Supported
H5	PFC→BI	0.187***	Supported
H6	PRT→BI	0.107**	Supported
	Age→BI	-0.005#	
	Gender→BI	0.053*	
	Income→BI	0.045#	
	Culture→BI	0.378***	

Note: *p-value < 0.05, **p-value < 0.01, ***p-value < 0.001, # p-value non-significant

In addition, hypothesis H4 states that PDE significantly affects European consumers' BI to accept and drive/use HAPVs. Likewise, the results supported hypotheses H5 and H1 which stipulates that the determinants PFC and PE significantly affect European consumers' BI to accept and drive/use HAPVs

Besides, hypotheses H3 and H6 which hypothesized that the determinants SI and PRT significantly affect European consumers' BI to accept and drive/use HAPVs, were also supported. Meanwhile, the remaining construct EE is rejected given that it was found to be statistically insignificant.

6 DISCUSSION

Although there is much excitement surrounding the introduction of AVs, there are largely unknown at the moment which determinants of user acceptance will influence the uptake of HAPVs. The main purpose of this study was to gain a more detailed understanding of the factors that will affect potential end users' future acceptance of HAPVs. In that framework, the present work extends the original UTAUT model by incorporating PDE, PFC and PRT constructs. Most of the path coefficients in the proposed research model were found statistically significant except the path from EE to BI.

More specifically, five of the model's predicted relationships were supported, with PDE, PFC, SI, PRT and PE all making significantly unique positive contributions to users' BI towards HAPVs. Similar to Venkatesh et al. (2012), PDE was the strongest predictor, suggesting that the most important factor influencing positively consumers' intentions to drive/use HAPVs is how exciting, comfortable and enjoyable will find them. The above confirm the results of what Madigan et al. (2017) have studied about the factor of hedonic motivation and its impact on users' acceptance towards ARTS vehicles. In a similar manner, the aforementioned finding supports the results of Nordhoff et al. (2018), where the majority of survey respondents indicated that driverless vehicles would take away the driving pleasure or enjoyment.

Furthermore, our results show that PFC has a positive influence on BI towards HAPVs, indicating that the adoption of HAPVs is highly affected by economic factors such as purchasing costs and driving/usage operating costs (maintenance, insurance, fuel, etc). It should be noted that a small portion of respondents (almost three to ten) strongly agreed or somewhat agreed that the cost of purchasing PHAVs, as well as the operating cost of driving/using PHAVs will be at reasonable prices similar to currently used human-driven vehicles. The above finding is also confirms the results of what Howard and Dai (2015) have explored about the cost factor and its impact on consumers' perceptions towards self-driving cars.

Regarding the PE, this study found that PE has a statistically significant positive impact on BI towards HAPVs, within the proposed research model, suggesting that respondents are expected HAPVs will provide significant potential benefits (road safety, usefulness, etc) in performing their travel activities. Our results support other findings of previous research studies (Piao et al., 2016; Cho et al., 2017; Madigan et al., 2017; Panagiotopoulos and Dimitrakopoulos, 2018) where perceived usefulness and performance expectancy were important predictors in potential consumer's intensions towards autonomous vehicles and driving automation technology.

Furthermore, our results show that SI has a significant positive influence on BI, indicating that the opinions of others will have an effect on consumers' likelihood on driving/using HAPVs when they will become available on the international market. The above finding supports previous research studies, which found that social norms had a significant impact on behavioral intentions towards autonomous driving (Panagiotopoulos and Dimitrakopoulos, 2018) and ARTS vehicles (Madigan et al., 2017).

In addition, this study found that PRT has a significant positive influence on BI, indicating that perceptions of how trusted the autonomous driving system is to use will affect end users' decision to drive/use HAPVs for their travels. The above confirm the results of other studies about the important role of trust in autonomous and driverless vehicles along with other determinants of acceptance (Kaur and Rampersad, 2018; Nordhoff et al., 2018; Panagiotopoulos and Dimitrakopoulos, 2018).

Furthermore, the factor EE failed to reach significance in this study, suggesting that difficulty in driving/using HAPVs is becoming less of a concern for the potential consumers as they become more user-friendly. The above result is in contrast to other findings, where effort expectancy (Madigan et al., 2016) and perceived easy to use (Panagiotopoulos and Dimitrakopoulos, 2018) did have an impact on behavioral intentions towards ARTS vehicles and autonomous driving technology, respectively. On the other hand, our result is similar to other related studies (Choi and Ji, 2015) where effort expectancy and perceived ease to use were insignificant predictors of customers' intention towards vehicle automation.

Moreover, the relationship between the predictor variables PDE, PFC, SI, PRT, PE, EE and BI was found to be affected by moderating factors such as gender and culture, contrary to age and income, with the culture to be the strongest moderator. In regards to culture, findings show that respondents which reside in Northern Europe are more likely to drive/use HAPVs, when they become available on the market, contrary to the respondents from Southern Europe.

7 CONCLUSIONS

Gaining experiences with automation technologies in vehicles over the coming years, could lead us to better understand consumers' willingness to drive/use AVs. In this respect, the value of the contribution of this paper lies in the utilisation of an adapted version of the original UTAUT framework, through investigating the factors that influence potential European consumers' willingness to drive/use HAPVs, improving thus the overall understanding towards public acceptance of such vehicles. In this way, this paper is one of the few contributing to the knowledge about predictors that will lead to widespread adoption of HAPVs in the future by European end users.

In particular, results show that PDE plays a big part in consumers' desire to drive/use HAPVs for their travels. In this context, it is obvious that consumers will still want to enjoy the driving/usage of vehicles equipped with advanced driving automation technologies. Furthermore, the financial cost, the trust in automation technology, the social popularity and the performance expectancy all appear to be important deciding factors. Therefore, it is hoped that in order to maximize HAPVs uptake, designers and developers in the automotive field can consider the above issues when implementing more permanent versions of HAPVs.

Like any other studies, this research has some limitations that should be considered before interpreting the findings. In this manner, the presented implications need to be evaluated in light of the quite futuristic character of HAPVs at the time of the survey. Highly automated vehicles are not yet launched on mass consumer markets. Hence, our respondents did not have any hands-on experience with them and could only state their guesses based on our description provided at the beginning of the questionnaire as well as on information they might have gathered on their own. Also, majority of our sample individuals were relatively young (under 40 years old). Hence, differences might be found for other age groups. In addition, our survey was conducted via online means of communication websites, social media) and, hence, excluded people that do not use the Internet. Finally, since only European people were surveyed, our results might not hold true for non-European people as consumers' opinions and preferences also vary among different geographical regions.

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