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Battery and hydrogen-based electric vehicle adoption: A survey of Australian consumers perspective

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Abstract

Electric vehicles (EV) are a promising alternative for the current fossil-fuel-based vehicles. However, as of 2020, the share of EV sales was only 4.6% globally, and 1% in Australia. It is important to identify factors that promote or hinder consumer intentions of EV adoption. In addition, there are a few types of EVs, each with different advantages and disadvantages creating consumer segmentation. This study considered battery-powered EV and hydrogen fuel cell EV and sought to understand which factors influence the preferences for one of the two types of vehicles. We designed a survey on individual perceptions toward EV and collected data of 1735 consumers in Australia. Participants had a mean age of 44.9 years (SD = 16.71) and 41% of them were males. The median daily traveling distances was 8.7 km, and 74% of them reported using a personal car for commuting. The results show that the safety concern has a stronger impact on adoption intention than the purchase cost and perceived benefits. Age and consumers' current mode of transportation play a significant role in EV adoption intentions. In addition, the results indicate that preference for BEV is significantly affected by BEV range sufficiency, tolerability in battery charging time, and fear of hydrogen explosion, whereas the key preference factors for FCEVs is their longer driving range, and fear of battery explosion. Besides, the results reveal that part-time employees are more likely to prefer BEV than full-time workers. On the other hand, apartment residents tend to prefer FCEV more than people living in a house. Furthermore, female is more likely to still undecided than males whether they prefer BEV or FCEV.

Keywords: Zero-emissions vehicles; Sustainable transport; Technology acceptance model; Consumer attitude; Adoption intention

1. Introduction

In the early 1900s, electric vehicles (EV) were the dominant type of cars on the market. The emergence of internal combustion engines and their efficient production and marketing by Henry Ford ended the EV dominance (Høyer 2008). Today, most vehicles are powered by internal combustion engines burning fossil fuels while the transport sector accounts for 23% of global CO_2 emissions (IEA 2021a). With the growing concern over climate change, and the demand for net-zero or near-zero solutions, the automobile industry is under pressure to reduce its carbon footprint. Over the last decade, several technologies have been introduced such as biofuel-compatible engines, alternative fuel vehicles that can run on liquefied petroleum gas (LPG) or compressed natural gas (CNG), as well as hybrid EV (HEV) (Linzenich et al. 2019), which are still fossil-based but have a lower carbon footprint. These have all been considered as intermediate or bridging options toward the goal of zero-emission cars.

Among the several technologies, there are battery-powered EV (BEV) and hydrogen fuel cell EV (FCEV) that can be near carbon neutral as long as the electricity and hydrogen they use are produced from renewable sources (Hackbarth & Madlener 2013). As such, they are predicted to play an essential role in reducing the CO_2 emissions of the automobile industry over the coming decades (Crippa et al. 2016). The renewable energy revolution over the last decade has also facilitated this transition. With the massive decline in the costs of wind and solar power and the advent of cheaper and more efficient battery technologies, the feasibility of using/developing BEV has significantly improved. A similar trend is being observed in FCEV, which uses hydrogen for supplying the fuel for electric power generation.

In 2020, the share of EV sales was 4.6% of all new vehicles sold globally (IEA 2021b). In Australia, EV account for only 1% of all total sales (IEA 2021b), which can probably be explained by inadequate policies supporting EV adoption (Electric Vehicle Council 2020). So far, there have been no significant policy developments at the national level, with only a few new policies established at the state level. There are 12 passenger BEV models from eight different carmakers available on the market. There were 350 public fast charging stations and almost 2,000 public standard charging stations as of 2020, an increase of 40% since the year before (July 2019) (Electric Vehicle Council 2020). However, there are no FCEV commercially available. Besides, there is only one permanent hydrogen refueling station located at Hyundai's Sydney head office for their own use (Dowling 2020; Transport for NSW 2019).

In this study, we used a survey approach to examine Australian consumers' perception toward EV, as compared with petrol vehicles, and their influence on intention to adopt EV. It should be noted that we referred to EV as an alternative to petrol vehicles and thus it was not specific to a particular type of EV. In a more specific view, we focused on BEV and FCEV as they are the two alternatives that run solely on the electric drive train and have no combustion engine involved. Therefore, hybrid EV and plug-in hybrid EV are not included in this study. We examine the perception toward functional attributes of BEV and FCEV, and their influence on the choice between the two. It should be noted that we neglected the purchase cost and their availability in the market as we are focusing more on the functional attributes of the two different technologies. We aim to answer two research questions: (1) what are the main drivers/barriers for consumers' EV adoption intention? And (2) what functional attributes influence the choice between BEV and FCEV?

Even though many studies have examined consumer attitudes and intentions of EV adoption, they only focused on consumers' opinions regarding either a particular type of EV or alternative fuel vehicles. To the best of our knowledge, there is hardly a study that simultaneously investigates public perceptions about BEV and FCEV which have different attributes, including safety, charging/refueling time, maximum travel distance.

The paper continues as follows. In Section 2, the literature review and conceptual framework are presented. Section 3 focuses on research methodology. In the following Section 4, results are presented. Discussions are presented in Section 5. Theoretical and practical implications are presented in Section 6. Limitations are pointed out in Section 7. Lastly, the paper overviews its findings.

2. Framework and decision factors

2.1. Definition and theoretical foundation

The factors that have often been pointed out as keys of an introduction of new technology including attitude and adoption (Kollmann 2004). In the area of attitude research, according to Kollmann (2004), an introduction of new technology can be considered success if a customer has inner positive will to buy a product. Meanwhile, in the area of adoption research, an introduction of new technology can be considered success when a user purchased the product. Kollmann (2004) proposed the term acceptance as a supplement for the terms attitude and adoption. In this respect, adoption refer to the act of purchase, whereas acceptance refer to the act of use.

There is no consensus about the definition of acceptance (Adell et al. 2014). Adell (2009) classified different definitions of acceptance identified in the literature in 5 categories. Firstly, acceptance is simply defined by the word accept. Secondly, acceptance is described as the satisfaction of the needs and requirements of users, which can be seen as the usefulness of the technology. The third category views acceptance as sum of all attitudes in an evaluation of the usefulness of the technology. The fourth category defines acceptance as the intention to adopt the technology. Finally, the fifth category sees acceptance as the actual use of the technology. In the vehicle context, Adell (2009) proposed a definition of driver acceptance as the incorporations of technology into the driving.

There are several theories and models about the adoption and acceptance of technologies, including that of renewable energy technologies. The theory of reasoned action (TRA) developed by Fishbein & Ajzen (1975) proposes that a person's behavior is the result of their intention to perform the behavior, which in turn is a product of their attitude towards the behavior and subjective norms. In 1991, Ajzen extended TRA to develop the theory of planned behavior (TPB), which uses attitude, subjective norms, and perceived behavior control to explain individual's behavioral intentions (Ajzen 1991). In TPB, perceived behavior control refers to people's perception of their own ability to perform a given behavior. Eventually, these theories gave rise to a family of models specific to adoption, starting with the technology acceptance model (TAM). Another alternative (and in a way pioneer) to TAM is the diffusion of innovation (DoI) proposed by Rogers (1962). DoI was supported by the Riccati differential equation-based model developed by Bass (1969). This school of model is focused on temporal diffusional aspects and are less useful to understanding cross-sectional issues. Besides, from a cross-sectional perspective, key aspects of DoI are covered by TAM constructs, which is specialized in the cross-sectional view of the problem (Lee et al. 2011). Given that we are looking at a snapshot or cross-sectional view of state of adoption, TAM is deemed a more appropriate framework.

TAM was introduced by Davis (1989) and was later modified to TAM2 (Venkatesh & Davis 2000), the unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al. 2003), and TAM3 (Venkatesh & Bala 2008). TAM explains how potential users shape their opinions and accept specific technologies (Park et al. 2018; Wang et al. 2018). Perceived usefulness and perceived ease of use are two psychological factors that influence users' attitudes and intention to use new technology (Wang et al. 2018; Wang & Dong 2016). In this regard, attitude refers to an evaluation of a specific technology that positively affects intention to accept the technology or vice versa (Wang et al. 2018). Several studies found a positive association between attitude towards a specific technology and intention to use it (Park et al. 2018; Perry 2016; Wang et al. 2018; Yang et al. 2020). In addition, there is a direct effect between perceived usefulness and attitudes toward the technology (Wang et al. 2018).

According to Featherman et al. (2021), attitude is influenced by salient beliefs. Positive beliefs result in perceived benefits, while negative beliefs result in perceived risks. Perceived benefits refer to consumers' beliefs about possibility of positive consequences, while perceived risks are the beliefs about potential negative results of technology adoption (Featherman et al. 2021; Yang et al. 2020). Furthermore, when consumers perceived a particular technology as easy to operate, they were more likely to form a positive attitude toward it (Kim & Shin 2015). However, consumer behavior research rarely includes both benefits and risks into the decision models (Featherman et al. 2021).

2.2. Decision factors

2.2.1. **Perceived benefits**

For the new technology to achieve market success, the perceived benefits by the users must be attractive enough to compensate for the perceived disadvantage (Carley et al. 2019). The benefits of new technology can be viewed from different perspectives, namely societal benefits, and individual benefits (Adell et al. 2014). To achieve acceptance of new technology it is necessary to value the personal importance to the user (Ausserer & Risser 2005). In the context of EV, the personal benefits to the users could be the low operational cost. The is because EV offers excellent energy efficiency and thus fuel economy. Carley et al. (2013) found that fuel economy is recognized by the users as an advantage of EV. This advantage became even more salient after the users experiencing EV in the field trial (Bühler et al. 2014). In addition to fuel economy, EV requires less maintenance than conventional vehicles and has lower maintenance costs. This is because the electric drive train typically have fewer moving parts and do not need oil and filter change (Hagman et al. 2016). In a study by Egbue & Long (2012), the lower maintenance cost is ranked by the participants as the second most appealing attribute of EV, following the fuel economy.

Regarding the societal benefits, due to no petroleum consumption and thus reducing vehicle emission, EV are regarded as environmentally friendly (Jena 2020; Yang et al. 2020). Degirmenci & Breitner (2017) found that environmental performance of EV has a stronger influence on attitude and purchase intention than price and range. Several studies viewed the advantages of reducing vehicle emission of EV as climate change mitigation potential (Carley et al. 2013; Egbue & Long 2012; White & Sintov 2017). The reduction in vehicle emission also resulted in the better air quality and thus human health (Gireesh Kumar et al. 2021; Malmgren 2016). Choma et al. (2020) confirmed that EV led to health benefits in terms of reductions in fine particulate matter ($PM_{2.5}$) attributable mortality. Besides, as EV are quieter than petrol cars, they have low noise emission (Bakker & Jacob Trip 2013). In a field trial study, Bühler et al. (2014) found that low noise emission was the most frequently reported advantage by the drivers after experiencing an EV.

2.2.2. **Purchase cost**

The higher purchase cost, as compared to conventional vehicles, is one of the common barriers to EV adoption (Ghadikolaei et al. 2021; Krishna 2021; Wang et al. 2018). The purchase of an

EV may result in consumer financial consequences for many years (Featherman et al. 2021). Therefore, a high purchase cost can cause consumer perceived financial risk. Earlier studies suggest that EV adoption is associated with the tradeoff between high capital and long-term operating costs (Sovacool, Abrahamse, et al. 2019). Besides, the limited understanding regarding the total cost of ownership of EV could potentially hinder users' intention to purchase EV (Hagman et al. 2016).

Prior studies have confirmed that cost is a significant barrier for EV adoption (Coffman et al. 2017; Egbue & Long 2012; Hidrue et al. 2011; Park et al. 2018; Tarigan 2019). Although the running cost of EV is relatively lower than petrol cars, the magnitude may not large enough to compensate the higher purchase cost. (Coffman et al. 2017). Moreover, several studies indicated that financial incentives positively influence EV adoption (Ghasri et al. 2019; Kim et al. 2019; Li et al. 2020). Hackbarth & Madlener (2013) found that while consumer are willing to pay considerable amounts for alternative fuel vehicles with greater fuel economy than conventional vehicles, BEV and FCEV would only be in demand if there were substantial subsidies. Jenn et al. (2018) found that $1000 offered in rebate potentially increase 2.6% in EV sales in the US. Similarly, Wee et al. (2018) found that $1000 subsidies results in 5-11% increase in EV registration in US state. Furthermore, Jenn et al. (2020) reveal that tax credit and rebate are the most important incentives for EV purchasers in California.

2.2.3. **Safety concerns**

The low risk tolerance of consumers is one of the common challenges faced by any new technology (Diamond 2009). As EVs have not been widely used compared to conventional vehicles, users might be biased against them (Yang et al. 2020). When buying a new car, safety is regarded as an important feature desired by consumers (Daziano 2012). In the context of EV, prior studies found that safety concerns are negatively associated with the support of EV; the same stands for all alternative fuel vehicles in general (Browne et al. 2012; Hardman et al. 2017; Tarigan 2019).

In recent years, fire and explosion of BEV during charging or while parking has been reported (Barelli et al. 2021; Christensen et al. 2021). Moreover, in the case of road accidents, the damaged batteries can re-ignite after the incident and a significant amount of water is required for fire suppression. More importantly, according to Christensen et al. (2021), there are no clear procedures for extinguishing BEV fires at present. On the other hand, FCEV failure reports are limited (Smaragdakis et al. 2020). However, several surveys have been conducted on public perceptions toward hydrogen energy. Providing proper safety information can help in addressing the lack of knowledge and building trust. A study by Ono et al. (2019) found that providing risk information on hydrogen refueling increases the acceptance of hydrogen refueling stations in the vicinity of the homes of respondents. When people are better informed and know the risks, they are more likely to accept things.

Besides the fire and explosion risks, being noiseless, EV potentially poses a risk to other road users (Aravena & Denny 2021; Fabra-Rodriguez et al. 2021; Krishna 2021; Pardo-Ferreira et al. 2020). Wu et al. (2011) indicate that the risk of accident is double when a hybrid car run using the electric drive system compared to when it runs using the internal combustion engine. Similarly, Pardo-Ferreira et al. (2020) reveal that EV drivers rate the risk of accident caused by the absence of noise of EV at a medium level. The researchers argue that adding fake noises to EV, as required in the European Union and the USA, does not necessarily mean this is an effective solution and more research is needed.

2.2.4. **BEV technical factors**

BEV are assembled from several parts, mainly batteries, electric motors, and controllers. The batteries are rechargeable from the main electricity via a plug (Jena 2020). The distance BEV can travel on a single charge depend on battery capacity (Egbue & Long 2012). In addition, battery cost is a key factor to determine BEV price and their economic viability (Egbue & Long 2012).

Misperceptions about driving range, charging time, and the availability of charging stations are common barriers to adoption (Hardman et al. 2017; Hardman & Tal 2018; Khan et al. 2020; Trencher et al. 2020). Besides, the related uncertainty such as battery life, the availability of charging infrastructure (whether it is used by others when needed), and depreciation also play a role in consumers' decisions (Liao et al. 2017). Li et al. (2020) found that along with the main attributes of BEV, battery warranty positively affects the adoption among Chinese consumers. Furthermore, direct experience with alternative fuel vehicles significantly influences consumers' attitudes and purchase intention (Kim et al. 2019; Schmalfuß et al. 2017). For instance, BEV early adopters realized that charging time is longer than refueling conventional vehicles but they can save time in a way that they do not need to take a detour out of their route to refill at the stations (Hardman et al. 2017). They also perceived that the ability to be recharged at home as well as the easily recharging method is a convenient feature of BEV.

2.2.5. **FCEV technical factors**

FCEVs are assembled from many of the same parts as BEVs, namely electric motors and power controllers (Pollet et al. 2012). The difference between FCEV and BEV is the main energy source. While both vehicles are electric drive, BEVs source the electricity from the battery. Hydrogen based FCEVs, however, use hydrogen as a fuel to generate electrical energy with water as an exhaust (Lee et al. 2022; Rodrigues de Moraes et al. 2022). These FCEVs are equipped with high-pressure hydrogen tanks, and have comparable driving range and refueling time to conventional vehicles (Lee et al. 2021; Lee et al. 2022; Pollet et al. 2019; Staffell et al. 2019). At present, FCEVs are more expensive than BEV in terms of both purchase and operating cost. Nevertheless, they can be cheaper if the manufacturing volumes rise (Staffell et al. 2019).

Compared with BEV, there is notably less literature examining the consumer perception and adoption of FCEV (Hardman et al. 2017; Hardman & Tal 2018; Khan et al. 2020; Trencher et al. 2020). According to Hardman et al. (2017), the sparse hydrogen infrastructure, the concerns about the possible fossil fuel origin of hydrogen, the inability to recharge at home, and safety concerns pertaining to hydrogen storage are barriers to adopting FCEV. Safety considerations of FCEV, BEV, as well as conventional vehicles are different, but comparable. Although hydrogen can ignite more easily than gasoline, the damage caused by hydrogen fires is little due to their localized nature (Staffell et al. 2019). In the case of hydrogen tank safety, Pollet et al. (2019) argued that several tests have been done to ensure safety of hydrogen cylinders, namely crushing test, impact damage test, penetration test with armor-piercing bullets and fire.

Similar to BEV, driving experience can help in addressing possible misperceptions. For example, Lipman et al. (2018) conducted a study providing a month-long period of FCEV driving and refueling experience to participants. They found that the drivers feel more positive toward FCEV after driving and refueling themselves.

2.2.6. **Socio-demographic factors**

The impacts of socio-demographic characteristics also play an important role in the adoption of both BEV and FCEV. Lin & Tan (2017) studied factors influencing the environmental values of BEV in the four biggest Chinese cities. The results showed that people with higher income and owning cars have better knowledge and more positive opinions about BEV. Besides, people with higher education levels were more likely to pay more for BEV. Similarly, Kim et al. (2019) found that education level significantly affects intentions to purchase BEV among Korean consumers. Moreover, age also has an impact on consumers' perceptions. Ghasri et al. (2019) conducted a stated preference survey in New South Wales, Australia, to examine consumer perception toward BEV and the impact on consumer preference. The results reveal that the middle-aged group has a higher probability of BEV adoption as compared to young and older adults. However, the impact of demographic attributes such as age, education level, and income may differ by country, as found in a comparative study on BEV purchase intentions of Chinese, Russian, and Brazilian citizens (Habich-Sobiegalla et al. 2018). Apart from that, current traveling behavior also plays a role in consumer opinion. Tiwari et al. (2020) found different opinions regarding BEV adoption between private car users and public transport users. Private car users are likely to adopt BEV in the future, while people who frequently use public transport are not expecting to adopt BEV.

On the other hand, Al-Amin et al. (2016) explored FCEV purchase intention in Malaysia. The results showed that environmental knowledge significantly influences attitude toward FCEV. Additionally, attitude, subjective norms, and perceived behavioral control positively and significantly influence FCEV purchase intention. Khan et al. (2020) found that education level affects Japanese consumer preferences for FCEV. Furthermore, they also found that apartment parking positively influences consumer preferences for FCEV. Apartment occupants are more likely to prefer FCEV than BEV because of the unavailability of battery charging infrastructure in the apartment parking, while hydrogen refueling is like conventional gasoline/diesel refueling in that no infrastructure installation is required.

2.3. Conceptual model

Based on the discussed theoretical foundations and influential factors above, a conceptual framework of this study has been designed (Figure 1). In this study, we want to explore the public perceptions towards the adoption of EV as an integrated system of interacting components. Particularly, we want to understand how perceived benefit, purchase cost, and safety concerns influence consumers' intention to adopt EV. We also seek to understand the characteristics of BEV and FCEV that impact and differentiate these two key classes of EV in terms of consumer choice.

Earlier, we introduced the TAM family of technology adoption models as foundational to our work. In this section, we describe how we adapted the TAM model to derive the conceptual model. In support of such modifications, previous research (Hong et al. 2014) emphasizes the need to not only rely on the original model but also suggests adding, removing, or decomposing the core constructs of the theoretical model to apply the model in the studied context. On this basis, the conceptual model is developed based on assessing "EV adoption intention" and "choice of EV" where both are influenced by "socio-demographics". Each of these will be explained next.

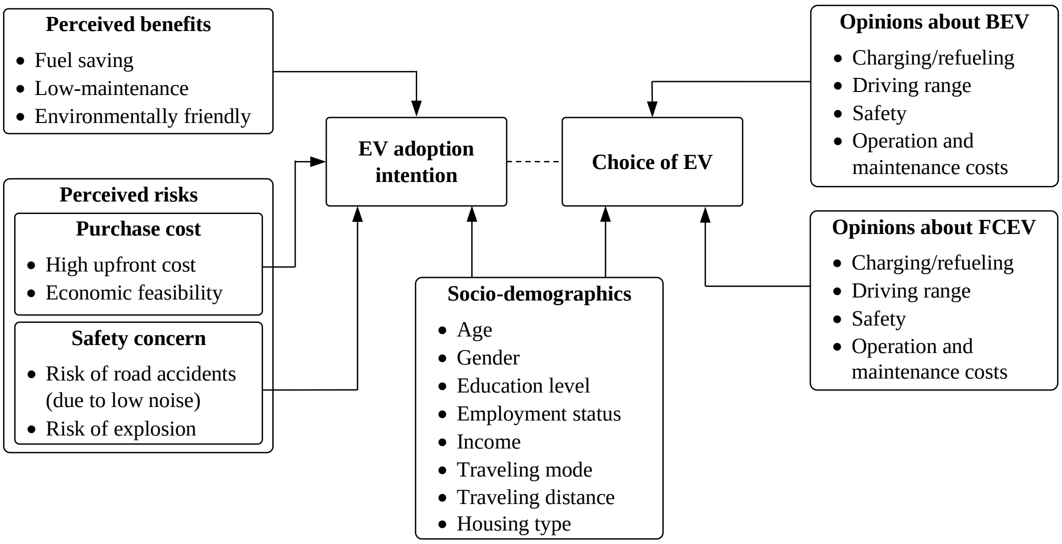


Figure 1 Conceptual model for assessing "EV adoption intention" and "choice of EV"

EV adoption intention: In this model, intention is assumed to be influenced by perceived benefits, purchase cost, and safety concerns. However, it should be noted that TAM includes another stage of latent construct, namely attitudes, before arriving at the intention to adopt. According to Featherman et al. (2021), consumer purchase decisions are influenced by a set of contradicting beliefs. Therefore, instead of integrating the contradicting beliefs into a single attitude variable, measuring them individually allows us to examine consumer purchase decisions on a more fine-grained level. Given that EVs are an expensive investment, capital cost or the purchase price needs special attention. The safety concerns have also been identified as relevant. Key benefits such as fuel economy, maintenance economy, and environmental friendliness are also expected to play a role in the EV adoption intention.

Choice of EV: This measures the users' choice of two EVs, i.e., BEV and FCEV. We hypothesize that these could be influenced by multiple factors such as refueling or charging considerations, driving ranges, and safety concerns. The reason to separate came as an afterthought, when we found that intention to adopt a generic EV was both conceptually as well as computationally separate from intention to choose a product type.

Both the EV adoption intention as well as choosing a specific type of EV product would be influenced by socio-demographic factors. At this stage, the conceptual model can be treated as a collection of hypotheses. In a subsequent section, we will delve deeper and explore the validity of the conceptual model.

3. Research methodology

3.1. Participants and procedure

Our data collection mode was online. We used the Qualtrics platform (Qualtrics 2020) to conduct the survey. The university's research ethics committee approved human ethics protocols and data privacy protection before beginning data collection, approval number ETH19-4469. The estimated time to complete the questionnaire is 10 minutes. Since the minimum age for unsupervised driving in Australia varies between states, ranging from 16.5 years to 18 years, the participants recruited were of age 18 and over. In addition, the following criteria were set: (1) geographical IP location must be Australia (2) response time must not be less than 180 seconds (3) same IP address could take the survey only once. After completing the questionnaire, respondents could earn rewards from Qualtrics.

A pilot survey of 50 samples was done in June 2020 to test the reliability and feasibility of the questionnaire design. After revising the questionnaire, a final survey of 1735 samples were conducted in July 2020, all of which are valid for analysis.

Of the participants, 41% are male and 59% are female; mean age 44.9 (SD = 16.71); mean personal income A$41187.0 per year (SD = 24484.18); median traveling distances 8.7 km per day. 56% of the participants are high school/vocational graduates and 44% are degree holders. Most of the participants (74%) reported that they use a private car for commuting, 11% use public transportation, 8% are pedestrians, and the remainder, 7%, use other modes of transportation. Most of the participants, 82%, live in a house with the remainder 18% living in apartment or other type of accommodation. From those living in a house, 39% have solar panels and 61% do not have solar panel.

3.2. Questionnaire

The questionnaire has three parts. The first part included questions about participants' socio-demographic information. In the second part, we explained the difference between petrol vehicles, BEV, and FCEV in simple words and figures to avoid misperception about EV driving range and charging (Figure 2). We chose Toyota Corolla Sedan 1.6L to represent petrol cars, Nissan Leaf S to represent BEV, and Toyota Mirai to represent FCEV. For BEV, charging time at station are assumed to be 50 kW quick charging, while the charging time at home are assumed to be 7 kW standard charging.

The third part of the survey consisted of 22 statements to measure respondents' opinions toward EV. All items in the third part were measured on a scale of 0 to 100, representing participant's level of agreement to the provided statements. Some generic questionnaire items were adapted from the literature and adjusted to the context of this study (Ghasri et al. 2019; Linzenich et al.

2019; Schmalfuß et al. 2017). The complete questionnaire is available in Appendix A (Supplementary file).

3.2.1. Perceived benefits

The scale to measure 'Perceived benefits' consists of 3 items reflecting benefits of using EV in terms of lower fuel cost, lower maintenance cost, and more environmentally friendly, as compared to petrol cars. The rating format is on a scale of 0 to 100, ranging from strongly disagree (0) to strongly agree (100). Cronbach's alpha of 'Perceived benefits' is 0.70.

3.2.2. Purchase cost

'Purchase cost' was measured with 2 items reflecting the initial cost of EV compared to petrol cars, and the economic feasibility of EV. The rating format is on a scale of 0 to 100, ranging from strongly disagree (0) to strongly agree (100). Cronbach's alpha of 'Purchase cost' is 0.37.

3.2.3. Safety concern

A two-item scale was used to measure 'Safety concern'. We included items reflecting the concern about explosion risk, and the concern about road accidents. The rating format is on a scale of 0 to 100, ranging from strongly disagree (0) to strongly agree (100). Cronbach's alpha of 'Safety concern' is 0.68.

3.2.4. EV adoption intention

The scale to measure 'EV adoption intention' consists of 2 items. These items reflected whether participants prefer EV over petrol cars, and whether they are considering buying an EV. The rating format is on a scale of 0 to 100, ranging from strongly disagree (0) to strongly agree (100). Cronbach's alpha of 'EV adoption intention' is 0.58.

3.2.5. Opinion about BEV

The opinion about BEV consists of 5 items. These items reflected participants opinion toward driving range, charging time, battery cost, and battery explosion risk. The rating format is on a scale of 0 to 100, ranging from strongly disagree (0) to strongly agree (100).

3.2.6. Opinion about FCEV

The opinion about FCEV consists of 7 items. These items reflected participants opinion toward hydrogen-based cars, driving range, hydrogen cost, hydrogen infrastructure, hydrogen tank, and hydrogen explosion risk. The rating format is on a scale of 0 to 100, ranging from strongly disagree (0) to strongly agree (100).

3.2.7. Choice of EV

Choice of EV reflected the preference between BEV and FCEV. More particularly, participants indicated to what extent they prefer BEV over FCEV on a scale of 0 to 100, ranging from strongly disagree (0) to strongly agree (100).

Section 2: Explanations about BEVs and FCEVs

EVs are vehicles with electric motors and include:

Battery electric vehicles (BEVs) have an electric motor and a large battery that recharges by connecting to external power supply. BEVs are fully electric and have zero tailpipe emissions. Because of their simplicity and reliability of the electric motor, they have lower running costs. Examples of BEVs are Renault Zoe, BMW i3, Tesla Model S, Nissan Leaf.

Hydrogen fuel cell vehicles (FCEVs) convert compressed hydrogen into electricity to power an electric motor and, like BEVs, have zero tailpipe emissions. FCEVs are not yet on sale in Australia and are only a small proportion of EV fleets in other countries. They are generally more expensive but offer the advantages of longer operating ranges, lighter weight and rapid refuelling capability, which may suit long distance freight operation, once available. Examples of FCEVs are Toyota Mirai, Hyundai ix35 Fuel Cell, Honda Clarity Fuel Cell.

(Source: NSW Electric and Hybrid Vehicle Plan, Future Transport 2056)

	Petrol	Battery EV	Hydrogen Fuel Cell EV
	TOYOTA Corolla Sedan 1.6L	**NISSAN Leaf S**	**TOYOTA Mirai**
Buying price		1.6x of petrol car	3x of petrol car
Driving range	700 km	270 km	550 km
Refueling/charging price		-62% compared to petrol	-34% compared to petrol
Refueling/charging time at station	5 min	60 min	5 min
Refueling/charging time at home (when available)	5 min IF AVAILABLE	8 hour IF AVAILABLE	5 min IF AVAILABLE

Figure 2 The explanations about the difference between petrol vehicles, BEV, and FCEV provided at the beginning of the survey (For picture sources, see Appendix B in supplementary file)

3.3. Analyses

Our exploratory analysis consisted of three stages. We first started with descriptive statistical analyses of the attitudinal questions using R (RStudio Team 2020). Then, we employed partial least squares structural equation modeling (PLS-SEM) to examine factors affecting EV adoption intentions, using SmartPLS software version 3.3.3 (Ringle et al. 2015). Finally, we used multinomial logistic regression (MLR) to examine factors influencing the choices between BEV and FCEV, using SPSS version 28.0.

Regarding the examination of factors affecting EV adoption intentions, it is worth noting that our focus is to explore and predict the relationship between the input data on measures of perceived benefits, purchased costs, and safety concerns, and the output measures of intention. We are not looking to carry out any theory testing. In addition, SEM offers the ability to construct latent variables from observed variables (Chin & Marcoulides 1998). Therefore, PLS-SEM is the appropriate technique for this task (Reinartz et al. 2009). Meanwhile, a multinomial logistic regression allows us to predict the probability that a respondent belongs to a pre-defined group (preferring BEV or FCEV in our case) by ascertaining which independent variables best explain the variance of the categorical dependent variable (Langer et al. 2018). Therefore, this approach is appropriate for the examination of factors influencing the choices between BEV and FCEV.

3.3.1. PLS-SEM model evaluation

3.3.1.1. Common method bias

Harman's one-factor test was performed to test common method bias. The test results indicate 17.6% of the variance is explained by the measurement items. Thus, the common method bias should not be a concern in this study (Harman 1976).

3.3.1.2. Measurement model assessment

The constructs in this study are formed reflectively. For the reflective construct, three criteria should be examined, namely internal consistency reliability, convergent validity, and discriminant validity (Hair et al. 2017). Cronbach's alpha and composite reliability are used to identify internal consistency reliability. As shown in Appendix G, the Cronbach's Alpha of the purchase cost and the intentions constructs were 0.37 and 0.58, smaller than the threshold value of 0.6. The composite reliability value of all constructs was larger than the threshold value of 0.6. However, as suggested by Chin & Marcoulides (1998) and Hair et al. (2017), Cronbach's Alpha tends to underestimate the internal consistency reliability. Since the composite reliability value of the purchase cost and the intentions constructs were satisfactory, its internal consistency reliability is therefore valid.

Next, convergent validity was tested based on factor loading and average variance extracted (AVE). The results of a bootstrapping procedure with 5,000 samples showed that factor loading values of all items are significant. However, there were 2 items that have factor loadings below the acceptable value of 0.7. As suggested by Hair et al. (2017), items with weaker factor loading (< 0.7) can be retained in order to maintain content validity. The threshold value of 0.4 indicates the very low factor loading that the item should be eliminated. Since factor loadings of the 2 items were 0.537 and 0.622, we decided to retain the items to maintain content validity. On the other hand, the AVE value of all constructs was greater than the recommended value of 0.5. Therefore, convergent validity of the measurement model is confirmed.

Lastly, cross-loadings and the Fornell-Larcker criterion were used to examine discriminant validity. The requirement for discriminant validity is that the items should load more on their intended constructs than on other constructs (Hair et al. 2017). For the Fornell-Larcker criterion, the square root of the AVE should be larger than the highest correlation with any other construct (Hair et al. 2017). The results show that all item's loadings on associated construct were greater than their cross-loading on other constructs (Appendix E). At the same time, square root of the AVE was larger than the highest correlation with any other construct (Appendix F). Therefore, these examinations confirm the discriminant validity of the measurement model.

3.3.1.3. Structural model assessment

Structural model assessment consists of four criteria, namely indicator collinearity (Variance inflation factor (VIF)), the coefficient of determination (R^2 value), the f^2 effect size, and the predictive relevance Q^2. The assessment results show that all VIF values of the items were below 5, indicating no collinearity issue (Hair et al. 2017). The R^2 value represents a measure of in-sample predictive power. The R^2 value was 0.237, indicating a moderate level of predictive accuracy in behavioral research (Cohen 1992). Meanwhile, the f^2 effect size indicates the relative impact of a predictor construct on a target construct. All relationships had small effects with f^2 ranging from 0.026 to 0.104. (Hair et al. 2017). According to Chin et al. (2003), a small effect size does not necessarily mean an unimportant effect. On the other hand, the Q^2 value is an indicator of the out-of-sample predictive power of the model. The Q^2 value was above zero, confirming that items are well reconstructed, and the model has predictive relevance among endogenous variables in the model.

3.3.2. Multinomial logistic regression model reliability

The model was first assessed for the independent of the irrelevant alternatives (IIA) by checking the VIF value. All independent variables had a VIF value lower than 5.0, indicating no multicollinearity issue (Hair et al. 2017). Therefore, IIA assumption holds. The likelihood-ratio test showed a Chi^2 of 642.188; $p < 0.001$, indicating a good fit of the model (Langer et al. 2018). The Pearson Chi-Square goodness-of-fit display a non-significant ($p = 0.073$), indicating again a good fit of the model (Allison 2014). On the other hand, the McFadden's pseudo-R^2 value was 18.5%, indicating moderate reliability (Langer et al. 2018). Finally, the classification accuracy was 61.7%, larger than the proportional by chance accuracy of 48.3%, indicating model is useful in predicting the preference for BEV versus FCEV (White 2013).

4. Results

4.1. Descriptive statistics

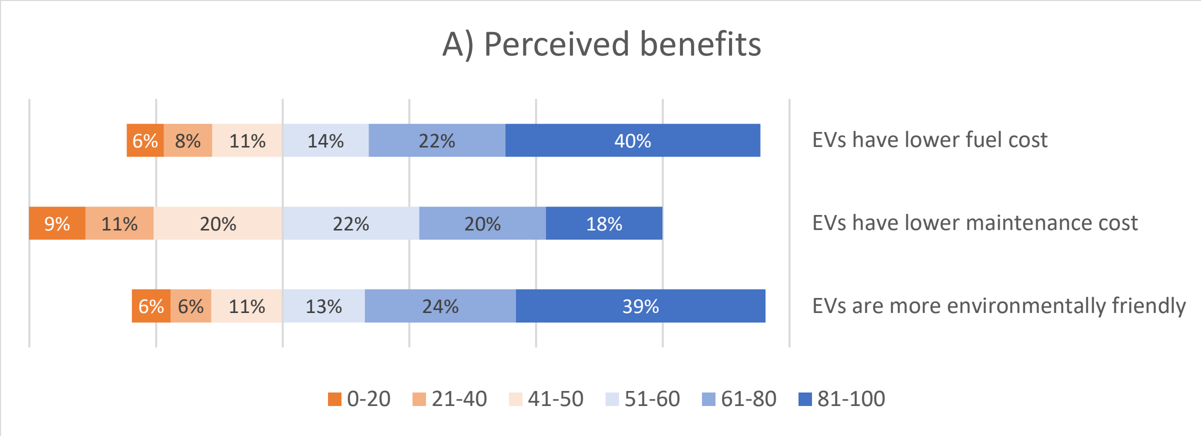
Figure 3 illustrates the percentage of opinion toward each provided statement. The scales were divided into 6 levels of agreement, namely 0-20, 21-40, 41-50, 51-60, 61-80, and 81-100. The levels of agreement of 0-20 and 81-100 are considered as “strongly disagree” and “strongly agree”, respectively. The intervals of 21-40 and 61-80 are interpreted as “disagree” and “agree”. Meanwhile, the level of agreement between 41-60 is considered “neutral”. The means and standard deviations of each statement are presented in Appendix A in supplementary file.

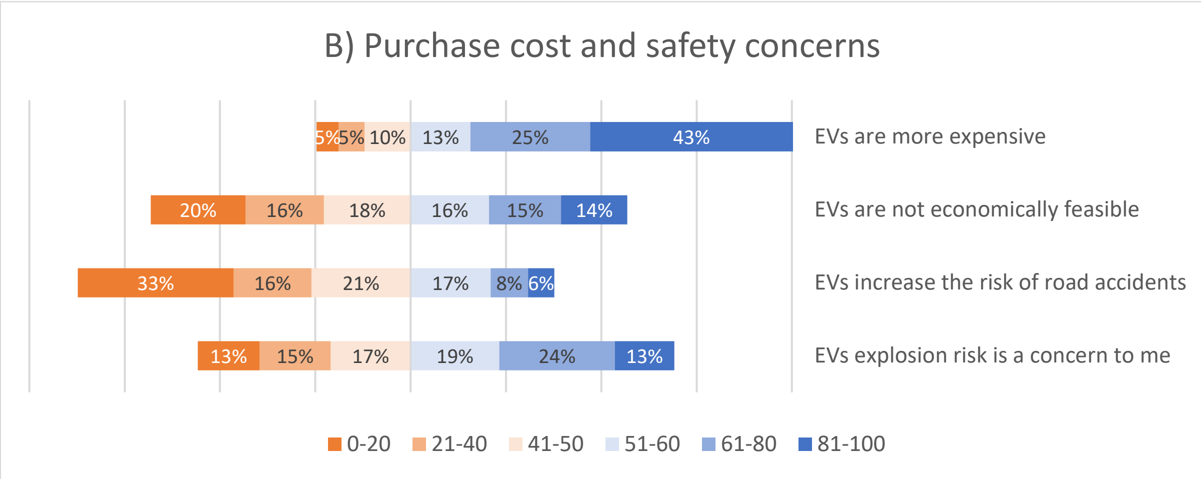
Most participants agreed that, compared to conventional vehicles, EV are more environmentally friendly, have lower fuel costs, but are more expensive. Approximately 40% of participants strongly agreed with these statements (Figure 3A and Figure 3B). Despite the high percentage of participants expressing their agreement that EVs are more expensive than conventional cars, more than half of participants believed that EVs are economically feasible, with 20% of participants expressing their strong agreement (Figure 3B). In addition, 38% of the participants agreed that EVs have lower maintenance costs than conventional vehicles, with 18% of participants strongly agreeing (Figure 3A). Although participants seem to have positive perceptions toward EV, almost half of the participants indicated that they prefer petrol cars over EV (27% strongly agree, 20% agree). Besides, only 4% of the participants stated that they are considering buying an EV (Figure 3E). Regarding safety concerns, 37% of the participants expressed their concern about the explosion risk of EV, while almost half of the participants (49%) did not think that EVs increase the risk of road accidents (Figure 3B).

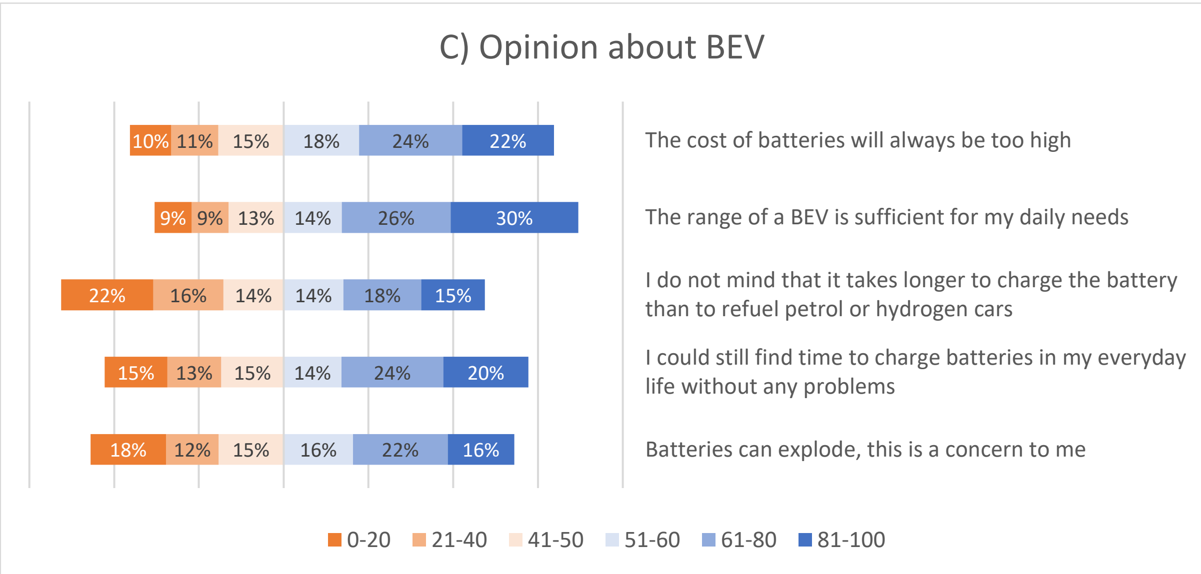
More than half of the participants stated that they did not know the difference between BEV and FCEV before reading our explanations. If choosing between BEV and FCEV, 38% of the participants prefer BEV, while 42% were neutral.

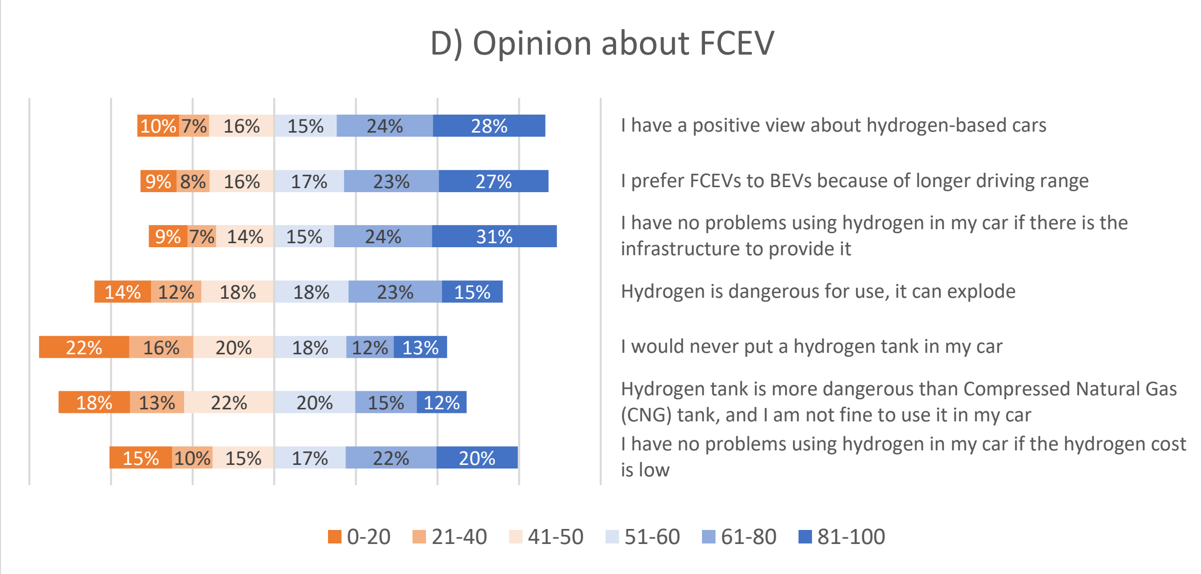
Regarding specific attitudes toward BEV (Figure 3C), there is a slightly higher fraction of participants concerned about the long charging time of BEV (38%) than those who are not (33%). Interestingly, however, almost half of the participants indicated that they could still find time to charge batteries in their daily life without any problems. In terms of the BEV driving range, more than half of the participants indicated that the driving range of BEV is sufficient for their daily needs (30% strongly agree, 26% agree). In addition, almost half of the participants believed that the cost of batteries would always be too high. Regarding safety concerns, 16% of the participants strongly agree, and 22% agree with the concern over battery explosion.

In the case of FCEV (Figure 3D), at least half of the participants indicated a positive attitude toward hydrogen-based cars. 44% of participants stated their acceptance of using hydrogen for their vehicle if the cost is low. Meanwhile, 55% of the participants expressed their acceptance of using hydrogen for their vehicle if there is the infrastructure to provide it, with only 16% rejecting it. Moreover, half of the participants stated they would prefer FCEV to BEV because of the more extended driving range. Regarding safety concerns, 15% of the participants strongly agree, and 23% agree with the concern over hydrogen explosion. In the case of the hydrogen tank, 38% of participants indicated a positive attitude towards putting hydrogen tanks in their cars, and 38% were neutral. Meanwhile, 27% of the participants were concerned that the hydrogen tank is more dangerous than the CNG tank.


A) Perceived benefits
6% 8% 11% 14% 22% 40%
EVs have lower fuel cost
9% 11% 20% 22% 20% 18%
EVs have lower maintenance cost
6% 6% 11% 13% 24% 39%
EVs are more environmentally friendly
0-20 21-40 41-50 51-60 61-80 81-100


B) Purchase cost and safety concerns
5% 5% 10% 13% 25% 43%
EVs are more expensive
20% 16% 18% 16% 15% 14%
EVs are not economically feasible
33% 16% 21% 17% 8% 6%
EVs increase the risk of road accidents
13% 15% 17% 19% 24% 13%
EVs explosion risk is a concern to me
0-20 21-40 41-50 51-60 61-80 81-100


C) Opinion about BEV
10% 11% 15% 18% 24% 22%
The cost of batteries will always be too high
9% 9% 13% 14% 26% 30%
The range of a BEV is sufficient for my daily needs
22% 16% 14% 14% 18% 15%
I do not mind that it takes longer to charge the battery than to refuel petrol or hydrogen cars
15% 13% 15% 14% 24% 20%
I could still find time to charge batteries in my everyday life without any problems
18% 12% 15% 16% 22% 16%
Batteries can explode, this is a concern to me
0-20 21-40 41-50 51-60 61-80 81-100



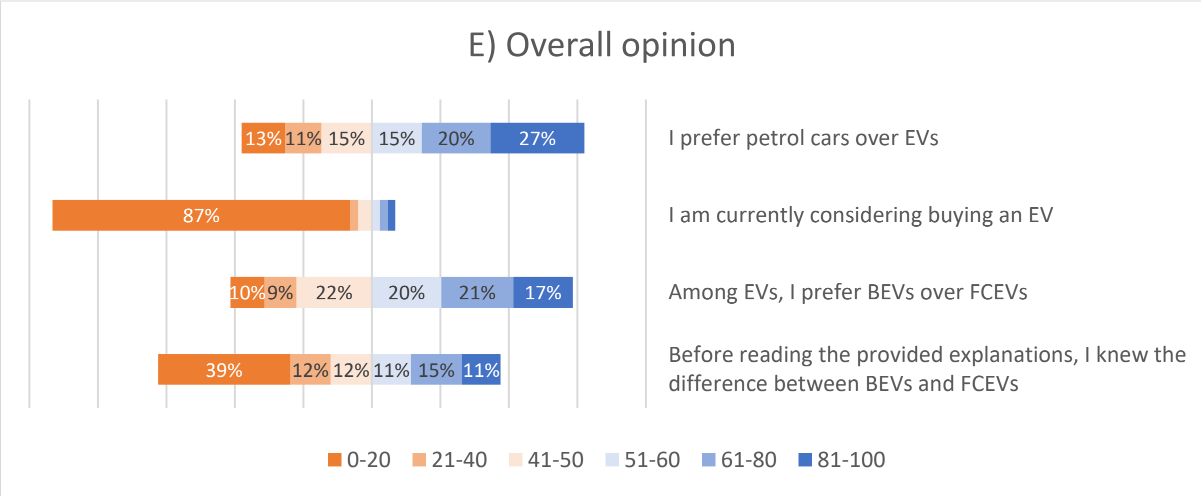


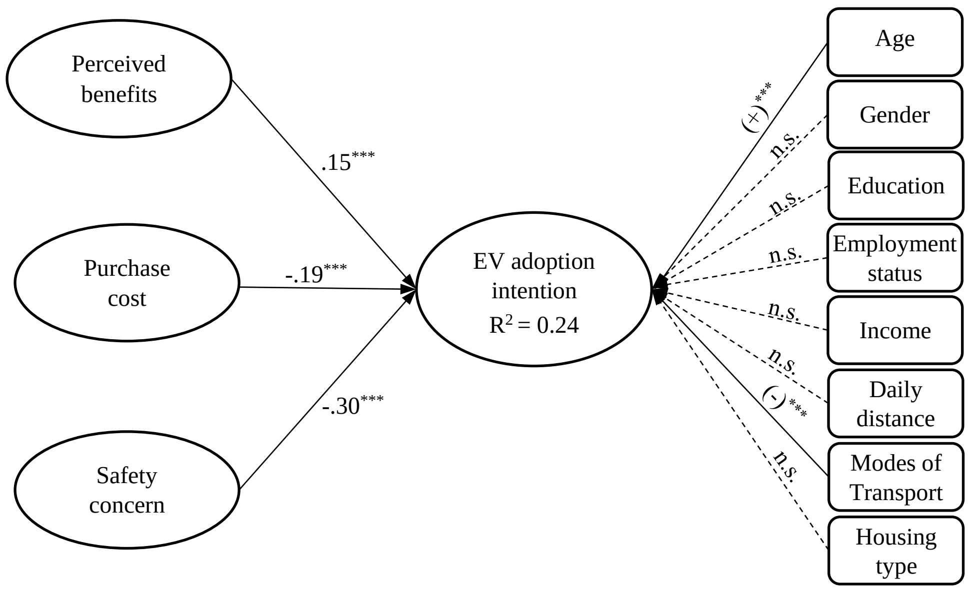
Figure 3 Perceptions towards EV

4.2. The influential factors of EV adoption intention

Before running the PLS algorithm, all the socio-demographic variables were reorganized into fewer levels (see Appendix D in supplementary file) and converted to dummy variables (Benitez et al. 2020). It should be noted that 13 responses in the ‘intersex’ and ‘prefer not to answer’ gender categories were unavoidably excluded from the modeling. With these response categories combined (13 responses out of the total of 1735 responses), they constitute less than 1%. While these responses shed light on responses from minority groups and are hence important, they were not useful for model development. As a result, the sample size for PLS-SEM was 1722.

Figure 4 presents the structural equation model results that examine factors that promote or hinder EV adoption intention. According to the significance of the path coefficients, perceived benefits, purchase cost, and safety concerns are significant predictors of EV adoption intention at a significance level of 0.001. By looking at the sign of the path coefficients, perceived benefits positively influence adoption intention, while purchase cost, and safety concern negatively influence adoption intention. In other words, perceived benefits are a driver of EV adoption intention, while purchase cost, and safety concern are barriers to the adoption intention. In addition, by looking at the magnitude of the path coefficients, the impact of each the two barriers on consumers' EV adoption intention are larger than the impact of the positive driver. To be more precise, safety concern (path coefficient = -0.299) is the strongest predictor of EV adoption intention, followed by purchase cost (path coefficient = -0.190), and perceived benefits (path coefficient = 0.147). These results suggest that in order to enhance EV adoption intention, emphasis should be given to mitigate safety concerns. Considering that consumers are less familiar with EV than with conventional vehicles, therefore trust is lacking. Furthermore, lowering purchase cost could also enhance EV adoption intention. Given that the current EV price is relatively high compared to conventional cars in the market.

Regarding the socio-demographic variables, an interpretation is similar to the regression analyses with dummy variables (Hair et al. 2013). A positive coefficient means that EV adoption intention is higher for the dummy variable than for the reference group. In contrast, a negative coefficient means that EV adoption intention for the dummy variable is lower than for the reference group. Other than the sign of the variable (positive or negative), the magnitude of the coefficients is not interpretable (and hence are not shown in the forthcoming figure). Based on our results, there are statistical differences in EV adoption intention across age groups and modes of transportation. Within the 'Age' variable, the '56 and more' age group is assigned as a reference group. Therefore, based on the positive sign of the coefficient, EV adoption intention for the '18-35' and '36-55' age groups are significantly higher than for the '56 and more' age group. In other words, younger age groups are more interested in adopting EV than older age groups. On the other hand, the coefficient of the 'Mode of transport' variable is negative. Since the 'Other mode of transport' is assigned as a reference group, the results suggest that EV adoption intention for the 'personal car' group is significantly lower than for the 'Other mode of transport' group. In other words, personal car users have lower intention to adopt EV than the users of the other modes of transportation, such as public transport and pedestrians.



Path significance: *** $p < 0.001$; n.s. = not significant
Socio-demographic variables are dummy coding
Age groups include: 18-35, 36-55, and 56 and more (the 56 and more is the reference group)
Modes of transport include: personal car, and other mode of transport (other mode of transport is the reference group)

Figure 4 Results of PLS-SEM showing factors affecting consumers' EV adoption intentions

4.3. The influential factors of EV choices

Before performing a multinomial logistic regression, outliers are identified and removed. A standardized residual greater than 3.0 or smaller than -3.0 is considered an outlier. Besides, a Cook's distance larger than 1.0 is considered an influential outlier. The original scale of the dependent variable was a level of agreement ranging from 0 to 100. Due to the distribution of the responses, the dependent variable was transformed into a nominal variable with three categories, namely preferring BEV, preferring FCEV, and being undecided. A series of preliminary analyses was tested to find an optimal cut-off value for each category. Finally, the dependent variable was transformed to 0-35 refer to preferring FCEV, 36-64 refer to undecided, and 65-100 refer to preferring BEV.

The relationship of independent and dependent variables is presented in Table 1. We investigated factors that were statistically significant in separating between (1) preferring BEV versus FCEV, (2) preferring BEV versus being undecided, and (3) preferring FCEV versus being undecided. Bold typed figures indicate significant factors.

Table 1 Multinomial logistic regression results

Variables	**BEV vs. FCEV**			**BEV vs. Undecided**			**FCEV vs. Undecided**		
	B	**Sig.**	**Exp(B)**	**B**	**Sig.**	**Exp(B)**	**B**	**Sig.**	**Exp(B)**
Hight battery cost	**0.009**	**0.019**	**1.009**	0.004	0.138	1.004	-0.005	0.136	0.995
BEV range sufficiency	**0.036**	**0.000**	**1.036**	**0.022**	**0.000**	**1.023**	**-0.014**	**0.000**	**0.987**
Tolerability in the BEV charging time	**0.036**	**0.000**	**1.036**	**0.010**	**0.002**	**1.010**	**-0.026**	**0.000**	**0.974**
Ability to allocate time to charge batteries	0.007	0.144	1.007	**0.009**	**0.012**	**1.009**	0.002	0.666	1.002
Batteries explosion risk concern	**-0.013**	**0.005**	**0.987**	-0.006	0.091	0.994	0.007	0.067	1.007
Positive view about hydrogen-based cars	-0.008	0.097	0.992	-0.002	0.456	0.998	0.005	0.186	1.005
FCEV longer driving range	**-0.014**	**0.001**	**0.986**	-0.005	0.070	0.995	**0.009**	**0.016**	**1.009**
Hydrogen infrastructure	0.000	0.975	1.000	0.001	0.851	1.001	0.001	0.908	1.001
Hydrogen explosion risk concern	**0.033**	**0.000**	**1.033**	**0.017**	**0.000**	**1.017**	**-0.016**	**0.001**	**0.984**
Refusal of putting hydrogen tank in cars	**0.020**	**0.000**	**1.020**	0.007	0.050	1.007	**-0.013**	**0.005**	**0.987**
Dangers of hydrogen tank concern	**0.015**	**0.010**	**1.015**	**0.008**	**0.046**	**1.008**	-0.007	0.158	0.993
Acceptance of hydrogen if the cost is low	-0.005	0.272	0.995	**-0.007**	**0.017**	**0.993**	-0.002	0.530	0.998

Variables	BEV vs. FCEV			BEV vs. Undecided			FCEV vs. Undecided		
	B	**Sig.**	**Exp(B)**	**B**	**Sig.**	**Exp(B)**	**B**	**Sig.**	**Exp(B)**
Demographic:									
Age 18-35*									
Age 36-55	-0.171	0.430	0.843	0.030	0.833	1.031	0.201	0.295	1.223
Age 56 and more	-0.268	0.264	0.765	-0.089	0.593	0.915	0.179	0.390	1.196
Male*									
Female	-0.080	0.667	0.924	**-0.502**	**0.000**	**0.606**	**-0.422**	**0.010**	**0.656**
Intersex and prefer not to answer	0.068	0.957	1.071	-0.982	0.165	0.374	-1.051	0.346	0.350
Lower than bachelor's*									
Bachelor's	0.352	0.099	1.421	**0.289**	**0.041**	**1.335**	-0.063	0.743	0.939
Higher than bachelor's	0.031	0.908	1.032	0.175	0.349	1.191	0.143	0.553	1.154
Working full time*									
Working part time	**0.668**	**0.021**	**1.951**	0.125	0.501	1.133	**-0.543**	**0.035**	**0.581**
Student, unemployed, others	0.041	0.876	1.042	-0.071	0.688	0.931	-0.112	0.626	0.894
Up to $60,000*									
More than $60,000	**0.496**	**0.039**	**1.642**	0.290	0.069	1.336	-0.207	0.336	0.813
Up to 20 km*									
More than 20 km	-0.287	0.183	0.750	-0.130	0.390	0.878	0.157	0.401	1.170
Personal car*									
Other modes of transportation	-0.192	0.358	0.825	0.111	0.437	1.117	0.303	0.103	1.353
House with solar panel*									
House without solar panel	-0.249	0.222	0.779	-0.130	0.335	0.878	0.119	0.510	1.127
Apartment and others	**-0.520**	**0.045**	**0.594**	-0.152	0.398	0.859	0.369	0.107	1.446

* Reference category

4.3.1. BEV vs. FCEV

For the choice between BEV and FCEV, the sufficiency of the range of BEV (B = 0.036 ; p < 0.000), the tolerability in the longer charging time (B = 0.036 ; p < 0.000), the concern about hydrogen explosion (B = 0.033 ; p < 0.000), the concern about the dangers of the hydrogen tank (B = 0.015 ; p < 0.05), and the refusal of the hydrogen tank (B = 0.020 ; p < 0.000) significantly increases the probability of preferring BEV over FCEV. If the participants believed that the range of BEV is sufficient, or they can tolerate the long charging time, the likelihood of preferring BEV increase by a factor of 1.036. Similarly, if the participants concern about hydrogen explosion, concern about the dangers of hydrogen cylinder, or refuse to have hydrogen cylinder in their cars, the probability of preferring BEV increase by a factor of 1.033, 1.015, or 1.020. Contrary to our expectations, if the participants believed that the cost of battery will always be too high (B = 0.009; $p < 0.05$), the likelihood of preferring BEV still increase by a factor of 1.009. The possible explanation for this counterintuitive result is that BEV usually comes with a battery warranty from the manufacturers. Therefore, consumers may be less worried about the battery cost. The results also revealed that part-time workers (B = 0.668; $p < 0.05$) are more likely to prefer BEV over FCEV than full-time workers. Furthermore, participants who earn more than $60,000 a year (B = 0.496; $p < 0.05$) tend to prefer BEV over FCEV than those who earn less than $60,000 a year.

On the other hand, if the participants appreciated the longer driving range of FCEV (B = -0.014; $p < 0.01$), or fear of battery explosion (B = -0.013; $p <0.01$), the probability of preferring BEV over FCEV would be 0.986 or 0.987 times lower. As expected, apartment residents (B = -0.520; $p < 0.05$) are less likely to prefer BEV over FCEV than those who live in a house with solar panels.

By looking at the logistic regression coefficient (B), the coefficient of the most influential factors for the support of BEV (B = 0.036) are approximately two times larger than the coefficient of the most influential factors for the support of FCEV (B = -0.014). These indicate that when people believe that the range of BEV is sufficient, or they can tolerate the long charging time, their probability of support BEV is stronger than their probability of support FCEV when they value the longer driving range of FCEV. In the case of concern about explosion risk, the influence of concern about hydrogen explosion (B = 0.033) on the support of BEV (in other words, decrease the support of FCEV) is stronger than the influence of concern about battery explosion (B = -0.013) on the support of FCEV (decrease the support of BEV).

4.3.2. BEV vs. undecided

For the decision between preferring BEV and being undecided, the results are somewhat consistent with the results of the choice between BEV and FCEV. That is, if the participants believed that the range of BEV is sufficient ($B = 0.022$; $p < 0.000$), or they can tolerate the long charging time ($B = 0.010$; $p < 0.01$), the likelihood to prefer BEV (rather than being undecided) increase by a factor of 1.023 or 1.010. In addition, if the participants believed that they could manage to have time to charge battery ($B = 0.009$; $p < 0.05$), the probability to prefer BEV (rather than being undecided) increase by a factor of 1.009. Again, if the participants concern about hydrogen explosion ($B = 0.017$; $p < 0.000$), or concern about the dangers of hydrogen cylinder ($B = 0.008$; $p < 0.05$), the likelihood to prefer BEV (rather than being undecided) increase by a factor of 1.017 or 1.008. The results also revealed the roles of the education level. That is the bachelor's degree holders ($B = 0.289$; $p < 0.05$) are more likely to prefer BEV (rather than being undecided) than those who do not qualify for a bachelor's degree.

On the other hand, if the participants have no problem to use hydrogen if the cost is low ($B = -0.007$; $p <0.05$), the probability to prefer BEV (rather than being undecided) would be expected to lower by 0.993 times. Besides, gender seems to play a role in negatively influencing the preference for BEV. Based on our results, female ($B = -0.502$; $p < 0.000$) are less likely to prefer BEV (rather than being undecided) as compared to male.

4.3.3. FCEV vs. undecided

For the decision between prefer FCEV and being undecided, the results indicated that if the participants value the longer driving range of FCEV ($B = 0.009$; $p < 0.05$), the probability to prefer FCEV (rather than being undecided) increase by a factor of 1.009.

On the other hand, if the participants believed that the range of BEV is sufficient ($B = -0.014$; $p < 0.000$), or they can tolerate the long charging time of BEV ($B = 0.026$; $p < 0.000$), the likelihood to prefer FCEV (rather than being undecided) would be expected to be lower by 0.987 or 0.974 times. Moreover, if the participants concern about hydrogen explosion (B = -

0.016; p < 0.01) or refuse to have hydrogen cylinder in their cars (B = -0.013; p < 0.01), the likelihood to prefer FCEV (rather than being undecided) would be 1.017 or 1.008 times lower. Again, females are more likely to be being undecided than males. Based on our results, female (B = -0.422; p < 0.05) are less likely to prefer FCEV (rather than being undecided) as compared to male. Similarly, the part-time workers (B = -0.543; p <0.05) are less likely to prefer FCEV (rather than being undecided) than full-time employee.

5. Discussion

The study shows that, overall, most of the participants were positive about EV, especially because EV are more environmentally friendly and have lower operational costs than conventional vehicles. In addition, despite their agreement that EV are more expensive than conventional vehicles, more than half of the participants believe that EV are economically feasible. Although participants are likely optimistic about EV, more than half of participants indicated that they still prefer petrol cars over EV.

The results of PLS-SEM showed that perceived benefits have a significant positive impact on the intention to adopt EV. In contrast, purchase cost and safety concerns have significant negative impacts on EV adoption intention. These findings were in line with the results of several studies (Browne et al. 2012; Hardman et al. 2017; Park et al. 2018; Perry 2016; Tarigan 2019; Wang et al. 2018; Yang et al. 2020). More importantly, our findings emphasize safety concerns as a main barrier to EV adoption, followed by high purchase cost. This could be a reason to explain why most of the participants agree with the benefits of EV both in terms of expenditure saving and environmentally friendly, they still prefer petrol cars. These findings are consistent with Orlov & Kallbekken (2019) findings, which found that cost-saving and environmental impact of EV do not appear to be the main driver for the adoption. However, it is somewhat in contrast with the results of Degirmenci & Breitner (2017), which found that the environmental performance of EV has a more substantial effect on adoption intention than price value. These different findings might be explained by the fact that the studies were conducted in different countries. Therefore, not only cultural differences but also differences in EV-related situational factors, such as energy price, existing infrastructure, and government policy, may lead to different results.

Regarding socio-demographic variables, our results showed that age and current mode of transportation significantly impact EV adoption intentions. Our result showed that the participants in younger age groups are more interested in adopting EV than older age groups. This is intuitive that early adopters of new technology are believed to be young people, as older people are generally more conservative. However, this is in contrast with the studies in Korea (Kim et al. 2019) and Sweden (Westin et al. 2018). The possible explanation for these conflicting results is that the effect of age may differ by country, as also found in a comparative study conducted by Habich-Sobiegalla et al. (2018) among Chinese, Russian, and Brazilian. In addition, our results indicate that personal car users have lower intention to adopt EV than the users of the other modes of transportation, such as public transport and pedestrians. According to Krishna (2021), when people purchase a car, they tend to use it until its end of life. As a result, personal car users may stick with their present cars and do not consider buying any new ones in the near future.

In addition to investigating factors that influence EV adoption intention, we also examine factors that influence the preferences for BEV and FCEV. After explaining the differences between the two types of EV and conventional cars (see Figure 2), we then investigated participants’ perceptions of BEV and FCEV. As expected, the survey results indicated that many participants did not know the difference between the two EV before the survey.

Based on the multinomial logistic regression results, it was found that the BEV range sufficiency, the tolerability in the long charging time of BEV, and the concern about the hydrogen explosion are the most influential factors for the support of BEV. On the other hand, the longer driving range of FCEV, and the concern about battery explosion are the most influential factors for the support of FCEV.

In this study, range anxiety may not negatively affect the preference for BEV because most of the respondents in our study (93%) have a daily traveling distance of less than 50 kilometers, which is within the range of BEV. Regarding the BEV charging time, our findings are somewhat consistent with the findings of Carley et al. (2013) which found that the length of charging time is believed to be the least problematic, compared purchase price and driving range. Meanwhile, the significant impact of the concerns about hydrogen and cylinder safety is consistent with the findings of Hardman et al. (2017), which found that safety concerns pertaining to hydrogen storage are barriers to adopting FCEV.

In the case of FCEV, our finding is consistent with Hardman et al. (2017) that although the BEV range is enough, there is a demand for the longer range of FCEV. The range of BEV can fulfil daily needs but may not be enough for other use cases, such as holiday trips. Users may need to find solutions for such long-distance trips (Melliger et al. 2018). Meanwhile, the impact of the concern about battery explosion in influencing the support of FCEV may be because there are reports about fire and explosion of BEV during charging or while parking in the recent year (Barelli et al. 2021; Christensen et al. 2021).

Considering the strength of the influence, the results showed that BEV influencing factors are two times stronger than that of FCEV. At this point, we may infer that consumers are more confident with BEV than FCEV. Even though the longer driving range of FCEV is attractive, the impact of the concern about hydrogen safety is larger. This is not surprising because FCEV are less mature. More importantly, our results indicated that there is limited awareness about the differences between BEV and FCEV among the respondents (Figure 3D). Prior studies emphasized the importance of awareness in the successful spread of energy-saving products (Ha & Janda 2012), as well as FCEV (Kar et al. 2022; Schneider 2017).

Furthermore, we also found that the low cost of hydrogen could also work against the preference for BEV. Accepting hydrogen if the cost is low influences the respondents to be undecided rather than preferring BEV. This might be because hydrogen, as vehicle fuel, has not yet been commercially available, and thus the cost is believed to be expensive. Our results are in line with the findings of Hardman et al. (2017) that FCEV will not be competitive unless the cost of hydrogen refueling is cheap.

Regarding socio-demographic variables, employment status and income appears to be the influential factors for the support of BEV. Part-time workers are more likely to support BEV than full-time workers. The potential explanation for the significant impact of the employment status could be that part-time workers might be more flexible with their time arrangement. As a result, they might be less worried about allocating time to charge BEV and plan their trips. For income, the high-income group are more likely to support BEV than low-income group. This might be because BEV are readily available in the market, and it is more affordable for high-income people.

In the case of FCEV, living in an apartment shows the propensity to support FCEV. Our findings also support the results of Khan et al. (2020) that apartment parking significantly affects consumer preferences for FCEV. People who live in an apartment may not find it as convenient as those who live in a house. According to Krishna (2021), it is difficult for the residents of rented apartments to install BEV chargers, as they need to get approval from their landlords. Apartment occupants are more likely to prefer FCEV than BEV because of the unavailability of battery charging infrastructure in the apartment parking, while hydrogen refueling is similar to conventional gasoline/diesel refueling in that no infrastructure installation is required.

In addition, we also found the influence of gender on being undecided. A previous study (Sovacool, Kester, et al. 2019) concludes that men valued EV's speed, acceleration, and symbolic attributes. In contrast, women tended to prioritize safety and convenience. As supported by our results, females appear to be a significant factor in being undecided rather than preferring BEV or FCEV. This implies that when considering vehicle attributes, compared to males, females feel more uncertain with both new technologies that are different from familiar conventional ones.

6. Theoretical and practical implications

6.1. Theoretical implications

This study provides theoretical implications for factors that influence to adoption of alternative fuel vehicles. This study underlines safety issue as an important factor of adoption intention of emerging vehicle technologies. In a broader view, safety concern is a stronger predictor of adoption intention of emerging vehicle technologies than purchase cost and perceived benefits. When considering between the two alternatives, safety concern still play an important role along with other technical attributes. Future research in the vehicle adoption should consider include safety concern as one of the influential factors.

6.2. Policy implications

The findings of this research have several implications for promoting the adoption of EV. Firstly, considering the negative effect of purchase cost and given that Australia still lacks policies that support the uptake of EV, some financial incentives can help. The importance of financial incentives for EV adoption is confirmed by the prior studies (Ghasri et al. 2019; Hackbarth & Madlener 2013; Jenn et al. 2020; Jenn et al. 2018; Kim et al. 2019; Li et al. 2020; Wee et al. 2018). The existing state government EV subsidies such as stamp duty exemptions and vehicle registration discounts seem inadequate in making EV cost competitive. In addition, considering the significant differences in the intention to adopt EV between the private car users and the other modes of transportation, these two groups of consumers might be attracted by different incentive schemes. Making EV cost-competitive would be an attractive incentive for first-time car buyers. Meanwhile, for car owners, trade-in programs might encourage them to replace their conventional cars with EV as their next cars.

Secondly, considering the considerable negative impact of safety concerns on the intention to adopt EV, as well as the significant impact of the concern about battery explosion, and the safety of hydrogen and hydrogen tank when choosing between BEV and FCEV. Establishing regulations, codes, standards, as well as development of risk mitigation strategies can help build trust and address safety concern. For example, crash testing in line with national standard that consumers are familiar with (Hardman et al. 2017). Unarguably, EV are less mature compared to conventional vehicles. Similarly, FCEV are less mature compared to BEV. Therefore, there is the need to ensure consumer about the safety-related issues so that both BEV and FCEV can achieve the same trustworthy level as conventional vehicles.

Lastly, considering the limited awareness about the differences between BEV and FCEV among the respondents, as well as the difference in the strength of the supporting factors of BEV and FCEV, educating consumers about BEV and FCEV features is an effective measure to enhance consumer acceptance and accelerate the successful phase-out of the internal combustion cars powered by diesel or petrol. Providing knowledge can help consumers to be clearer about the features of different vehicle technologies. As BEV and FCEV have different pros and cons, they can complement each other in replacing conventional vehicles. Governmental agencies and EV dealers can disseminate information to explain the performance and benefits of EV. More importantly, by providing knowledge and information regarding risks we can also reduce consumers' safety concerns. Furthermore, offering driving and charging/refueling experiences can also reduce safety concerns. In fact, test driving activity is not new in conventional vehicle marketing campaigns. However, in the case of BEV and FCEV, charging/refueling experiences is especially relevant to build consumer confidence because BEV charging and FCEV refueling is totally different from refueling petrol cars. The role of experience in enhancing perceived benefits and addressing concern have been confirmed by Egbue & Long (2012), Bühler et al. (2014), and Lipman et al. (2018).

7. Limitations

This research is subject to several limitations. First, considering the online questionnaire survey, we were unable to control the survey situation. The participants were those who happen to have internet access and decided to fill in the questionnaire. Therefore, selection biases exist in this study. Our sample might not be representative of the general population. As a result, our results are not generalizable. Second, this research did not analyze participants experience with EV which could influence the results. Thus, future research should take experience with EV of the participants into consideration. The third limitation regards the scale reliability. The scale in this study is quite short. Future research should consider the scales with enough items to enhance scale reliability. Fourth, regarding R^2 of the PLS-SEM model, 24% of the variance of the EV adoption intention is explained by perceived benefits, purchase cost, and safety concern. This indicated that EV adoption intention could be explained by other variables that have not included in this study. Future research should consider adding new variable to improve the model. Fifth, this research measures the adoption intention of EV, which is not the actual adoption behavior. Intention may not completely translate into actual behavior, which leads to an intention-behavior gap. Sixth, the survey had a clear educational component, when information was provided to the respondents about issues they were surveyed about (Figure 2), As a result, we do not know to what extent the answers were influenced by the information just learnt, whether we are analyzing the level of agreement of respondents to the information provided rather than their intrinsic preferences and attitudes. This can be especially significant, bearing in mind that 39% of respondents did not know much about FCEV beforehand. Seventh, the survey was conducted among Australian people. Given the difference in available EV models on the market, relevant EV infrastructure, availability of other modes of transportation, as well as government policies among different countries may lead to different results. A comparison across countries can help to gain insight into the context of regional differences.

8. Conclusions

This study surveyed the public opinions toward EV and examined the factors that influence the consumer intention to adopt EV in the context of Australia. We considered two different types of EV, namely BEV and FCEV. The explanations about the differences between these two EV technologies and conventional vehicles were provided to the participants to avoid confusion. The results reveal that safety concern has a stronger impact on adoption intention than purchase cost and perceived benefits. Besides, there are statistical differences in the EV adoption intention across age groups and modes of transportation. Furthermore, our findings indicate that perceived BEV range sufficiency, tolerability in battery charging time, and fear of hydrogen explosion significantly increase the likelihood of preferring BEV. On the other hand, the longer driving range of FCEV, and fear of battery explosion significantly increase the likelihood of preferring FCEV. We also found that part-time workers are more likely to prefer BEV than full-time workers. On the other hand, apartment residents are more likely to prefer FCEV than people living in a house. Furthermore, female is more likely to still undecided than males whether they prefer BEV or FCEV. In addition, this study showed that most of the participants do not have sufficient knowledge about the differences between BEV and FCEV. The research findings provide implications for promoting the adoption of EV.

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