Public perceptions of hydrogen fuel cell vehicles on the Island of Tenerife

Interreg Atlantic Area
European Regional Development Fund
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1. Contens

1. Executive Summary

Aim: The overall aim was to elicit public preferences, values and opinions toward the use of rented alternative fuel cell vehicles (FCV) on islands and identify and invite relevant stakeholders to a series of meetings to gather information on the potential benefits of implementing hydrogen fuel cell technology on the Island of Tenerife. This was facilitated via four separate focus groups involving tourists and local car hire company managers and then followed up with a discrete choice experiment (DCE) survey. This document reports on the results of the DCE survey.

Key words: Choice experiment, fuel cell vehicle, mobility, public preferences

Methods: A detailed literature review was conducted on the use of stated preference methods, particularly choice experiments to estimate factors influencing consumer demand and willingness to pay for FCV. The attributes derived from the focus groups were used in the choice experiment which contained 6 attributes and 12 choice sets. The survey was piloted and conducted by a professional survey company based on the island of Tenerife between January 2020 and July 2021. Empirical data on a sample of 202 respondents was analysed using Stata and NLogit software.

Results: Most respondents are willing to rent an FCV on the island as part of their vacation. Respondents have a preference for green hydrogen and vehicles with longer fuel range but are sensitive to daily vehicle rental costs and detour time to refuel. We find a surprising result: vehicle size, drive and comfort, normally an important variable affecting decisions to purchase an FCV does not influence a subjects' preferences. Behavioural differences and motivations between decisions to rent an FCV while on holiday as opposed to purchasing one when not are identified, explained and their policy implications discussed.

2. Introduction

In Europe, the transport sector accounts for more than 25% of the EU's GHG emissions (European Environment Agency, 2021). Recent advances in hydrogen fuel cell technologies combined with reductions in the costs of wind and solar power have opened up new opportunities for the use of green hydrogen in Europe as a means of reducing transport emissions (Alves et al., 2000; GREBE, 2017).

Renewable resource endowments in island settings is renown (European Commission, 2021; Notton, 2015) but Island communities are often remote, disconnected from mainland energy systems, heavily reliant on the hospitality sector, vulnerable to the effects of climate change and they often lack the means to effectively make green power widely accessible in public and private transportation (Alves et al., 2000; Gils and Simon, 2017; GREBE, 2017; Cabrera et al. 2018).

Key challenges include a lack of hydrogen infrastructure, fuel stations, availability of green hydrogen, technical skills to maintain vehicle fleets and infrastructure and the perceived prohibitive costs of hydrogen FCV's (Kim et al., 2008; Achtnicht et al., 2012; Andrews and Shabani, 2012).

To better comprehend these challenges, demand side assessments using stated preference methods have been documented in the literature to identify factors influencing public preferences for FCV across a variety of transport modes and stakeholder groups including taxis, buses, street cleaners, mopeds and private cars (Mourato et al. 2004; Hoen and Keotse 2014).

However, all of these studies have considered decisions to purchase a vehicle not to rent one . Preferences and behaviour is likely to differ substantially in terms of whether the decision involves the purchase of an FCV or, alternatively, its rental.

In terms of vehicle purchase, consumers associate FCV with high purchase costs, limited refuelling infrastructure, and restricted benefits and performance in terms of range, power and luggage storage capacity (Hardman et al 2016) and these factors give rise to low levels of adoption. On the other hand car manufacturers may be reluctant to supply FCV due to a lack of consumer demand. Statutory agencies or private companies are understandably reluctant to deploy the refuelling infrastructure because it may not pay for itself in the absence of strong demand for hydrogen fuel . This leads to the so called chicken and egg scenario, widely documented in the literature concerned with FCV (Martin and Rice 2012). However, rental fleets could break this cycle since both the monetary and non-market costs associated with rentals to individuals is considerably less than vehicle purchase.

The decision to rent a vehicle for a short period requires less commitment, is less irreversible and is likely to differ substantially in terms of behaviour with respect to time preference, and crucial drivers of utility permia .

In a setting involving mass tourism on islands this is of interest from a policy perspective because it could represent a solution to the chicken and egg scenario provided sufficient numbers of tourists were involved in the use of FCVs. Temporary rental of FCVs by large numbers of tourists could help to play an important role in helping to pay for the fuelling infrastructure at relatively lower costs to the individual consumer compared with vehicle purchase. The purchase of a FCV will involve multiple trips to refuel over a longer duration by fewer numbers of individuals.

In contrast, FCV rental on small islands over short trips will typically involve only 1-3 trips to refuel. This can be thought of as a broad and shallow vs. deep and narrow approach to the FCV market. This would depend on high volume use and adoption of FCVs by tourists during their vacation refuelling a limited number of times. In theory Islands involving mass tourism should provide sufficient capacity to support a broad and shallow approach. However, it is still not clear if sufficient demand exists to do this and to support the phased development of refuelling infrastructure in the context of island mass market high volume tourism.

To demonstrate if this is possible requires a detailed examination of welfare estimates associated with FCV rentals. This can then be compared with the welfare burden associated with vehicle purchase which is widely reported in the literature (Hoen and Keotse 2014). Although an established literature exists on demand side assessments involving FCV ownership (Mourato et al. 2004; Hoen and Keotse 2014) as well as Internal Combustion Engine (ICE) and EV rental adoption and behaviour using stated preference methods (Dimatulac et al. 2018), we are not aware of any work that elicits preferences for FCV by households in the international mass tourism rental market. Lines et al (2008) investigated the use of FCV rentals in Florida but this did not examine stated preferences.

Our work provides methodological and policy contributions to the literature. Our methodological contribution examines preferences and behavioural factors influencing the uptake of FCV rental by tourists. Our policy contribution evaluates the extent to which FCV use by tourists does indeed represent a solution to the chicken and egg scenario outlined above. We first ask if our respondents are WTP to use FCV's while on holiday. Second we compare the welfare estimates of the rental vs. the purchase decision and discuss the implications for widespread adoption of FCV using a broad and shallow approach in the context of island mass market tourism.

This report is part of Work package 7 which involves three phases. Phase 1 (Literature review) and phase 2 (Qualitative focus groups report) have been reported and are available here: (Link to reports). This report presents the findings from phase 3 (Quantitative report) of work package 7 on the SEAFUEL project: It reports on the findings of an online discrete choice experiment survey conducted on the Island of Tenerife between January 2020 and October 2021.

A number of key themes have emerged from this research which relate to the factors that influence willingness-to-pay for FCV as well as technological and social adoption, knowledge and information, drive and refuelling experience and safety and awareness of hydrogen and its use. An explanation of the DCE used in the survey is provided. This is followed by results of the study and conclusions. We begin with a brief review of the literature given as background to the study.

3. Background

A review of the relevant literature on FCV is provided below.

3.1. Purchase cost, rental cost and fuel cost

Hardman et al. (2016) provide an excellent summary of the factors influencing the adoption and purchase of FCV. Vehicle purchase price represents one of the most important barriers to widespread uptake of fuel cell vehicles (Hoen and Koetse 2014; Fúnez Guerra et al. 2016; Hardman et al. 2016), although for a small group of consumers this is not an obstacle (Hardman et al. 2016). Several studies suggest that in the case of vehicle purchase, consumers are not WTP for running costs which exceed those of an ICE vehicle despite the associated environmental benefits of a FCV (Fúnez Guerra et al. 2016; Southhall and Khare 2016), although see Ziegler (2012) for findings to the contrary. Hoen and Koetse (2014) find that operating costs may have substantial effects on consumer preferences for AFVs. Since costs for FCV rental are not available, we provide some examples from the literature associated with Electric vehicle (EV) rental and car sharing. Lines et al (2008) find the ability to exchange a FCV for an ICE at no extra cost, is important to consumers (Lines et al 2008).

3.2. Fuelling infrastructure, detour time and range anxiety

Refuelling infrastructure represents a major impediment to the adoption of FCV in terms of the decision to buy or to rent a FCV (Lines et al. 2008; Martin and Rice 2012; Hackbath and Madlener 2013; Hoen and Koetse 2014; Fúnez Guerra et al. 2016; Hardman et al. 2016; Yang et al. 2017). A number of studies examine preferences with respect to fuel station infrastructure. This is usually measured in terms of distance travelled (km) to fuel station or in terms of time travelled (minutes), although the density or number of fuel stations has also been used (Mourato et al 2004; Hoen and Koetse 2014). Hoen and Koetse (2014) used a detour attribute involving time travelled out of their way to refuel. All of these studies find significant negative utility associated with detour (Horne et al 2005; Achnicht et al. 2012; Ziegler 2012), or positive utility associated with an increasing number of fuel stations. The number of fuel stations is a very important factor influencing the decision to use an FCV (Hackbath and Madlener 2013; Hackbath and Madlener 2016; Yang et al. 2017).

Several studies suggest range anxiety is an important concern for FCV drivers.. Kuby (2019) reports that drivers of AFV refuel more frequently at the same stations, at higher tank levels, more on work related trips, in mid trip, less frequently near home, often on their way and take longer detours compared with drivers of ICE vehicles.. In terms of the purchase decision, fuel station reliability (Martin and Rice 2012), call repair, safety, convenience, refuelling services have also been examined and is found to be a much greater problem compared with ICE drivers and a reason why respondents change and re-prioritize their fuel station of choice post adoption (Richardson et al. 2015; Krafft et al. 2021).

Habla et al. (2021) report that ICE drivers respond to monetary incentives but EV drivers do not and they argue that non market factors including psychological and time costs related to vehicle use and refuelling are far more important as part of EV adoption compared with ICE vehicles. They report that range anxiety is a concern but it should not be (because the vehicle was always full). It serves as a reminder of differences between what the respondent believes and the actual facts. They suggest this is the type of situation where it might be important for respondents to experience a test drive.

It is evident that range is the primary impediment to adoption of battery-powered EVs for any multipurpose transportation. However,since the driving ranges of hybrids, plug-in hybrids and flexi fuel vehicles do not differ from that of conventional cars [Hoen et al, 2014], we can assume range itself will not be an overriding limitation to the adoption of FCV.

The costs of installing and maintaining fuel station infrastructure needs to be weighed against the social value of their services to the public. The density of fuel stations needs to efficiently meet aggregate demand for fuel pump services but at the same time the infrastructure needs to be socially optimal in order to cover the capital cost of deployment. Hydrogen fuel stations represent a sophisticated capital intensive infrastructure. Their use will need to meet standard financial/economic efficiency criteria - fuel stations need to pay for themselves, and avoid becoming stranded assets which will fail to cover the capital cost of their deployment (Southhall and Khare 2016). Balancing these trade-offs between unmet demand for green hydrogen and oversupply by way of too many fuel stations in order to ensure for conditions of social optimality is essential as a part of a medium term strategy to develop hydrogen fuels to support mobility in island economies.

Tourists will require an accessible, reliable, easy to use, safe refuelling infrastructure.

The placement, location and phasing of this infrastructure needs careful consideration particularly for early adopters (Richardson et al. 2015) in order to be economically optimal. It needs to coincide with people's activities that take place during their trips in the different places they stay while on holiday.

3.3. Environmental attitudes and green hydrogen

Several studies indicate consumers are WTP more to use a FCV because of its environmental benefits (Fúnez Guerra et al. 2016; Ziegler 2012) Ziegler et al. (2012) find environmentally aware car buyers had a higher stated preference for hydrogen and electric vehicles.

It is worth stating that over 95% of the world's hydrogen production is not produced from a renewable (green) source. Yet consumers exhibit a strong preference for green hydrogen. Our findings from the focus group study reveal that the use of green hydrogen was an important concern for respondents. Nonetheless there is a substantial cost differential between green hydrogen and grey hydrogen which is produced from fossil fuel sources. Recent estimates of the costs of green hydrogen (from wind and solar power) range from €3.23/kg- €17.01/kg (Zhao et al. 2019), compared to grey hydrogen at <€2/kg.). Southhall and Khare (2016) estimated production costs of hydrogen from 2MW turbines at £9.44/kg (without a FIT) and £8.05 (with a FIT) in the UK.

3.4. Vehicle comfort and lifestyle choice

In terms of the purchase decision, vehicle brand, lifestyle fit, comfort and image represent important factors for early adopters, particularly high end buyers of FCVs (Hardman et al. 2008) but appear to be less significant for individuals who rent a EV vehicle privately or through a car sharing scheme (Giordano et al. 2021).

3.5. Demographics, attitudes, safety, experience,

Several studies indicate that income, education and other demographic variables represent important factors influencing decisions to purchase a FCV (Hardman et al. 2016). Safety concerns have also been identified as an impediment to adoption and Martin et al (2009) suggest consumers want an opportunity to test drive FCV to allay safety concerns. California drive clinics show that short-term exposure can improve consumer perceptions of hydrogen performance and safety (Martin et al 2009).

Participants in phase 2 of our study (focus groups) suggested using hydrogen in local transport i.e., buses to build confidence. Acceptance may depend on positive consumer attitudes towards vehicles - consumers attitudes post trial in U.K see FCV's as mostly similar to incumbent internal combustion engine vehicles. The main barriers perceived: lack of infrastructure and high costs (Hardman et al 2016).

Comparative safety studies of fuel leaks from petrol and hydrogen fuel cell cars performed in Miami, clearly demonstrate that hydrogen-fuelled cars pose less of a fire risk than petrol fuelled cars (Schlapbach 2009).

According to Ricci et al. (2008) gender and age differences also were significant. Men appeared to have stronger beliefs than women, both positive and negative. Positive beliefs tended to be associated with younger groups and high education level.

Ricci et al. (2007) also suggest that the public are concerned about distributional effects - whether it would disrupt people's lifestyles and require a significant change in collective and individual behaviour, how the economic and social costs would be distributed, and to whom any tangible benefits would accrue.

Schulte (2004) states prior experience is a key factor by which public attitudes can be changed. Therefore, a combination of product exposure, formal education and marketing should be implemented in order to improve the understanding of hydrogen fuel and its benefits.

3.6. Vehicle rental use and drive tourism

A number of studies have focussed on the use of AFV for drive tourism. Most of the studies have focussed on EVs and hybrid vehicles . However there is limited literature applying DCE's specifically to Hydrogen in the tourism mobility sector.

3.7. Policies and Incentives:

Habla et al. (2021) find that drivers respond to monetary incentives in the case of ICE vehicles but not EVs. EVs are driven shorter distances compared with ICEs even if costs are similar. The types of incentives include priority parking at tourist locations (Lines et al 2008),free parking andtax incentives.

3.8. Preferences forFCV vehicle purchase vs. FCV vehicle rental

An individuals preferences and behaviour is likely to differ in terms of whether the decision involves the purchase of an AFV or, alternatively, its rental for a limited period of a week or two while on vacation. Economic theory suggests a decision to purchase a vehicle is influenced by its attributes, mileage, total costs of ownership (TCO) which is highly correlated with mileage as well as ancillary services such as refuelling infrastructure... FCV purchase represents a major financial commitment. TCO is substantially higher for FCV compared with ICE vehicles even with subsidies particularly if green hydrogen is used.. Notwithstanding the fact that TCO are known to be underestimated for individuals, perceptions of the TCO for ICE vehicles are likely to be more accurate than for FCV.

Vehicle purchase involves sunk costs. Sunk monetary costs are likely to be larger for FCV compared with ICEV given the purchase costs differences between the vehicle types. Sunk costs can be attributed to loss aversion, an aversion to regret, and psychological commitment.. In terms of psychological commitment non-market costs are also relevant. Psychological commitment includes facing limited range, less model choice, refuelling and range anxiety over the life of ownership.

The decision to rent a FCV on the other hand does not entail substantial sunks costs ,requires minimal financial or psychological commitment, loss aversion and aversion regret . An individual can select between a FCV or an ICEV for each trip. Renters avoid fixed costs. Variable costs depend on the period of rental, fuel costs and mileage. Costs associated with additional detour time to refuel and range anxiety are short lived, and decisions to cease using the vehicle easily reversed , especially if the rental agency agrees to provide a rental ICE if the consumer is not satisfied with the FCV as part of the rental agreement (Lines et al. 2008).

High mobility demand days are thought to influence choice of vehicle type in the case of ownership (Habla et al. 2021) but this is likely to be less of a concern in the case of vehicle rental over a short vacation on a small island . The concern may also be higher in the case of ownership for single vehicle households which cannot switch to a second vehicle. This is likely to be less important in the case of a vacation rental vehicle.

4. Methods

4.1. Non-market valuation: choice experiments

Stated preference studies have been widely used in transport economics and environmental protection using surveys or experiments by analysing consumer preferences for a hypothetical situation by offering a change in these goods or services. Contingent valuation and choice experiments can both be used in preference elicitation for environmental goods. Contingent valuation asks consumers their willingness to pay or willingness to accept for a change in an environmental good or service. In choice modelling on the other hand respondents choose between two or more choice situations among shared attributes of the good but with different levels of the attributes (Hoen and Koetse 2014).

In choice experiments respondents rank alternative outcomes in order of preference. It has been argued that it is more difficult for respondents to answer strategically in a choice experiment compared with contingent valuation due to the difficulties associated with such deception due to the changing attribute levels in each choice set (Yadav et al. 2013).

Designing choice experiments

Attribute selection is a crucial stage in the methodology. A thorough literature review and pilot study involving focus groups is essential. As a general rule, no more than four or five attributes should be selected, including the cost attribute (Brennan and van Rensburg 2020).

The levels associated with these attributes need to be decided. A status quo option is usually included but not always. A full factorial design is then implemented which contains all of the possible combinations of attribute levels for each option but a small number of choice sets are possible with different designs including fractional factorial designs

Limitations of choice experiments

Choice experiments are associated with a number of inherent biases. Hypothetical and strategic bias can occur when respondents do not believe the choice set scenario presented to them. Pilot testing can help to prevent this in order to ensure that the scenario is plausible. Heterogeneity can be difficult to analyse using Standard Random Utility Models (RUM). Interaction techniques or mixed logit models, such as the RPL model which allows model parameters to vary over individuals offer a potential solution. Framing affects occur when the hypothetical scenario is conveyed in an overly negative positive manner. This can addressed by testing for effects with focus groups. Choice task complexity and respondent fatigue has been highlighted (Adamowicz and Boxall, 2001) but with the right design, these issues can be avoided (Bateman et al. 2002).

4.2. Empirical Specification

The theoretical framework underlying choice experiments is random utility theory. This asserts that a good can be assessed in terms of its attributes and the levels of these attributes, (Adamowicz and Boxall, 2001) The utility associated with the selection of an option depends on its attributes, a respondents utility function and an unobservable element.

Following Adamowicz and Boxall (2001), an individual's utility can be described as:

$$U = V + \varepsilon$$

where V is the indirect utility function containing the attributes and describes the unobservable stochastic element . V can then be broken down further:

$$Vj = \beta_k X_j$$

where X is a vector of k attributes related to option j, e.g. detour time, car hire cost etc. and is a coefficient vector.

The conditional choice probability of selecting alternative j is:

$$Prob\ (j) = \frac{exp(\mu\beta_k X_j)}{\sum_{i \in C} exp(\mu\beta_k X_i)}$$

where μ represents a scale parameter and C the choice set. In this situation μ is combined with the parameter vector and cannot be isolated (Adamowicz and Boxall, 2001).

The Multinomial Logit (MNL) model can account for some observed heterogeneity by assuming that utility is a function of individual specific variables Zi, which vary across respondents but are constant across choices, and Xi which are specific to each option :

$$U_{ij} = Z_i X_i + \varepsilon_{ij}$$

This assumes that the utility an individual derives from FCV rental depends on the characteristics of the vehicle (attributes), individual characteristics and unobserved idiosyncrasies, represented by a stochastic component. The multinomial logit (MNL) framework assumes that unobserved factors which may impact the choice of alternatives are strictly independent of each other, that is, the odds of choosing alternative j over alternative j' do not depend on the other alternatives in the choice set (Independence of Irrelevant Alternatives, IIA). This may not actually be the case. It is possible that unobserved factors that impact on the utility from using the vehicle A B or the status quo option are correlated with the observable factors included as attributes.

With the random parameter logit (RPL) model the restrictions of the MNL model are relaxed. The former permits unobserved factors to be random and follow any (normal, lognormal, uniform etc.) distribution (McFadden and Train, 2000). A theoretical framework applied in this study for deriving a respondent's WTP is shown below.

In each choice set, the respondent faces a choice between a set of three alternatives: FCV option A and FCV option B define two FCVs with different attribute levels whilst option C represents the status quo option (no new FCV). An individual is assumed to choose the option from each choice set that gives them the highest utility. This choice can be seen as the probability of choosing option A, B or C and so this choice is analysed using the logit framework.

In general, a respondent q's utility from choosing alternative j in choice situation t in a random utility function with random parameters can be defined as:

$$U_{jtq} = V_{jta} + \varepsilon_{jtq} \equiv \beta'_{qk} X_{jtqk} + \sigma'_k z_q X_{jtqk} + \varepsilon_{jtq}$$

where respondent q (q=1,....Q) obtains utility U from choosing alternative j (Option A, B or C) in each of the choice sets t (t=1,...12). The utility has a non-random component (V) and a stochastic term (ε). The non-random component is assumed to be a function of the vector of k choice specific attributes: X_{jtqk}, with corresponding parameters β_{qk} which may vary randomly across respondents due to preference heterogeneity with a mean β_k and standard deviation σ_k k. There are 6 attributes in this vector, HIRE COST, FUEL COST, DRIVING RANGE, ADDITIONAL DETOUR TIME, FUEL SOURCE, and CAR SIZE and the alternative specific constant (ASC) representing the status quo option (this takes a value of 1 when the respondent chooses the option of no fuel cell car rental – i.e. the respondent decides not to rent the fuel cell vehicle). The ASC also captures all the attributes erringly excluded from X_{jtqk} and the utility associated with not choosing the status quo. It is assumed that the individual chooses the option j that provides them with the highest utility. We now discuss the survey.

4.3. Survey design and Methodology:

Deriving the attributes for the choice experiment.

Attributes and levels were extracted from an extensive literature review and later tested and confirmed in a qualitative exercise involving tourists and car hire managers on the island of Tenerife in June 2019. Four focus groups took place (N = 3) with tourists and (N = 1) with local car hire company managers. Previously identified features were confirmed and their relevance to both groups was assessed. The focus group discussions allowed us to identify additional unidentified attributes and realistic levels that would be relevant to both groups. Additionally, the focus groups were used to test the clarity of the attributes, levels and trade-offs to be used in the survey. Six attributes (four attributes with three levels and two attributes with two levels) were included in the final discrete choice experiment design. Table 1 below presents the attributes and levels derived from the focus groups:

Attributes	*Level 1*	*Level 2*	*Level 3*
Hire cost	€25	€25	€75
Fuel cost	€5	€10	€15
Driving range	200k	400k	600k
Additional detour time	10mins	20mins	30mins
Fuel source	Green	Not Green	
Car size	Medium	Family SUV	

Description of attributes and levels used:

- Hire cost: The cost of hiring a hydrogen fuel cell vehicle, which ranges from €25, €50 and €75. This cost includes the full comprehensive insurance.
- Fuel cost: The fuel cost for the hydrogen fuel cell vehicle per 100km (60 miles). This ranges from €5, €10 and €15 euro per 100k.
- Driving range: An estimated distance that the car will travel, which ranges from 200k, 400k and 600k.
- Additional detour time: In order to refuel you must drive to a hydrogen station and these are limited in number so will require additional detour time to get to. We want you to consider how far out of your way you would be willing to drive to a hydrogen fuel station. The additional detour time could be 10 minutes, 20 minutes or 30 minutes.
- Fuel source: This refers to the source of energy used to make the hydrogen fuel to power the car. Hydrogen can be made from a locally available renewable energy source such as solar or wind power which has zero carbon dioxide emissions and zero sulphur dioxide and nitrous oxide emissions. Alternatively, hydrogen can be produced from imported fossil fuel sources such as gas, oil and coal, which does produce carbon dioxide emissions, sulphur dioxide, and nitrous oxide emissions. "GREEN" means the hydrogen used to power the car comes from a renewable energy source. "NOT GREEN" means the hydrogen used to power the car comes from a fossil fuel source.
- Car size: The size of car available for hire is either a medium sized car, which can accommodate up to five people or a large family size vehicle like an SUV, which can accommodate up to eight people.

Experimental Design:

The DCE choice sets were designed using using NGene software. The carefully chosen design consisted of 12 choice sets so that each participant only had to select their preferred option from 12 choice sets.

4.4. The survey

The survey consisted of four main sections. In the first section (A-B), respondents were presented with a quiz to test their knowledge on hydrogen as a fuel source. The quiz was used to assess their knowledge about hydrogen. Respondents were then asked to indicate their level of agreement with a variety of statements regarding familiarity with hydrogen fuel cell vehicles and AFV's as a solution to climate change.

The third section (C) presented the discrete choice experiment. A brief outline of the main purpose of the DCE was provided and an example on how to complete the exercise outlined. Participants were then presented with 12 choice sets and asked to select their preferred option from a set of hypothetical descriptions of hydrogen fuel cell cars. The hydrogen fuel cell vehicles were described by six attributes: (1) Hire cost, (2) fuel cost, (3) driving range, (4) additional detour time (5) fuel source, and (6) car size. Respondents were also given the option to opt out by choosing the status quo alternative which meant they would hire a conventional ICE vehicle. To reduce the hypothetical bias in our choice experiment, respondents were asked to treat the choice decisions in the context of their own personal budget. Furthermore, in the task description, respondents were given the option to opt out and select a conventional car to reflect real market conditions. To further increase realism in the hypothetical vehicle choices, the distance they had to travel was based on realistic estimates provided by the local car hire companies.

Finally, the fourth section (D) included several socio-economic and socio-demographic questions, such as age, income, and educational level, but also questions regarding specifics of the length of stay on the island, place of residence, holiday experience, and their transport utilization habits while on holiday and, willingness to hire alternative fuel vehicles.

Data collection, sample size and recruitment:

The data on tourist's preferences for hiring hydrogen vehicles in Tenerife was collected in an all Island, online survey conducted between January 2021 and August 2021 by a professional survey company based in Tenerife. In total, 202 respondents completed the survey.

5. Results

5.1. Summary Statistics

As shown in Table 2 the sample data contains slightly more male respondents than female, however is broadly similar to the gender distribution for the visiting population of tourists for Tenerife. The sample data for age is also comparable to the age data on the island. The level of higher education for the survey data is somewhat lower than for the visiting population of tourists.

The Statistics for income are not directly comparable since the national statistics use household income as a measure. The survey data used individual income.

DEMOGRAPHICS	Canary Islands Tourist Survey[1]	SEAFUEL sample data
Gender		
Men	49.8%	52.7%
Women	50.2%	47.3%
Age		
Average age (years)	47.8	44.8
Education		
No Studies	3.7%	NA*
Primary	2.4%	0.0%
Secondary	21.8%	38.3%
Higher	72.1%	61.7%
Employment Status		
Salaried Worker	50.9%	66.5%
Self-Employed	12.0%	NA*
Unemployed	1.4%	7.9%
Business Owner	10.4%	NA*
Student	3.8%	13.8%
Retired	19.8%	10.8%
Unpaid Domestic Work	0.5%	0.5%
Others	1.2%	NA*
Annual Household/ Individual income		
	Household Income	**Individual Income**
< €25,000/ < €15,600	15.3%	36.5%
€25,000-€49,999 / €15,600 - €23,399	37.6%	9.5%
€50,000 - €74,999 / €23,400-€46,799	23.7%	28.6%
> €74,999 / > €46,800	23.4%	25.4%

1 Source: Profile of tourist visiting the canary islands, 2019. (https://turismodeislascanarias.com/sites/default/files/promotur_islas_canarias_2020_en_0.pdf). * No equivalent categories available.

5.2. Empirical Model:

The modelling was conducted using NLogit 5. Only 3 respondents out of the entire sample of 202 chose the status quo option, regardless of the combination of attributes presented.

Table 3 provides the output from the 2 models, a multinomial logit model (MNL), and a random parameters logit model (RPL).

The coefficient ADDITIONAL DETOUR, representing increases in the time taken to travel to a fuel station to refuel is negative for each model. This suggests that respondents experience decreased utility from travelling to refuel. The coefficient for ADDITIONAL DETOUR is highly statistically significant in both models. This corresponds with previous research (Hoen and Keotse 2014). The coefficient DRIVING RANGE, represents extended FCV range and it is positive for both models. This means that individuals receive increased utility with extended vehicle range. The coefficient FUEL SOURCE, is positive for both models. This means that individuals receive increased utility with the consumption of green hydrogen. The coefficient CAR SIZE, is positive but insignificant for both models.

The coefficient HIRE COST is negative and significant in both models, indicating the reduction in utility associated with increased cost.

The alternative specific constant (ASC) which represents the status quo is negative and highly statistically significant in each model. This indicates the overall preference for the two alternatives over the status quo alternative of not hiring an FCV.

Attribute	MNL (s.e)	RPL (s.e)	Std. Dev
Additional detour	-0.440*** (0.070)	-0.757*** (0.117)	0.841*** (0.091)
Driving range	0.467*** (0.068)	0.879*** (0.113)	0.583*** (0.100)
Fuel cost	-0.368*** (0.075)	-0.410*** (0.110)	0.400*** (0.084)
Fuel source	1.753*** (0.101)	3.197*** (0.261)	2.635*** (0.261)
Car size	0.091 (0.103)	0.083 (0.196)	1.306*** (0.205)
Hire cost	-1.016*** (0.086)	-1.539*** (0.129)	
Status quo	-0.965*** (0.289)	-1.815*** (0.487)	3.966*** (0.394)
Log-Likelihood	-1828.53	-1447.96	
McFadden Pseudo R2	0.21	0.46	
A.I.C	1.51	1.21	
No. of observations	2424	2424	
No. of respondents	202	202	
No. of Halton draws		500	

5.3. Welfare estimates

Table 4 indicates the marginal willingness to pay (WTP) values for the two estimated models. The results for both models are significant in most cases, only CAR SIZE is insignificant.

The estimated WTP for additional detour time in both models is negative and highly significant. Respondents are willing to pay between €0.43 and €0.49 less in hire cost[1] for each minute of detour time required to travel to a fuel station to refuel. The welfare estimates for driving range are positive in both models. Individuals are willing to pay between €0.46 and €0.57 more in hire cost for each 100km of additional vehicle range. The estimates for fuel cost is negative in both models.

Individuals are willing to pay between €0.27 and €0.36 less in hire cost for an additional euro of fuel cost per 100km. The welfare estimates for fuel source is positive in both models. Individuals are willing to pay an additional €1.72 to €2.08 more in daily hire cost for green hydrogen.

Attribute	MNL (s.e)	RPL (s.e)
Additional detour	-0.43*** (0.04)	-0.49*** (0.05)
Driving range	0.46*** (0.10)	0.57*** (0.10)
Fuel cost	-0.36*** (0.05)	-0.27*** (0.06)
Fuel source	1.72*** (0.18)	2.08*** (0.23)
Car size	0.09 (0.10)	0.05 (0.13)
Log-Likelihood	-1.016*** (0.086)	-1.539*** (0.129)
Status quo	-0.965*** (0.289)	-1.815*** (0.487)
Log-Likelihood	-1828.53	-1447.96
McFadden Pseudo R2	0.21	0.46
A.I.C	1.51	1.21
No. of observations	2424	2424
No. of respondents	202	202
No. of Halton draws		500

[1] The payment vehicle used is car hire cost. The parameter estimates are therefore estimated in terms of daily car hire cost.

5.4. Comparing FCV rental vs. purchase costs

One of the aims of the study was to estimate the costs of FCV rental costs in order to compare this with FCV purchase costs. Although we do not estimate purchase costs directly, information from the literature on the subject can be used as a useful guide. Table 5 contrasts the costs of vehicle rental per individual with the costs of vehicle purchase for the same/similar attributes to those found in the literature. The estimated rental cost on a daily basis is calculated at €36.20[2]. In Table 5 this compares with a purchase cost of €21,793 for a new FCV (Hoen and Keotse 2014). The estimated rental costs per tourist for the duration of their stay, were they to hire a hydrogen vehicle are significantly below the costs faced by an individual in purchasing a FCV. The estimates for hydrogen fuel costs for an individual covering 1000km for the duration of their stay were they to hire a FCV on Tenerife are between €2.70 and €3.60.

Table 5 A comparison of estimated costs for FCV rental vs. FCV purchase

Attribute	*This study - Vehicle Rental*	*Hoen and Keotse (2014) Vehicle purchase*
Vehicle cost (purchase/rental)	-€36.20 (Per day)	€-21,793
Fuel cost (per 100km)	€-0.27 to €-0.36	-
Driving range (per 100km)	€0.46 to €0.57	€19 (per km)
Additional detour time (per minute)	€-0.43-€-0.49	€-234
Fuel source	€1.72-€2.08	-
Car size	-	€5

The estimated costs per individual in terms of detour time are derived below. Assuming an average mileage of 1000 km/trip an individual might be expected to refuel 3 times during their stay involving a combined detour time of 45 minutes (45 x €0.49- RPL WTP result for attribute Additional Detour) with an estimated value for a typical trip of €22.05. This is significantly less than the costs per minute in the case of vehicle purchase.

Using the WTA values from the MNL model, Figure 1 indicates the additional WTP or the negative WTP for a typical respondent that might rent a FCV over a week according to fuel source type (Green/ Not Green); driving range (200/400/600) and detour time (10 mins/ 20 mins/30 mins). This highlights the strong disutility from having to detour in order to refuel the vehicle, since only the shortest distance – a 10 minute detour with green fuel source and highest driving range results in a positive WTP of €1. The greatest negative WTP arises from a scenario where the fuel source is not green, the driving range is 200km and the detour time to refuel is 30 minutes. The figure shows that detour time has a larger relative impact on individual welfare compared with the utility derived from fuel source or driving range.

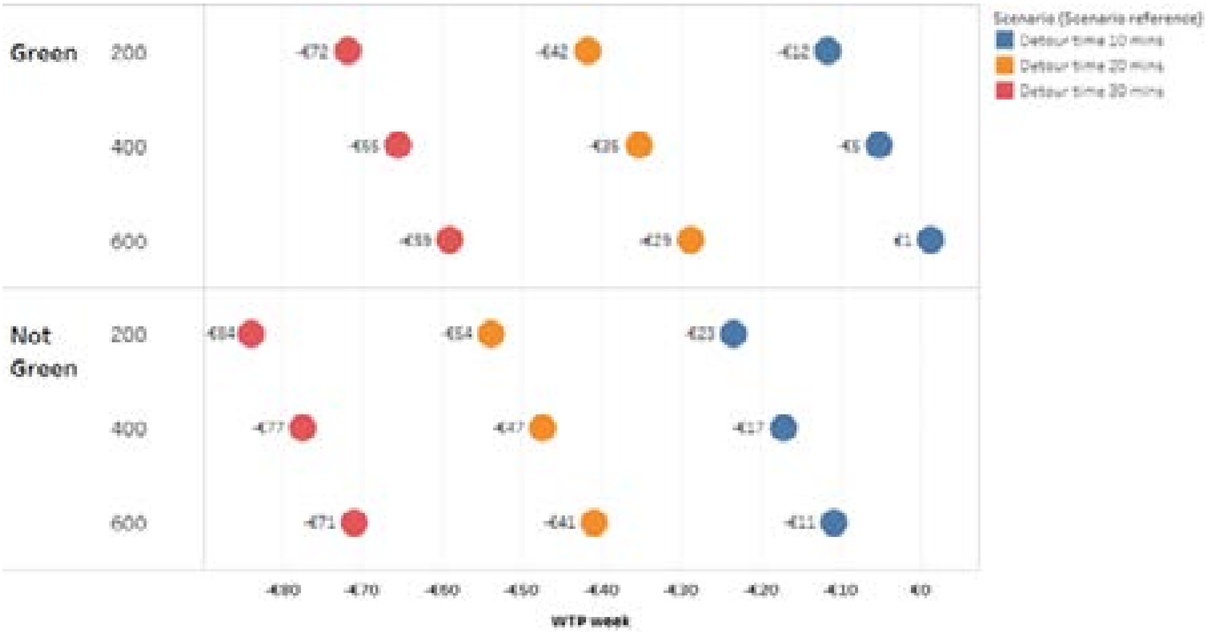

Figure [1]: Additional WTP pp/p week by fuel source type, range and detour time

With respect to detour time to refuel, a relevant question is what is the source of disutility associated with having to go out of their way to refuel for tourists on holiday. In response to this the study offered respondents a number of alternatives in the form of likert scale questions. These are shown in the first column of Figure 2.:

Figure 2 highlights the average Likert scores for four particular concerns that respondents may have about hiring an AFC vehicle. Respondents ranked their agreement with each of the below statements from 1 (no agreement) to 5 (full agreement):

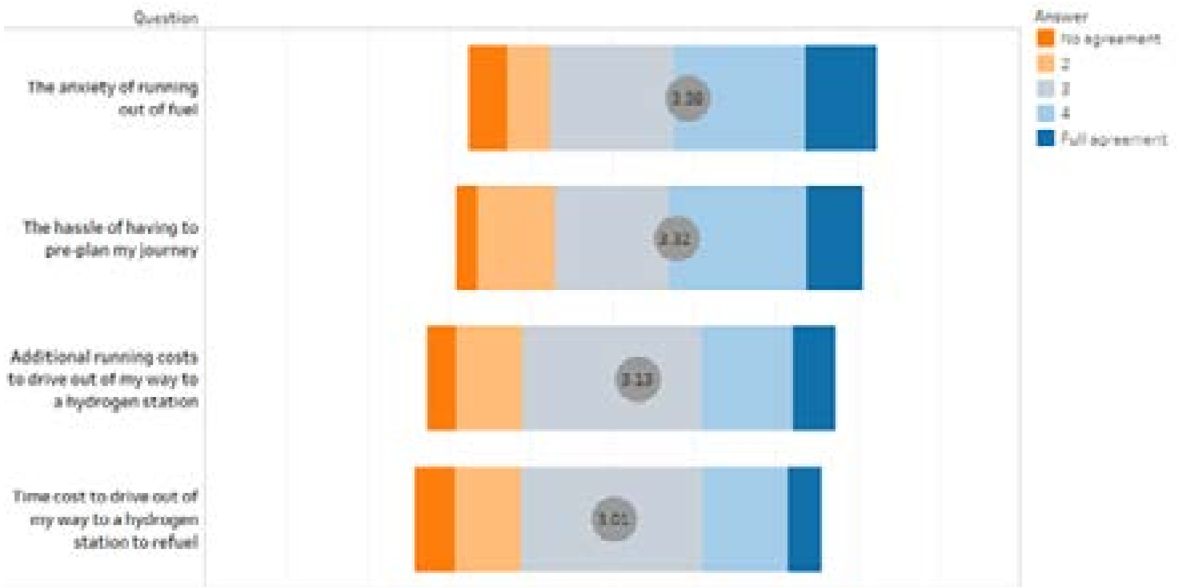

Figure [2]: Issues of concern for respondents in relation to additional detour time to refuel.

[2] The estimated average hire cost for 7 days is €241.36 from the survey data. The hire cost in the choice set is derived on a per day basis. Then the estimated willingness to pay for a hydrogen car over a week from the MNL Fuel Source results = €1.72*7=€12.04. This is then added to the average hire cost for survey respondents gives a value of €253.40, or a daily estimate of €36.20.

Figure 2 indicates that the issue of most concern to respondents is fuel anxiety (average score 3.38/5) and the issue of least concern is the time cost vs holiday aspirations (3.01/5).

Approximately 50% of respondents either somewhat agreed (32.1%) or fully agreed (17.3%) that the anxiety and fear of running out of fuel was a concern. Some 20% of respondents had little (10.4%) or no concern (9.4%) about this issue.

Approximately 48% of respondents either somewhat agreed (33.7%) or fully agreed (13.9%) that having to pre-plan their journey and holiday activities around the locations of hydrogen stations to avoid running out of hydrogen fuel was a concern. Approximately 24% of respondents had little (18.8%) or no concern (5.5%) about this.

About 33% of respondents either somewhat agreed (22.3%) or agreed fully (10.4%) that the additional running costs to drive out of their way to a hydrogen station was too high. 23% of respondents either somewhat disagreed (16.3%) or fully disagreed (6.9%) with this statement.

Lastly, 29% of respondents either somewhat agreed (20.8%) or fully agreed (8.4%) that the cost to them of the additional time spent (in minutes) to drive out of their way to a hydrogen station was too high. Approximately 26% of respondents either disagreed somewhat (16.3%) or fully disagreed (9.9%) with this statement.

6. Conclusions

This study examines public preferences for FCV rental on the Island of Tenerife, Spain using a choice experiment as part of a national survey. An important aim of this study was to evaluate if tourists are willing to hire a FCV while on holiday in Tenerife. |We find that a very large majority of respondents are willing to rent a FCV whilst on holiday in Tenerife instead of a conventional ICE vehicle.

The MNL and RPL models used in this study both performed according to expectations and produced what appear to be reasonable results. Willingness to pay is price sensitive and all attributes except car size have a significant impact on the choice of a FCV. Respondents prefer FCV's powered by green hydrogen. They also prefer shorter detour distances to refuel and vehicles with longer range.

Our findings suggest there may be some important differences between the decision to purchase a vehicle compared to its rental. The additional fuel costs and rental costs are substantially less than those incurred by individuals that might purchase a FCV. The non-market costs associated with detour time are also significantly lower than those observed in the literature related to FCV purchase (Hoen and Keotse 2014). Habla et al. (2021) also noted similarl differences for EVs and they find that EV penetration is much higher in the car sharing fleet compared with the private car fleet. They also find that car sharing clients who rent EVs are more likely to buy an EV instead of an ICEV (Burghard and Dütschke, 2019).

Notably our car size attribute is insignificant. This indicates that for most respondents, vehicle size does not influence their decision to hire a FCV. On the other hand several papers suggest that car size and comfort represent important determinants of the FCV purchase decision, particularly for high end consumers (Hardman..2016).

Respondents elicit a preference for the use of green hydrogen to be used in FCV rental instead of hydrogen from fossil fuels. This is consistent with several other studies on FCV's.

The study involved a number of limitations. The number of respondents in this survey was small and is not nationally representative. Despite this limitation, results are statistically significant and robust in the models used. Face-to-face interviews do have some advantages and were considered but were not feasible due to the Covid 19 restrictions on the island. Face to face surveys also have their disadvantages, namely social desirability bias wherein respondents may select answers which they believe will make the interviewer view them more favourably (Yadav et al. 2013). This issue is lessened when conducting choice experiment studies which are difficult to answer strategically due to the changing attributes in each set. The survey was thoroughly tested through the use of pilot surveys and focus groups.

From a policy perspective it is likely that FCV rental could play a role in circumventing the chicken and egg dilemma associated with FCV use. We would caution though that detour time had the largest impact on respondent utility and represents an important impediment to the take up of FCV on the island. It would appear that range anxiety is a more significant underlying influence on detour time compared with say additional time spent looking for a fuel station while on holiday. The roll out of an adequate number of fuel stations on the island to meet future demand is essential. Deciding what is a socially optimal number of fuel stations for the island and weighing the associated costs and benefits is beyond the scope of this work. But this is an important topic and a subject that should be afforded particular priority for future research.

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