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The public perception of adopting hydrogen fuel cell vehicles in Kuala Lumpur, Malaysia

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Abstract

Hydrogen fuel cell vehicles (HFCV) are leading as alternative energy-saving vehicles that replace non-renewable energy use and support sustainable transport systems for developing and developed countries. Public adoption of new transport technologies is vital for the successful evolution of a sustainable energy system. Previous studies have focused more on people's attitudes towards hydrogen energy as alternative fuel energy. This article aims to assess the public perception of the adoption of HFCV in Kuala Lumpur, Malaysia. The overall results of this study found that demand-side action for HFCV among the public is influenced by supply-side aspects, including support infrastructure, characteristics of HFCV, operational costs, safety concerns, competitive markets, and the social equilibrium of the innovation. The current study also found that most respondents have a scant idea of the environmental benefits of using HFCV. The evidence from this study suggests that stakeholders should educate the public regarding the benefits of HFCV - an essential step when adopting new technologies. It is timely to seek innovative solutions and address appropriate policies for both energy security and environmental concerns globally in the transportation sector for the sake of present and future sustainability.

Keywords: Alternative energy-saving vehicles, energy security, Hydrogen Fuel Cell Vehicles, public perception, public adoption, sustainable transport system

Introduction

The transportation sector became the leader in powering a country's socio-economic growth (Pakpahan & Purwanto, 2021) and challenged policymakers to promote more sustainable and ecologically friendly solutions (Zainal & Mohamad, 2013). The transportation sector worldwide is still heavily reliant on fossil fuel resources, rapidly depleting diesel, coal, and natural gas supplies. High fossil fuel consumption in the transportation sector has created various environmental problems such as climate change, environmental pollution, urban heat islands, and degradation. For example, direct hazardous carbon emissions from the transportation sector

significantly contribute to 29% global warming (EPA, 2019). Although several developed and developing countries have been implementing a green economic system, the concept of green and smart transport systems is still new. A deep understanding of technical evolution in scaling backstop technologies is essential for implementing an effective transition to alternative energy to replace non-renewable energy. There are already many green technologies available that are increasingly used to generate power; these include solar panels, windmills, biomass processors, and hydrogen fuel cells. The development of green technology will meet current energy demands, lower costs, and provide more friendly solutions (Al-Amin, 2017). Most previous studies focused on alternative energy options by introducing technologies to switch from fossil to non-fossil fuels and seeking innovative solutions for future environmental sustainability in the transportation sector.

Several studies have focused on biofuel production sourced from various types of agricultural commodities as alternative fuel sources. These have included such things as sugar-rich corn (Amer et al., 2021), sugarcane (Huang et al., 2020; Mohan, 2017), palm oil (Kurnia et al., 2016; Mahlia et al., 2019), soya beans (Weightman et al., 2011), sunflowers (Havrysh et al., 2020; Perea-Moreno et al., 2018) and wheat (Kaparaju et al., 2009; Srivastava et al., 2020). Both developed and developing countries such as the United States, Germany, Japan, Brazil and India have boosted their use of biodiesel in their vehicles (Ambrose et al., 2016). However, the alternative energy sources of fuel from agricultural commodities pose different problems due to unstable world market prices, insufficient supply structures, and potential environmental degradation (Enweremadu & M.M. Mbarawa, 2009). Solar energy and hydrogen are the best long-term and sustainable alternative energy sources to replace fossil fuels. Although solar energy usage is encouraged, concerns about its ability to efficiently replace conventional energy have slowed progress, particularly in terms of production, storage and efficiency.

Consequently, hydrogen has emerged as the most promising alternative energy source to meet long-term energy security and produce zero harmful emissions in smart transport systems. HFCV is also expected to support sustainable transport systems for both developing and developed countries. According to Eberle et al. (2012), automobile manufacturers have overcome most of the main technological obstacles for HFCV, and it is one of the innovative solutions to mitigate carbon emissions. IEA (2015) mentions that 150 million HFCV will be sold by 2050 as part of the Technology Roadmap and will cost from USD 900 to USD 1 900 for hydrogen infrastructure development.

It is not surprising that several countries are already introducing non-fossil energy for vehicles like HFCV to achieve carbon reduction and strengthen energy security without endangering economic growth. Introducing HFCV to the transport system may be a good starting point for powering green economic systems and addressing environmental concerns. Even though hydrogen fuel cells may not be an immediate solution to reducing environmental problems and be a complete energy alternative, some recent research investigations have recognized it has potential as a long-term solution (Al-Amin & Doberstein, 2019; Ambrose et al., 2017).

Several countries have started to adopt policies for establishing a hydrogen economy in their long-term national plan to switch to sustainable option pathways and to meet energy security. For example, Malaysia's government has launched a roadmap to assess the feasibility of developing a hydrogen fuel system as part of its sustainability strategy. Even though Malaysia is an oil-producing country, it is expected to be highly dependent on imported oil to fulfill rising demand in the future. In Malaysia, the transportation sector represents 37% of total energy consumption, and fossil fuel resources are needed for 98% of transport vehicles (Al-Amin et al.,

2016). According to Ambrose et al. (2016), Malaysia's carbon emissions might be reduced by up to 26 million tonnes of CO^2 by replacing 50% of conventional vehicles with HFCV. However, public adoption of new transport technologies, like HFCV, is vital for the successful evolution of a sustainable energy system for the transportation sector. Public adoption of HFCV is influenced by various factors such as energy prices, infrastructure, alternative technological developments, the cost to the user, and vehicle performance (Al-Amin et al., 2016). More research is required in this field to identify public acceptance and preferences for alternative sustainable energy sources, particularly HFCV. Hence, this article aims to assess public perceptions in relation to the adoption of HFCV in Kuala Lumpur, Malaysia. It is a timely study to seek innovative solutions and address a decarbonisation strategy in the transportation sector for the sake of present and future sustainability.

Method and study area

Data was collected from 175 respondents from Kuala Lumpur, which comprised two districts: Cheras (85 respondents) and Bandar Tun Razak (90 respondents). This study used a descriptive approach to assess the public perceptions of HFCV adoption in Kuala Lumpur. A survey questionnaire was adopted based on various researchers' work on HFCV and was adapted to meet the needs and requirements of this research. Respondents were questioned whether they believed Malaysia could adopt HFCV and their confidence in successfully introducing these vehicles to the country using the Kuala Lumpur area as a case study. Respondents were also questioned on the types of vehicles suitable as HFCV. The second section of the questionnaire focused on the HFCV adoption dimensions using the item statements as shown in Table 1. The item statements were measured using a 4-point Likert scale ranging from (1) Strongly disagree, (2) Disagree, (3) Agree, and (4) Strongly agree. The percentage of the agreement mentioned is based on the number of agreeing and strongly agree with responses.

Table 1. No. of item statements for HFCV adoption dimensions

Scale	No. of item statements
HFCV adoption dimensions	
• Public understanding of HFCV	15
• Public perception of HFCV	8
• Public's agreement on the economic benefits & challenges of HFCV adoption	8
Total	**31**

Results and discussion

Socio-demographic characteristics of respondents

Most Cheras and Bandar Tun Razak respondents were male at 51% and 51.1%, respectively (as shown in Table 2). All of the respondents from Cheras and 95.6% of respondents from Bandar Tun Razak were Malaysian citizens. Most of the respondents were between 21-30 years old, with Cheras at 72% and Bandar Tun Razak at 73%. The majority of the respondents also had

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undergraduate degrees, with Cheras at 83.5% and Bandar Tun Razak at 73.3%. The monthly household income of most of the respondents from Cheras was between RM5,001-RM7,000. In Bandar Tun Razak, most respondents had a monthly household income of less than RM5,000, representing 76% of the respondents from the district.

Table 2. The demographic profile of respondents from the districts in Kuala Lumpur

Demographic variable	Cheras		Bandar Tun Razak	
	Majority	(%)	Majority	(%)
Gender	Male	51.0	Male	51.1
Citizenship	Citizen	100.0	Citizen	95.6
Age	21-30 years old	72.0	21-30 years old	73.0
Education level	Degree	83.5	Degree	73.3
Occupational sector	Government	75.0	Private sector	51.0
Monthly household Income	RM5,001 – RM7,000	81.0	<RM5,000	76.0

The study found that all respondents from Kuala Lumpur think that Malaysia will be able to produce HFCV. The study also found that all respondents from Kuala Lumpur were confident that HFCV could be operated successfully in Malaysia. All Cheras and Bandar Tun Razak respondents believe that cars and busses are suitable for adopting hydrogen fuel cells, as shown in Figure 1. However, opinions varied on the suitability of lorries and heavy vehicles to adopt hydrogen fuel cells. Bandar Tun Razak had the lowest percentage of agreement on the suitability of lorries and heavy vehicles at 62.2%. However, 80% of respondents from Cheras believe that hydrogen fuel cells are suitable for lorries and heavy vehicles. As part of the study, all four Japanese vehicle manufacturers listed in the questionnaire (Toyota, Honda, Nissan and Mitsubishi) manufactured HFCV either commercially or conceptually, as shown in Figure 2. In Cheras, 97.6% of the respondents believe that Toyota has adopted HFCV in Malaysia, followed by Honda (91%), Nissan (25.9%) and Mitsubishi (11.8%). However, respondents from Bandar Tun Razak believe that Toyota also adopted HFCV in Malaysia with the highest percentage at 82.2%, followed by Honda (73.3%), Nissan (62.2%) and Toyota at 53.3%.

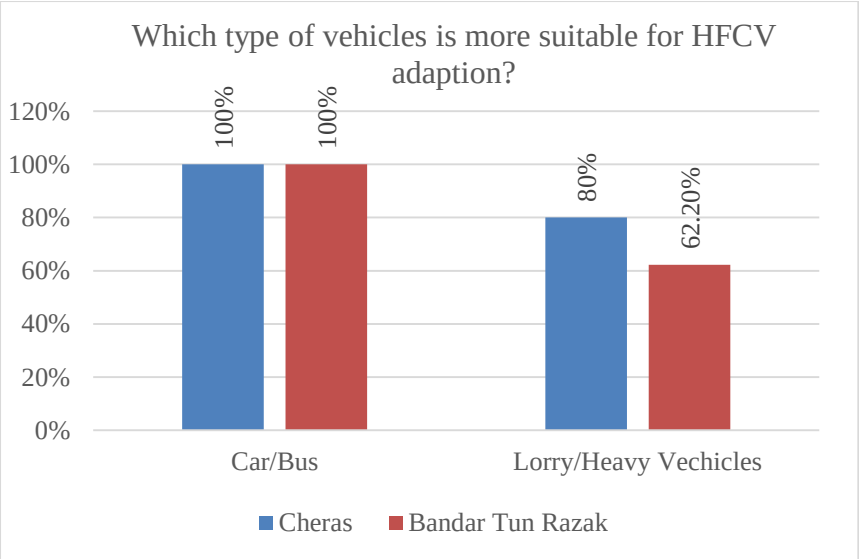

Figure 1. Public opinion on vehicle suitability for HFCV adoption

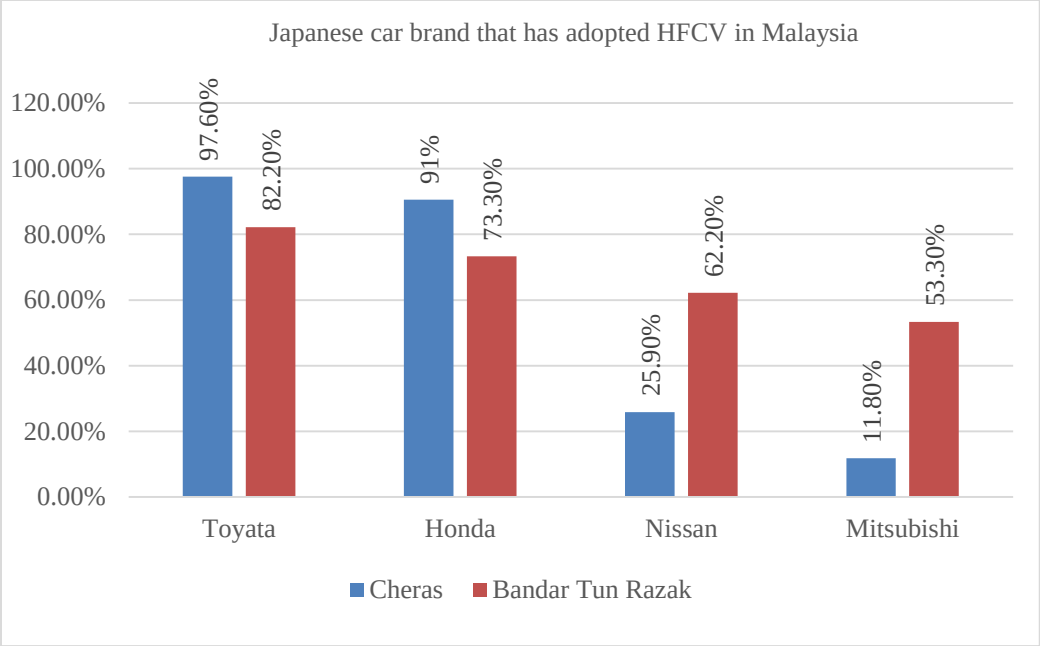

Figure 2. Perception and opinion of Japanese car brands that have adopted HFCV in Malaysia

The public understanding of HFCV in Malaysia

Several statements were included in the questionnaire to measure the respondents' level of understanding of HFCV, as shown in Table 3. The survey results of this study were not based on the respondents' experience of using HFCV but rather the general public's understanding and perception without the experience of using HFCV. The results indicate that 80% of the respondents from Bandar Tun Razak agreed to adopt the HFCV into their Malaysian lifestyle. However, only 1.2% of respondents from Cheras agreed about adopting the HFCV into their Malaysian lifestyle. The results indicate that 49.4 % and 44.4% of Cheras and Bandar Tun Razak respondents agreed that HFCVs have good performance acceleration. Most of the respondents from Bandar Tun Razak have a good understanding of the advantages of hydrogen fuel cells compared to respondents from Cheras. The former felt that HFCV had fast refuelling, quality engines, low oil dependence, and good road handling. They also believed that hydrogen fuel cells provide clean energy and less CO2 emissions, thus improving air quality and reducing pollution. However, to explore environmental issues, we found that only 12.9 % and 20% of Cheras and Bandar Tun Razak respondents respectively agreed that HFCVs have a low environmental impact. It means that respondents from both locations were less aware of environmentally friendly cars such as the HCFV.

HFCV has a high purchasing price and an inadequate support infrastructure, particularly regarding access to refueling stations to power fuel cell vehicles. However, most respondents from Cheras stated that low operation costs and purchasing prices need HFCV and had adequate support infrastructure to cater for HFCV. It means that most of the respondents from Cheras lacked awareness and knowledge about the disadvantages of HFCV compared to respondents from Bandar Tun Razak, who had a great level of awareness and knowledge. Interestingly, most of the respondents from Cheras agreed that HFCV had an excellent interior design and safety features and more efficient engines than conventional vehicles. Limited fuel sources for HFCV depend on hydrogen production, whether from renewable energy (like solar and wind) or non-renewable

energy (such as natural gas, nuclear power, biomass). However, according to Aaron Isenstadt and Lutsey (2017), hydrogen produced from renewable energy has a relatively high cost compared to hydrogen from fossil fuels. The results indicate that 38.8 % and 33.3% of respondents from Cheras and Bandar Tun Razak respectively agreed that fuel sources for HFCV are limited.

Table 3. The public understanding of HFCV in Malaysia

No.	Item Statement	% of agreement	
	In terms of my perception of HFCV adoption in Malaysia, I believe that HFCV will……	**Cheras**	**BTR**
1.	suit the Malaysian lifestyle	1.2	80.0
2.	have good performance acceleration	2.4	42.2
3.	have low environmental impact	12.9	20.0
4.	have fast refueling	17.6	22.2
5.	have quality engines	16.5	22.2
6.	have low oil dependence	18.8	20.0
7.	have good road handling	15.3	40.0
8.	have good safety and reliability	43.5	40.0
9.	have low running and operation costs	58.8	22.2
10.	have low purchase prices	51.8	28.9
11.	have a limited fuel source	38.8	33.3
12.	have good interior design	47.1	26.7
13.	have more efficient engines than conventional vehicles	48.2	26.7
14.	have adequate support infrastructures	49.4	44.4
15.	develop an image and sophisticated style of vehicle with hydrogen fuel cells	37.6	46.7
	Total score	**30.7**	**34.4**

The public perception of HFCV adoption in Malaysia

The findings for the public's perceptions of HFCV adoption in Malaysia are shown in Table 4. The results indicate that the respondents from Cheras and Bandar Tun Razak have a fair perception of HFCV implementation with a mean score of 1.89 and 1.76, respectively, indicating that most of them slightly agree with the item statements. The results showed that 83.5% and 48.9% of Cheras and Bandar Tun Razak respondents respectively believe that HFCV can increase energy conservation and improve efficiency in Malaysia's automotive industry. However, only 21.2% of Cheras respondents and 28.9% of Bandar Tun Razak respondents believe that HFCV will enhance the competitiveness of the Malaysian automotive industry. Most of the public believe HFCV is only at the beginning stage in Malaysia, and alternative fuel resources, like an HFC to substitute fossil fuels, still have some uncertainties that must be addressed. Hydrogen energy is a great clean energy carrier and can provide relevant solutions to environmental problems such as climate change, toxic gas emissions, and energy security. However, the results indicated that only 38.8% and 24.4% of Cheras and Bandar Tun Razak respondents respectively believe that HFCV will reduce negative environmental impacts and increase the quality of life. In other words, environmental concerns were considered to influence the adoption of HFCV and had a detrimental effect on market penetration. In this study, most respondents from Cheras state that HFCV will create new jobs and strengthen market forces, views not necessarily shared by respondents from Bandar Tun Razak. Most respondents from Bandar Tun Razak believe that HFCV will facilitate

research and interactions among stakeholders, ultimately leading to a sustainable transportation system using HFCV, a view not as strongly shared by respondents from Cheras.

Table 4. The public perception of HFCV adoption in Malaysia

No	Item statement	% of agreement	
	In terms of my perception of HFCV adoption in Malaysia, I believe that HFCV will……	**Cheras**	**BTR**
1.	Facilitate energy conservation and improve efficiency in the Malaysian automotive industry	83.5	48.9
2.	Enhance the competitiveness of the Malaysian automotive industry	21.2	28.9
3.	Reduce environmental impact and increase the quality of life through sustainable development and transportation	38.8	24.4
4.	Bring new job creation and contribute to a national competitive advantage	28.2	24.4
5.	Enable a market breakthrough of HFC technology, enabling market forces to drive a substantial public benefit	34.1	17.8
6.	Facilitate research efforts and give confidence to the automotive industry, public and private investors, and stakeholders to embark on long term HFCV programs	27.1	42.2
7.	Facilitate interaction between the vehicle industry in universities and research centres involved in fuel cell and hydrogen research	27.1	40.0
8.	Focus on fuel cell and hydrogen industrial competitive targets for cost, performance, and durability and overcome a critical hydrogen technology bottleneck	36.5	37.8
	Total score	**20.2**	**33.8**

The public perception of the economic benefits and challenges in HFCV adoption in Malaysia

The public perception of the economic benefits and challenges associated with HFCV adoption in Malaysia is shown in Table 5. The results indicate that most of the respondents from Cheras and Bandar Tun Razak slightly agree on the economic benefits and challenges of adopting HFCV, represented by a mean score of 1.75 and 1.68, respectively. In Malaysia, the energy industry contributes up to 20% of total GDP and is also a major oil-exporting country ASEAN-wide (Prambudia & Nakano, 2012). However, Malaysia's anticipated dependence on oil imports due to the gradual decline in producing oil, and industrial and transportation sectors are still deeply dependent on oil products. In this study, 4.7% and 60% of respondents from Cheras and Bandar Tun Razak believe that using hydrogen can reduce dependence on foreign oil imports. Besides that, 9.4% and 46.7% of respondents from Cheras and Bandar Tun Razak believe that HFCV could provide competitive market opportunities, particularly in the vehicle manufacturing industries. Most Cheras and Bandar Tun Razak respondents strongly believe that the adaption of HFCV can develop energy security and stabilise the energy process. In addition, the acceptance of HFCV by the public is also influenced by safety concerns about hydrogen transport and storage. Even though hydrogen is a highly flammable fuel source, it is much safer than other fuels because it evaporates quickly. The success of HFCV depends on recognising and accepting its advantages by the public and accepting that it is indispensable and safe. This study indicated that most respondents agreed that public education is required regarding hydrogen sources, their benefits to the environment and safety, and why people should change from conventional vehicles to HFCV.

Table 5. The public perception on the economic benefits and challenges towards HFCV adoption in Malaysia

No.	Item statement	% of agreement	
	I believe in the following economic benefits and challenges associated with the adoption of HFCV	**Cheras**	**BTR**
1.	Reduce dependence on foreign oil imports since hydrogen can be derived from domestic sources	4.7	60.0
2.	To be a developed country and competitive through high impact technology in vehicle manufacturing	9.4	46.7
3.	Provide reliable info to the public on hydrogen fuel safety and its benefits	27.1	37.8
4.	The level of understanding of Malaysians about HFCV is still low, and they need to be educated through the continuous dissemination of information.	38.8	24.4
5.	The current infrastructure for producing and getting hydrogen to consumers cannot yet support the widespread adoption of fuel cell vehicles	38.8	15.6
6.	Consumers must embrace fuel cell vehicles before their benefits can be realised, and consumers may have concerns about the dependability and safety of HFCV	32.9	33.3
7.	The adoption of hydrogen as a flexible energy carrier can contribute positively to energy security and stabilise the energy process as it can be produced from any primary energy sources	48.2	33.3
8.	To inform effectively and efficiently the general public about the advantages to the environment and to address any concerns which they might have about hydrogen safety	56.5	60.0
	Total score	**32.1**	**38.9**

Conclusion

This study addresses the public perception of adopting HFCV in Kuala Lumpur, Malaysia. Currently, Malaysia faces fuel depletion, high carbon emissions, and energy security issues due to its greater dependence on fossil fuels as the primary energy source in the transportation sector. The transportation system cannot be ignored in the context of socio-economic development and needs more sustainable and environmentally friendly options for alternative energy sources. Therefore, HFCV is expected to strengthen energy security and zero tailpipe emission by reducing fossil fuel dependence and supporting sustainable transport systems. Several developed nations have already moved towards a green hydrogen economy by slowly converting from conventional vehicles to HFCV. Notably, some developing countries, including Malaysia, are also looking to technological innovation to substitute non-renewable fuels (natural gas, oil, and coal) with hydrogen in their transportation systems. Even though hydrogen energy has potential for emission-free transport systems, safety concerns are still a constraint because it is a highly flammable fuel source and the high costs of investing in hydrogen fuel cell technology. In Malaysia, the policy of energy more consider R&D option and need a holistic approach to the successful evolution from a conventional energy economy to a sustainable energy system. This study focuses more on the understanding and perception of HFCV among the public by looking at the economic and environmental benefits, which are vital for the successful introduction of HFCV. In other words, the findings look more at the demand-side action with a focus on public perceptions concerning the adoption of HFCV. The results are consistent with other studies that considered the influence of consumer behavior on the purchase intention of HFCV (Al-Amin et al., 2016; Ingaldi & Klimecka-Ttar, 2020).

The overall results of this study found that demand-side action for HFCV among the public is influenced by supply-side aspects, including support infrastructure, characteristics of HFCV,

operation costs, safety concerns, competitive markets, and the social equilibrium of the innovation. Consequently, market demand and new technology adoption of HFCV will be successfully created with the adoption by the public that leads to the consumer's intention to purchase. The study also found that most respondents do not have much knowledge or awareness of the environmental benefits of using HFCV. The evidence from this study suggests that stakeholders should educate the public regarding the benefits of HFCV and create awareness through local advertising on television and radio - this is considered an essential step in the adoption of new technologies such as HFCV. The findings of this study also suggest that long-term planning and relevant policies by the Malaysian government are needed as it seeks new energy options and balances growing energy demands while at the same time developing a decarbonised economy through the introduction of HFCV. The opportunity to test drive the vehicles and use hydrogen fuel cells in local public transport will build confidence and acceptance of the new technology in local communities. Although this study focused on the Malaysian scenario, the findings can be utilised in other developing countries looking for sustainable energy security and reduced carbon emissions in the transportation sector by using HFCV.

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