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How can fuel cell vehicles bring a bright future for this dragon? Answer by multi-criteria decision making analysis

Long Zhang^{a,b,c}, Jing Yu^{a,b}, Jingzheng Ren^{d,*}, Linmao Ma^{a,b},
Weishi Zhang^e, Hanwei Liang^f

^a School of Economics and Management, China University of Geosciences, Wuhan 430074, China

^b Mineral Resource Strategy and Policy Research Center, China University of Geosciences, Wuhan 430074, China

^c Center for Energy Technologies, Department of Business and Technology Development, Aarhus University, Birk Centerpark 15, DK-7400 Herning, Denmark

^d Centre for Engineering Operations Management, Department of Technology and Innovation, University of Southern Denmark, Campusvej 55, DK-5230 Odense M, Denmark

^e Department of Geography and Resource Management, The Chinese University of Hong Kong, Wong Foo Yuan Building 251a, Sha Tin, Hong Kong

^f Collaborative Innovation Center on Forecast and Evaluation of Meteorological Disaster, School of Geography and Remote Sensing, Nanjing University of Information Science & Technology, Nanjing 210044, China

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ABSTRACT

Fuel Cell Vehicles (FCVs) has been introduced to the market around the world in recent years. As the largest automobile market of the world, China is also one of the potential FCVs market. However, a series of factors and barriers influence the willingness of China's customers to accept FCVs. By using Fishbone Diagram, field survey and workshop discussions, this paper proposes a group of factors that may affect customers' preferences on FCVs. Furthermore, Fuzzy AHP and Pareto Analysis are employed to prioritize these factors, and identify the critical ones. The results indicate that fuel availability, vehicle performance, and economic costs are the most important dimensions in affecting customers' attitude towards FCVs. More specifically, vehicle reliability and safety, purchasing cost, industry development, vehicle model and space contribute the most significance in customers' purchase decision. According to the results, some policy implications are proposed from the prospective of improving and demonstrating vehicle performance, government leading facility construction and operation, and costs reductions.

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Introduction

In recent years, driven by the increasing concerns about the environmental pollutions and GHG emissions of road

transports as well as oil peak and energy security issues [1,2], policy makers and automobile manufactures around the world have turned to sustainable transportation for solution. In fact, the transport sector have been the world's second largest CO₂ emitter for a long time, which accounted for a

* Corresponding author.

E-mail addresses: jjire@iti.sdu.dk, renjingzheng123321@163.com (J. Ren).

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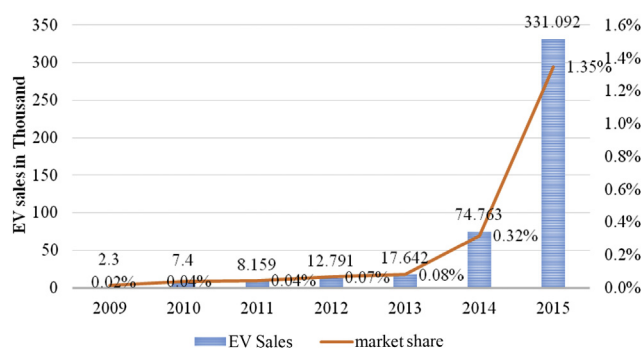
share of 23 percent in world total CO₂ emissions in 2013 [3]. In order to tackle the deteriorating energy security and environment quality, researchers have found that with electrification, the largest share of GHG emissions reductions would come from the transport sector [4]. Thus, reducing transport emissions, in particular vehicular emissions, is a key element for mitigating the risks of climate change [5].

In an attempt to take the place of the traditional internal combustion engine vehicles fueled by gasoline or diesel, a series of alternative fuel vehicles, cars run on alternatives to gasoline and diesel [6], including Fuel Cell Vehicles, Battery Electric Vehicles, Hybrid Electric Vehicles, and vehicles fueled by natural gas or bio-fuels, have developed by car manufacturers. Especially Electric Vehicles and Fuel Cell Vehicles, who powered by electricity and hydrogen fuel cells, catch much more public attentions and interests, due to their advantage of zero emissions [7].

During the past several years, Electric Vehicles have made great progress in global automobile market, with global market sales surpassing half a million in 2015 [8]. Comparatively, commercial introduction of FCVs started much later, when Hyundai started leasing FCVs in southern California and in a number of countries around the world in late 2014. After that, Toyota also announced it will begin FCV sales in the U.S. in 2015, and Honda claimed its FCV sales would start in 2016 [9]. Navigant Research forecasts that the annual sales of fuel cell vehicles—both cars and buses—will exceed 228,000 by 2024 [10]. In fact, hydrogen has been investigated and developed in industrialized countries for many years, and proved to be highly sustainable [11,12]. Harald Wester, Chief Technology Officer of Fiat Chrysler Automobiles, also the CEO of Maserati and Alfa Romeo, said that hydrogen fuel cells are a better choice for future powertrains of vehicles than batteries [13].

As the world's largest developing country, China has surpassed the United States as the world's largest automotive market in 2009 [14]. In order to cope with the increasingly shortage of fuels supply and the deteriorating environmental pollution problems, as well as to improve its competitiveness in global automobile market, this country turn to NEVs (New Energy Vehicles) seeking for solutions, including EVs and FCVs, which have been the focus of national policy and plan of China since 2001. By 2010, NEVs industry was categorized as the strategic emerging industry. Then, the State Council of PRC released the Energy Saving and New Energy Vehicles Industry Development Plan (2012–2020) in 2012, expecting the production and sales of NEVs reaching 500,000 units by 2015, and increasing that number to 2 million by 2020. Despite that the central government attached equal importance on EVs and FCVs, EVs do achieve much higher performance than FCVs in China. For instance, the EVs sales increased from 8159 thousand to 331,092 thousand from 2009 to 2015, and the market share went up from 0.02 to 1.35 percent (see Fig. 1). Someone may believe that these are fake numbers [15]; however, there is no doubt that China is among the countries with the most successful commercial EVs demonstration and promotion around the world [16].

By contrast, in 2015, only 10 FCVs are manufactured in China [17], and the roadmap of FCVs development is far more to be presented. With a batch of international auto manufactures introducing commercial promotion of FCVs in recent



Data source: China Association of Automobile Manufacturers

Fig. 1 – Electric vehicle sale and market share in China.

years, China has fallen far behind them in this field. Troubled by this dilemma, policy makers and auto manufactures in China are puzzled by the following questions:

- Should China follow the international trend to develop its own FCVs industry when it is making great progresses in the EVs field?
- Will it influence the current vibrant EVs industry if commercial promotion of FCVs are introduced in China?
- Can FCVs strike a bright future in China?
- What are the factors affecting customers' acceptance on FCVs?

To answer these questions, this paper identifies the factors that may potentially affect people's adoption of FCVs and group them into several groups by using Fishbone Diagram. To go a step further, it introduced the method of Fuzzy AHP and Pareto Analysis, which can be used to figure out how these factors affect people's adoption of FCVs. Lastly, it further draws some conclusions for this study, and proposes some policy implications for FCVs promotion in China.

Dimensions and factors

Scholars have done no shortage of researches on factors or values driving customer's willingness to pay for EVs or other alternative vehicles. However, as respect to FCVs, since its commercial introduction began only in recent years, so very few researches have investigated that. Mourato investigates the preferences of London taxi drivers for driving emissions-free hydrogen fuel cell taxis in the short term and in the long term [18]. O'Garra used to do an international comparison of public willingness to pay for air pollution reduction in four cities, Berlin, London, Luxembourg and Perth, by using a scenario of large-scale introduction of hydrogen fuel cell buses [19]. Keles et al. analyzed the market penetration of FCVs caused by different financial policies based on System Dynamics model [20]. Ball and Wietschel discussed the opportunities and barriers of introducing FCVs from different aspects [21]. Roche et al. reviewed the researches on public attitudes towards FCVs and the findings of some important researches [22]. Hardman et al. assessed consumer attitudes towards FCVs in the United Kingdom [23]. In their studies,

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