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Changing the fate of Fuel Cell Vehicles: Can lessons be learnt from Tesla Motors?

Scott Hardman [a,*], *Eric Shiu* [b], *Robert Steinberger-Wilckens* [a]

[a] *Centre for Hydrogen and Fuel Cell Research, School of Chemical Engineering, University of Birmingham, Birmingham, B15 2TT, UK*

[b] *Birmingham Business School, University House, University of Birmingham, Birmingham, B15 2TT, UK*

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ABSTRACT

Fuel Cell Vehicles (FCVs) are a disruptive innovation and are currently looking towards niche market entry. However, commercialisation has been unsuccessful thus far and there is a limited amount of literature that can guide their market entry. In this paper a historical case study is undertaken which looks at Tesla Motors high-end encroachment market entry strategy. FCVs have been compared to Tesla vehicles due to their similarities; both are disruptive innovations, both are high cost and both are zero emission vehicles. Therefore this paper looks at what can be learned form Tesla Motors successful market entry strategy and proposes a market entry strategy for FCVs. It was found that FCVs need to enact a paradigm shift from their current market entry strategy to one of high-end encroachment. When this has been achieved FCVs will have greater potential for market penetration.

Introduction

Previously [1] a market entry strategy for Fuel Cells Vehicles (FCVs) was described based on successful historic examples of disruptive innovations entering markets. The study briefly discussed Tesla Motor's method of market entry for Battery Electric Vehicles (BEVs). This paper presents the case of how Tesla Motors achieved high-end encroachment market entry with a disruptive technology in more detail. This historical case study is important for FCVs because it shows that high value disruptive technologies can enter markets with deeply entrenched incumbent technologies within the automotive sector. A greater understanding of how to successfully market FCVs and BEVs will result from this study. As is shown, Tesla's approach is easily distinguishable compared to other companies producing BEVs.

High-end encroachment is not a new market entry strategy for automotive technologies. Daimler, for example, has often introduced new automotive technologies in their flagship S-Class vehicle. Many of these innovations are expensive but the high price of the S-Class allows costs to be absorbed. More recently carbon fibre body panels and ceramic brakes have been introduced first in high value sports cars. These technologies are then diffused down to lower value vehicles as costs are reduced. In addition to these automotive technologies many other disruptive innovations have entered markers via high-end encroachment including; Quartz Watches,

* *Corresponding author*. Tel.: +44 (0)121 414 7044.
E-mail address: sxh993@bham.ac.uk (S. Hardman).
URL: http://www.fuelcells.bham.ac.uk

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Hydraulic Excavators, MP3 Players and Steamships to mention just a few [1]. Despite a legacy of high-end encroachment within the automotive sector and other markets, Daimler, Toyota and Hyundai do not appear to be doing this with FCVs. These companies appear to be attempting to introduce FCs in mass-market vehicles. In this paper we argue that this is not the best strategy to introduce FCVs to the market.

The BEV is shown in literature [2,3] to be a disruptive technology. BEVs are disruptive based on the Three Point Disruptive Technology Criteria [1], which states that innovations are disruptive if they; are produced by different manufactures in the supply chain, require new infrastructure and change the way the in which users interact with the technology. It could be argued that BEVs do not actually require new infrastructure as they can be charged using existing plug sockets. However with existing plug sockets, charge rates are extremely low and charging away from home is not possible. Therefore to use a BEV to its fullest potential faster home chargers are needed, as are public charge stations.

BEVs are not a new technology; they find their beginnings in Scotland in 1842 [4]. Initially they were preferred to gasoline and steam driven vehicles. In 1899 over 1500 BEVs were sold in the US compared to 900 gasoline vehicles [5]. In the first three decades of the 20th century New York had a charging station network for BEVs. BEVs were especially marketed to women as; 1) they were cleaner and had no emissions, 2) they were quieter than ICE vehicles, 3) they did not have any moving parts so were easier to maintain and 4) they didn't need to be started with a hand crank.

The market leading BEV company was Detroit Electric, operating between 1907 and 1939. Their BEVs were capable of achieving ranges of 211 miles, but commonly achieved 80 miles. By 1910 the company was producing 800 vehicles per year and peak sales reached 1800 units in 1916 [6].

From the 1930s Internal Combustion Engine Vehicles (ICEVs) drove BEVs out of the marketplace. ICEVs quickly became dominant and were consolidated as the primary vehicle choice. They were cheaper than BEVs [5,7], had longer ranges, could be refilled in minutes and were capable of higher speeds. Crucially, oil had become readily available at a low cost [4]. The invention of the electric starter motor for ICEVs, allowing them to be started easily, was damaging to BEVs. The ability of BEVs to be started with ease no longer added value, as ICEVs could do the same. All automobiles were initially expensive and only a minority could afford them. Automobile range and speed were important characteristics as racing and touring was popular, and members of the learned gentry began the noble sport of racing throughout Europe. This niche was important in the development of ICEVs. In this application ICEVs were more competitive than BEVs, which lost out due to poor battery quality, low power density, reliability and sturdiness. A similar story is presented in more detail by Geels [8].

The BEV did not disappear altogether; one notable use of BEVs was in milk floats in the UK. BEVs suited this niche as they complied to post WWI legislation, stating that delivery vehicles making repeated stops in housing areas should be non-polluting [5]. The limited speed and range had no negative impact and the quiet running was advantageous. In the 1990s the BEV received a small revival in California. General Motors produced over 1000 of their BEV, the EV-1. Although the vehicles complied with California's Zero Emission Mandate they could not compete with ICE vehicles, partly due to the poor lead-acid batteries used. Another reason BEVs in California did not take off at this time could have been due to the introduction of hybrid BEVs [9]. Now, 23 years later BEVs are receiving a revival once more. Despite the BEV not being a new technology it can still be classed as an innovation. Rogers [10] states that a technology does not need to be new in order to be an innovation. If a new technology seems new to an individual it can still be considered to be an innovation. This is the case with BEVs.

The objective of this paper is to identify a market entry strategy for new automotive technologies and especially FCVs. In particular this paper investigates how disruptive automotive technologies that are more expensive than incumbents can nevertheless enter market through high-end encroachment. This is a useful insight because most often innovative and disruptive products in the automotive industry are more expensive upon market entry. This research therefore has implications for the automotive industry and can be applied to other market sectors and disruptive technologies of a similar character.

Introduction to Tesla

Tesla Motors was chosen for this study, as it was the closest case that the authors were able to identify. Both FCVs and Tesla BEVs are considered to be an innovation, both are zero emission, both are fully or partly reliant upon the development of infrastructure and both exceed the cost of incumbent ICEVs. Table 1 shows a comparison between FCVs and Tesla along with other vehicles that were considered for this study. Unlike other BEV manufacturers who attempt to make their vehicles competitive with ICE vehicles, Tesla aims at making

Table 1 – Comparison between FCV, Tesla and other electric vehicles considered for this study.

Vehicle	Cost (USD)	New Infrastructure	Zero Emissions
Fuel Cell Vehicle	70,000	✓	✓
Tesla BEVs	75,000-95,000	✓	✓
Nissan Leaf	30,000	✓	✓
Plug-in Prius	30,000	✕	✕
Panamera Hybrid	96,000	✕	✕

its BEVs better than incumbent ICE vehicles. To achieve this, the company has invested a lot in research and development and has secured 117 patents with 258 patents pending. Its Model S BEV is a range leader at 265-314 miles, a Pack Cost leader by using already mass produced cells from Panasonic, and a Charge Rate leader achieving 50% charge in 30 min [11].

Tesla's goal is to eventually release a mass market BEV, but they are rolling this out over an extended period of time. According to CEO Elon Musk the company is pursuing a three-stage market entry strategy. Musk said in the 2013 shareholder meeting that it was always his intention to produce a mass market BEV [11], he reiterates this in the 2014 shareholder meeting [12]. In order to reach mass-market entry the three-stage market entry process is [13]:

1. Develop a high price low volume vehicle: The Roadster
2. Develop a mid price, mid volume vehicle: The Model S and Model X
3. Develop a low price, high volume vehicle: Due in 2016–2017 (Called the Model 3 or III).

Tesla's CEO draws analogy against the mobile phone, which was able to achieve impressive technological development and cost reductions over successive generations [14], but this occurred over a long time span. Tesla is trying to achieve this over a shorter period of time and with fewer generations. Tesla hope that the third generation model will be available from around half the price of the Model S [11], which would mean it would be priced between $30,000–45,000 (£19,000–29,000).

Theoretical underpinnings: disruptive innovation & high-end encroachment

Disruptive innovation theory was originally published by Christensen [15]. A disruptive innovation is defined as *"a product or service that displaces an incumbent product or service"*. Danneels [16] defined disruptive innovation as "A Technology that changes the bases of competition, changing the performance metrics along which firms compete". The most recent definition was by Gilbert [17] who defines it as *"A new technologies that unexpectedly displaces an established one"*. A 2013 study by the authors of this paper undertook a review of the theory and discovered that disruptive innovations are more expensive than existing technologies, the new technology will be less developed than the incumbent but the disruptive technology will posses added value features. It was also found that disruptive innovations will firstly fill niches towards the top of the market, and will then diffuse downwards into the more competitive mass-market levels [1].

Disruptive innovations initially enter niches that are not attractive to incumbent firms [15]. These markets are unappealing mainly due to low volume sales potential, and because they demand specialised products that could not be produced at an economically viable price. This means that incumbent firms cannot produce a product that will maintain existing profit margins. This makes it easier for the disruptive innovation to enter these markets, as there will be no existing competition. In these niches the new technologies are not seen as a threat to incumbents [1]. However once unit sales are increased and costs reduced they can diffuse down the market, it is as this stage that they become actually disruptive to the market leaders sales and profits.

Christensen did not include high-end encroachment in the original definition of disruptive innovation [18]. However much subsequent literature [1,19–21] does present a good case for including high-end encroachment into the theory. Additionally the mobile phone, which is an example of high-end encroachment, is classified as a disruptive innovation by Christensen [15,22]. The effects of high-end encroachment on the market can be immediate and significant, meaning that innovations that enter markets via high-end encroachment are disruptive [23].

There are three types of high-end encroachment. These are New Market, New Attribute and Immediate High-End Encroachment. The type of high-end encroachment depends upon the level of Core Attribute and Ancillary Attribute Performance changes compared to the incumbent innovation [21], as shown in Fig. 1. The first customers who purchase high end innovations are typically innovators, as based on Rogers [10] theory. These innovators typically place a higher value on the performance advancements of the high-end innovations, more than low end customers would [24].

New Market encroachment depends upon the highest level of core attribute improvements along with strong ancillary attribute improvements. The innovations will also be high priced; these innovations open up new markets at the top of a market [19,20]. This is usually the first stage of a market entry strategy and the innovations will generally diffuse down from this high-end market to progressively lower markets as cost reductions are achieved. This is the market entry approach that Tesla Motors have used, their first model the Tesla Roadster was targeted to high-end customers in a new market space at the top of the electric vehicle market.

New Attribute high-end encroachment is where core attributes are improved to a similar extent as new market encroachment. With this strategy ancillary attributes are only moderately improved compared to incumbent technologies. These innovations have higher costs than incumbent technologies, but the difference in cost is less significant than with new market innovations. These innovations enter the top of existing markets, they do not open new markets, the innovations then diffuse to lower market levels [19]. Innovations in the automotive sector that fit this pattern include hybrid

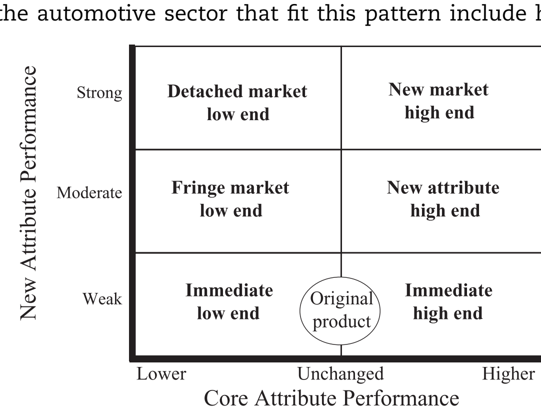

Fig. 1 – The six encroachment types as determined by new product performance and core and ancillary attribute dimensions [21].

Table 2 – On-the-road price of electric vehicles in the UK, excluding the £5000 BEV grant available off the purchase price [30–34].

	BMW i3	Citroen C-ZERO	Nissan Leaf	Peugeot iOn	Renault ZOE	Mitsubishi iMiEV
Cost (£)	£30,730	£26,216	£25,990	£26,216	£18,995[a]	£28,990
Range (Miles)	80–100	93	124	93	130	93

[a] Excludes battery rental at £70/month.

vehicles where ancillary attributes are moderately improved but core attributes are often much improved over comparable ICE vehicles. On market introduction hybrid vehicles were more expensive than ICE vehicles but less so than the Tesla Roadster or Tesla Model S.

Both FCVs and BEVs are disruptive innovations [1,3]. They are both automotive technologies entering a highly competitive market. They share a number of characteristics such as zero tailpipe emissions, silent operation, electric drivetrain, smooth acceleration and high torque figures. They also have some shared barriers to market entry, they are disruptive innovations, costing more than incumbent ICE vehicles, and both suffer from poor infrastructure access at present. For these reasons the comparison of Tesla BEVs to FCVs is appropriate to help understand how to market FCVs in the future. The higher than average prices of Tesla vehicles makes the comparison especially useful, this is because FCVs are expected to cost significantly more than conventional ICE vehicles due to the novel materials used and initial lack of economies of scale.

It should be acknowledged that for disruptive innovations high-end encroachment is not the only appropriate market entry strategy. Low end encroachment where technologies enter at the bottom of the market in low value applications is also possible [25]. Low-end encroachment is not being explored for FCVs because this market entry strategy would not be possible. The high prices inherent with FCVs mean they would not be able to compete with incumbent ICE vehicles on price. According to Van Orden et al., 2011 [21] there are 6 types of encroachment patterns, 3 high-end and 3 low-end encroachment patterns, as shown in Fig. 1.

Problems with mass market entry

A key aspect in the market entry of BEVs is customer identification. When target customers are being discussed within the literature, key themes arise. It is stated that early adopters of BEVs are highly educated, environmental conscious and have oil supplies concerns [4,26,27]. Most studies overlook the need for BEV users to have higher incomes due to the high prices of BEVs, some studies do acknowledge this, though [28]. Table 1 shows prices of BEVs currently available in the UK. It is clear that they are more expensive than a comparable ICE vehicle, and have shorter ranges. This is a major hurdle for mass market low-end encroachment market entry [29].

Price and payback times

Whilst BEV sales are increasing [35], market uptake is still low. A 2013 study found that intent to purchase a BEV is still very low [26]. Prospective customers see the main advantage of a BEV as potential fuel savings, however the initial purchase price of BEVs Table 2 compared to a similar conventional vehicle is too high to justify these fuel savings. Payback times are found to be unacceptably long [26].

A comparison can be seen in Fig. 2 showing the running costs of a Nissan Leaf with 4 similar rival vehicles. These running costs are based on the information in Table 3. Fig. 2 shows that the Nissan Leaf does not become the cheapest

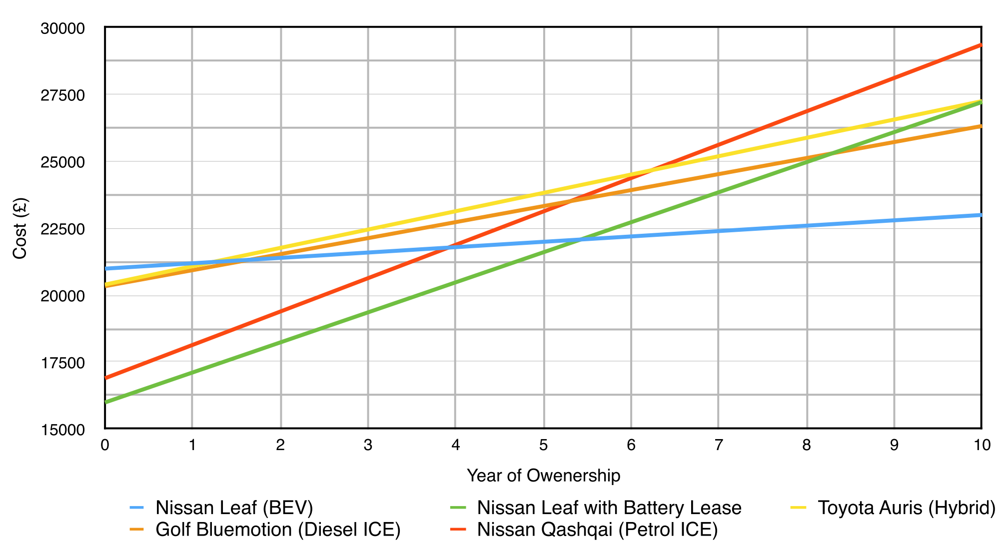

Fig. 2 – Running costs per year of the Nissan Leaf Compared to its rival hybrid, ICE and diesel cars. Based on purchase price, fuel costs and road tax, this is including the government £5000 plug in vehicle grant [31,36–38].

Table 3 – Running costs per year the Nissan Leaf and its rival vehicles [31,36–40].

	Nissan Leaf	Nissan Leaf (battery lease)	Toyota Auris hybrid	VW Golf Bluemotion	Nissan Qashqai
Purchase price (£)	25,990	20,990	20,395	20,335	16,895
Electric vehicle grant (£)	5000	5000	na	na	na
Battery lease (£ year^{-1})	na	922	na	na	na
Tax (£ year^{-1})	0	0	0	0	130
Combined cycle (MPG)	Na	na	74.3	88.3	45.6
Consumption (kWh mile^{-1})	0.34	0.34	na	na	na
Electricity cost (£ kWh^{-1})	0.07	0.07	na	na	na
Fuel usage (L year^{-1})	Na	na	515.79	434.02	840.43
Fuel cost (£ L^{-1})	Na	na	1.329	1.379	1.33
Fuel cost (£ year^{-1})	200.6	200.6	685.49	598.51	1,116.93
Running costs (£ year^{-1})	200.63	1,122.63	685.49	598.51	1,246.93

vehicle type almost 4 years of ownership. However, when the battery is leased (£70 per month) the Leaf is the lowest cost option from year 0, due to the reduced purchase price, but becomes more expensive than a Hybrid after 8 years and a Diesel ICE after 10 years due high battery lease costs. It is important to consider that these findings are based on a £5000 UK government grant available for plug-in vehicles. A cost comparison in the absence of these running costs can be seen in Fig. 3. The information in Fig. 3 suggests that the Leaf's does not become the cheapest vehicle type until more than 10 years when compared to a hybrid vehicle or an efficient diesel vehicle. BEV grants are not available in all nations meaning ICE vehicles are still often cost effective due to unacceptably long pay back periods. To suggest to consumer that mass market BEVs can save you money, on the basis of lower fuel costs alone, would be misleading and untrue according to these findings (Fig. 2).

Range

For consumers limited range is an issue, and a preventative factor when purchasing a BEV. Ranges of mass market BEVs are around 87 [41] to 124 miles [42]. Ranges are limited due to cost reductions. For many customers this limited range wouldn't be an issue; Pearre et al. [43] suggested that 75% of the US population could substitute an ICE for a BEV with limited disruption due to range. However, drivers still perceive the range as an issue. Daily, many people don't drive further than the range of a BEV (87–124 miles), but on a monthly or annual basis journeys exceeding these ranges are common. This raises the issue of high income being important in the adoption of BEVs. BEVs would form part of a multi-vehicle fleet, with a second ICE vehicle being available for journeys exceeding the BEVs range [44].

Core & ancillary attributes

In addition to mass market BEVs having lower ranges compared to ICE vehicles there are other core attributes with lower performance values. Mass market BEVs have slower 0-60 mph acceleration times, and lower top speeds. This means that vehicles have core attributes that are worse than the incumbents, and many core attributes, such as the visual appearance of the vehicle and the level of equipment (sat nav, radio, air conditioning etc.) remain unchanged. All of this would lead to a logical suggestion that these types of BEVs should be entering markets via low-end encroachment, but their high prices prevent this from being a possibility. As a result they are marketed at higher prices then ICEVs despite them not having improved core or ancillary attributes.

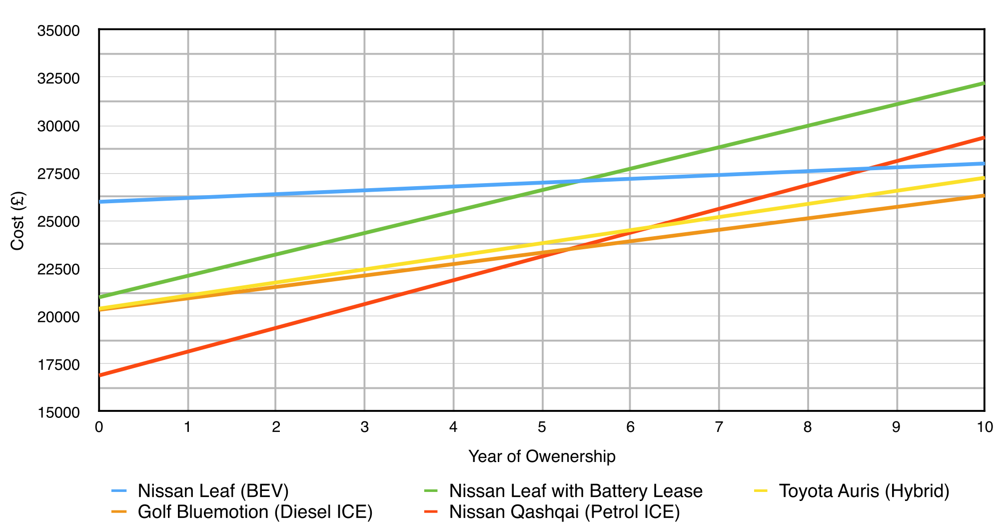

Fig. 3 – Running costs per year of the Nissan Leaf Compared to its rival hybrid, ICE and diesel cars. Based on purchase price, fuel costs and road tax, this is excluding the government £5000 plug in vehicle grant [31,36–38].

Consumer perceptions

Often the image of a technology or product is developed over a long period of time and their perception is based on previous experience and exposure. This is problematic for BEVs since current BEVs are much more advanced than previous ones. However, people may base their perceptions of BEVs based on previous prevailing opinions. In the UK it is suggested that buyers' perceptions of BEVs are negative because of previous experiences & observations of Milk Floats, Electric Golf carts and Quadricycle BEVs such as the G-wiz [45]. As a result of this, consumer's opinion of the core attributes of a BEV are even lower than the actual core values. There is a need to change these views in order to increase market uptake.

Garling & Thøgersen stated in 2001 that "*Higher prices, limited ranges, less loading capacities and lower top speeds are not a desirable package*" Whilst this statement was made in 2001 it still remains true today. Compared to their most direct rivals electric vehicles do fall short in these areas. Because of these inadequacies, it was suggested that BEVs should enter markets with low introductory prices and that drivers of high-end cars are unlikely to purchase a BEV over an ICE vehicle [4]. As a result of statements such as these many automotive manufactures have gone down the route of cost minimisation for mass market BEVs, but this leads to the core values of the technology being inferior to incumbent vehicles, and this causes the negative views of BEVs to continue. And indeed costs have not been able to be reduced to a level that makes them cost competitive compared to ICEVs.

There is an additional consequence of introducing poor quality products into to the market. Not only will initial market uptake be low, it can harm future diffusion rates. The first people to adopt new technologies are innovators & early adopters [10]. These people are often opinion leaders and are an important source of information for groups of later adopters [10]. Word of mouth marketing is important in the spread of new technologies [46] and the views of opinion leaders will either drive of halt market uptake. If the first adopters view BEVs as inferior they are unlikely to recommend the vehicles to others in their network, thus stifling their market uptake. The high-end encroachment strategy reduces the risk of this occurring.

Summary

With the BEV cost minimisation is not the answer, a market entry route that concentrates on improving core and ancillary attributes through developing a high quality product is more relevant. The poor core attributes of BEVs discussed here are only present in BEVs for mass markets, such as the Nissan Leaf, Peugeot iOn, Mitsubishi i-MiEV, and Smart electric. As we shall see, one automotive company has produced BEVs with none of the disadvantages of these BEVs and superior core and ancillary attributes compared to ICEVs. This company has developed a high value BEV without shortcomings of mass market BEVs. This high-end encroachment market entry approach has long been used within the automotive sector and indeed many other market sectors. However with BEVs & FCVs it has been neglected by many automotive organisations, with most companies seeking a route of mass-market entry first. Some of

Table 4 – Outline of Tesla data sources.

Source	Type	Dates filed	Data available	Available from
Form 10K	Annual Report	March 2011, Feb 2012, March 2012, March 2013, Feb 2014	Company Strategy, Sales Volumes	http://ir.teslamotors.com/sec.cfm?DocType=Annual&Year=&FormatFilter=
Form 10Q	Quarterly Report	Aug 2010, Nov 2010, May 2011, Aug 2011, Nov 2011, May 2012, Aug 2012, Nov 2012, May 2013, Nov 2013, May 2014, Aug 2014, Nov 2014	Company Strategy, Sales Volumes	http://ir.teslamotors.com/sec.cfm?DocType=Quarterly&Year=&FormatFilter=

these companies have seen success thanks to government incentives, especially Nissan with the Leaf; however this case study is less relevant for FCVs due to the lower purchase price of the Leaf. The price point of the Leaf is currently unattainable for FCVs and so this low cost market entry route is not appropriate for FCVs. This is the reason for the Leaf or any other BEV not being the subject of this study.

Methods

The use of historical case studies in research is a widely discussed issue. Flyvbjerg [47] presents a good case supporting the use of case studies as do Shiu et al. [48]. Gerring [49] presents a more detailed picture of the use of historical accounts to build case studies as part of research methods. These supporters believe that they are valuable tools for the researcher and that findings of case studies can provide worthwhile contributions to a researcher's subject area. Steinberger-Wilckens used similar historical case study methods when looking at disruptive technological market entry [50], this paper looked at mobile phones, small scale photovoltaic's, green electricity and double glazing. Geels [8] successfully uses case studies in order to create an improved understanding of technological change. A previous paper by Hardman et al. looked at historical examples of disruptive innovations [1], and another used a case study of mobile phone infrastructure to suggest a development strategy for hydrogen infrastructure [14]. Investigating historical examples of new product market entry is a valuable tool that can help us understand how to introduce innovations in the future. In this paper, by looking at a current example of a high-end encroachment for disruptive technologies entering the market, a more in-depth understanding of how to introduce high value innovations will emerge.

The main source of data for this study came from financial reports compiled by Tesla. Tesla files Form 10-K's once annually, Form 10-Q's once quarterly along with Form 8-K's on a monthly basis. A summary of these data sources is shown in Table 1. Tesla also release video footage of their Annual Share Holders meetings. These reports allow the company to communicate to investors. The reports contain a substantial amount of information including market analysis, financial data, sales volumes, order numbers, information on supplies and overall strategy of the company. These financial reports that are filed with the US Securities and Exchange Commission (SEC) are considered to be accurate and reliable. Laws and regulations surrounding the filings prohibit companies from reporting false or misleading information. To ensure compliance the forms are reviewed and audited by the US SEC and are made available to the public.

When carrying out secondary research it is important to ensure the quality and reliability of the data [48]. In order to further ensure the accuracy of the filings three accounting companies were requested to give advice on the reliability of such financial reports. The feedback from all three was that with current laws, regulations and audits the reports do not usually contain falsehoods. In addition to this, the reports were sent to one of the companies so that they could in detail assess the credibility of the reports. The conclusion of this was that the reports could be considered to be accurate in their professional opinion Table 4.

These SEC filings are only available from 2010 when Tesla was offered on the NASDAQ for the first time. This creates issues because the Tesla Roadster was released for sale in 2008, therefore alternative sources of information are required for 2008–2010. This information was obtained from media reports that were released at the time; many of these reports were following the market introduction of the Tesla Roadster from 2008 onwards. At the time this was an exciting event so coverage was substantial. Some information is also obtained from Tesla's own press releases. Tesla CEO Elon Musk is a high profile CEO and hence has been interviewed many times and done many presentations. Much of these are available on video streaming websites. These interviews provide a good insight into Tesla and can provide additional information not included in the SEC filings.

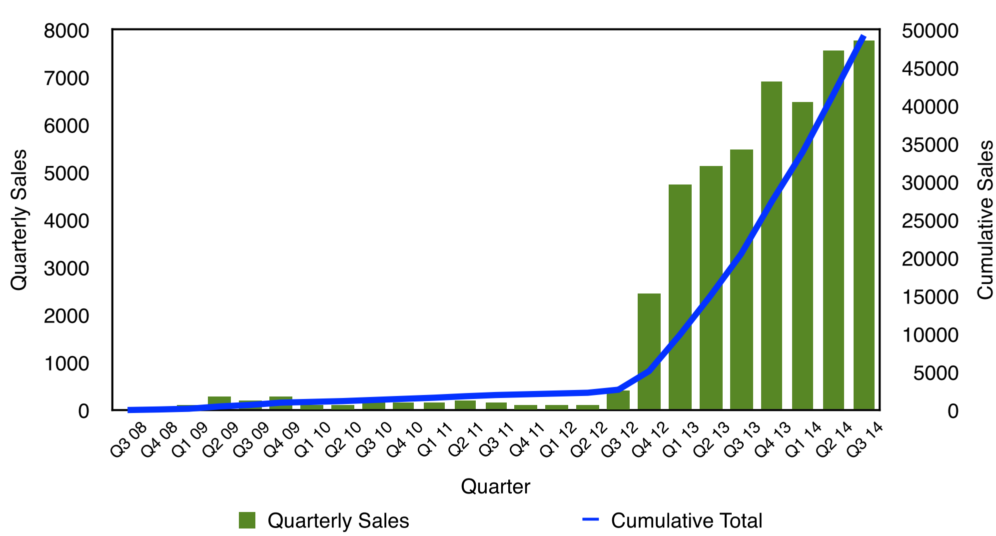

Fig. 4 – Summary of Tesla Roadster and Model S sales figures 2008–2014 Q3.

Results and discussion

Overview

The automotive sector is mostly dominated by large automotive OEMs producing ICEVs, it is a market with deeply entrenched incumbents. Tesla Motors is a new market entrant within the sector, they are produces of BEVs, which are a disruptive innovation. Tesla released its first models, the Roadster in 2008, and since then they have achieved sales close to 50,000 units (Fig. 4). The company entered at the top of the market by selling a high-value Roadster in low numbers. Since then they have released their second vehicle, the Model S. This is being sold at larger volumes, and at a lower price than the Roadster. The company has plans to release its third model, the Model X in 2015 at a similar price to the Model S. Beyond the Model X the company hopes to release the Model III. It is hoped that this model will be sold at even greater units and at a lower price. This is a clear case of high-end encroachment for a disruptive innovation. Tesla has entered at the top of the market and are now slowly moving downwards as cost reductions are achieve. The authors hope that a similar market entry strategy can be adopted for FCVs (Fig. 5).

Tesla Roadster

In the 2013 shareholder meeting, Tesla CEO Elon Musk remarked that Tesla could have launched their first BEV for around $70,000 (£45,000) [11]. At this price the vehicle would be a mid size family car with poor range and performance. By adding $30,000 (£19,000) to the price tag Tesla were able to make a sports car that was much more appealing for buyers. In this market the vehicle is competitive on price, performance, looks, range and has lower running costs [51]. The key to Tesla's market entry was the correct market positioning of their first vehicle.

When the Roadster was launched in 2008 it was clearly a market leading BEV. The Roadster was the first federally compliant BEV in the US. It was the first highway capable BEV and had market leading range on each charge (245 miles). Tesla was aiming this vehicle at owners of sports cars such as the Porsche 911. In this market Tesla was able to compete on price, performance and had 70% lower running costs according to Tesla. This means that the Tesla Roadster compared to a Porsche 911 will pay back in less than 3 years (Fig. 4). This is achieved without any purchase incentives. In the UK the running costs of the Tesla could be as low as £220 per year if changed on a low cost electricity tariff (£0.07/kW economy 7 rate) [39], this is compared to over £2000 in petrol and road tax for the Porsche. The high running costs for the Porsche are due to low fuel efficiency (29.4 mpg), high UK fuel cost and high UK road tax.

It could be argued that high-end early adopters of BEVs are not concerned about pay back times and running costs of their vehicles. However existing literature identified that early adopters of BEVs will be high income and be concerned about the rising cost of fuel [28,52]. Hence will their purchase decisions will be motivated by potential cost savings associated with BEVs. Additionally the concept of rational economic behaviour indicates that the reduction of running costs is a logical decision for consumers to make regardless of their income [53,54]. This payback time is also coupled to high performance, low emissions, bold looks and high brand equity, which are core attributes that consumers value and the Roadster has ancillary attributes such as silent drive, smooth drive and zero tailpipe emission. Early adopters of Tesla BEVs are acting in a reasonable and logical manor by seeking to reduce running costs. These cost reductions are achieved whilst maintaining the same core and ancillary benefits they receive from this type of high-end, high-performance vehicle Table 5.

Model S

The technology in the Roadster was designed so that it could serve as a foundation technology for future models. The Model S is Tesla second vehicle, and is designed for a wider

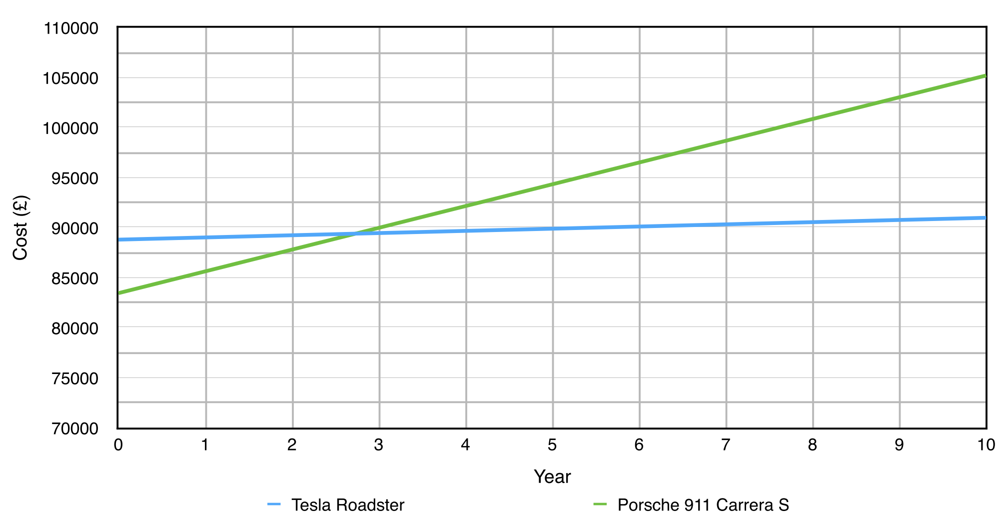

Fig. 5 – Running costs per year of the Tesla Roadster compared to a rival ICE vehicle the Porsche 911 [56–58].

Table 5 – Running costs per year the Tesla Roadster and its rival vehicle the Porsche 911 [39,55,56].

	Tesla Roadster	Porsche 911
Purchase price (£)	88,795	83,448
Electric vehicle Grant (£)	na	na
Battery lease (£ $year^{-1}$)	0	0
Tax (£ $year^{-1}$)	0	460
Combined cycle (MPG)	0	29.7
Consumption (kWh $mile^{-1}$)	0.37	na
Electricity cost (£ kWh^{-1})	0.07	na
Fuel usage (L $year^{-1}$)	na	283.84
Fuel cost (£ $year^{-1}$)	na	1,290.35
Fuel cost (£ L^{-1})	na	1.329
Fuel costs (£ $year^{-1}$)	218.3	1,714.88
Running costs (£ $year^{-1}$)	218.34	2,174.88

market than the Roadster. The vehicle is more practical, with 5 seats with the option of 7 and is available for a lower price around $62,000 (£40,000) in the US after the $7500 (£4800) federal tax credit. This makes the car price-competitive with similar cars in the luxury sedan class; Tesla lists Audi, BMW, Lexus and Mercedes as competition for the Model S. In this market the Model S is price competitive and has strong core and ancillary attributes compared with these vehicles. Due to vehicles in this class being inefficient due to their large engines and weights the Model S can provide significant savings in running costs. Fig. 6 shows that even without any subsidies the Model S pays back within 4 years of ownership, compared to its most efficient and lowest cost rival. This is 6 years faster than the payback time of the Nissan Leaf. With the UKs £5000 grant, which it is eligible for, the Model S is immediately cheaper. The running costs of the Model S would be £220 per year based on £0 road tax, 8430 miles of driving, £0.07/kW electricity cost [39] and 0.37 kWh consumption per mile [59] (Fig. 7), Fig. 8 Table 6.

Deliveries of the Model S began in June 2012, and by December 2012 3100 had been delivered with over 15,000 reserved. By Q4 of 2014 46,000 Model S's were delivered to customers, these were mainly in North America and the Model S was the top selling BEV in the US throughout 2013 beating the Mercedes S Class, Porsche Panamera, Audi A8 and BMW 7 Series [63]. Sales figures, which is measured by the number of vehicles delivered, of the Model S can be seen in Fig. 6. In late 2013 sales of the Model S began in Europe and Asia. Orders for the Model S continue to come in at a rate of 20,000 per annum. By the end of 2014 sales of the Model S will exceed 50,000 units.

The Model S represents the first part of the second stage of Tesla's three-stage market entry. The Model S is a mid to high price medium volume production car. The S is cost competitive to other luxury sedans in the market (Fig. 6). The Model S has received numerous awards including car of the year [64] and was Consumer Reports highest scoring car ever tested. Consumer Reports said that it is the best car on sale today despite being an electric car; the report goes on to say the electric drive train is the reason the Model S achieves its high score [65].

Model X

The Model X will share the same basic architecture as the Model S, but with a larger body and 4-wheel drive. The Model X is a cross between a sports car, SUV and Mini van with none of the compromises of any of these vehicle types. The Model X is the first BEV with dual motor 4-wheel drive. It also has innovative doors allowing easy access to the back two rows of seats. The Model X sits in the second stage of Tesla's market entry strategy. The Model X will be sold at a similar price and volume as the Model S. By having a larger interior capacity and 4x4 drive it is hoped that the X will open up additional markets for Tesla. The Model X will be available around Q2 2015 [63,66,67].

Supercharger network

Many innovative and disruptive technologies require new infrastructure, with BEVs requiring electric recharging infrastructure. BEVs can be charged with standard mains supply electricity but this results in slow charge rates. Tesla is developing a network of supercharging stations. These stations can charge the Model S's batteries by 50% in 30 min [51].

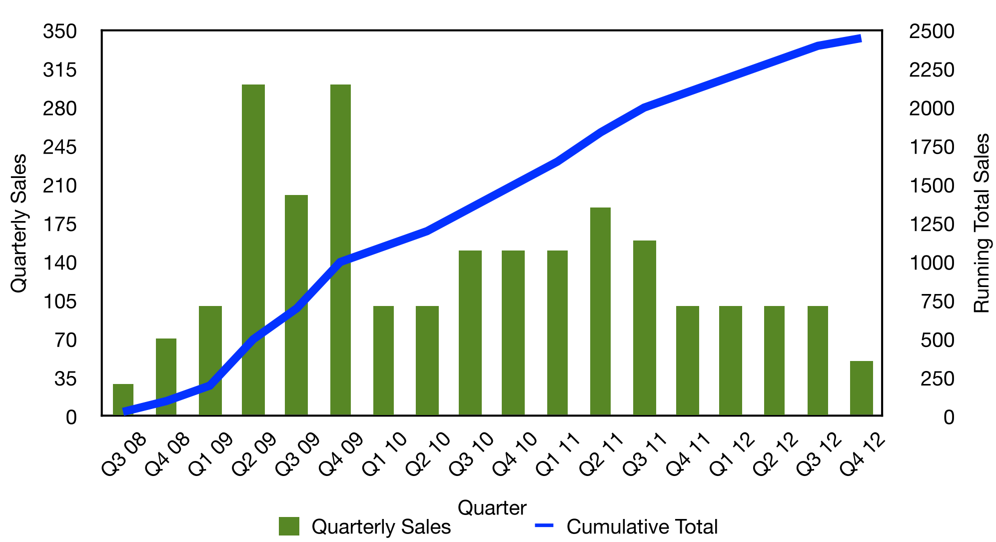

Fig. 6 – Tesla Roadster sales from Q3 2008 to Q2 2012.

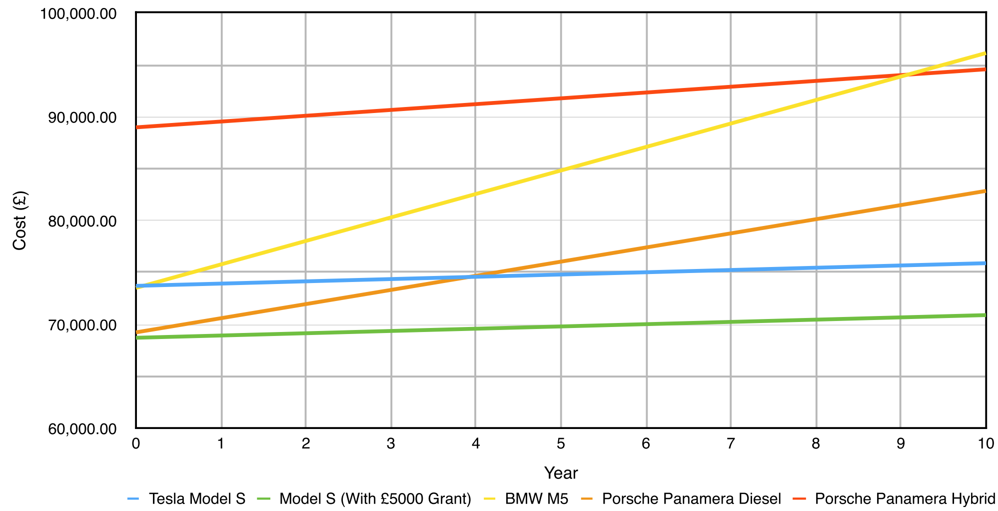

Fig. 7 – Running costs per year of the Tesla Model Compared to incumbent ICE, diesel and hybrids vehicles [59–62].

This high speed charging is achieved using 120 kW max charge rates and with batteries that have a lower taper point than other batteries [11]. The supercharger network is free to use forever, when the option is purchased with the vehicle or comes as standard with the vehicle. In 2015 the Supercharger network will cover 98% of the population in the US. There are currently 129 superchargers in the US, 89 in Europe and 34 in Asia. Tesla plans on this doubling before the end of 2014 [63]. The purpose of this network is so that Tesla can show that it is possible to drive long distances in BEVs. A team from Tesla completed a coast-to-coast road trip in the Model S to prove this. The network does not support the Tesla Roadster due to technological incompatibility [11]. Tesla has also began development of the Supercharger network in Europe, development began in Norway, which already has one of the highest concentrations of BEVs in Europe [68] and the first Model S to be sold in Europe were sold in Norway [69], with 500 being delivered to customers between August and September 2013 [70]. In addition to Norway Supercharger stations are now in Germany, The Netherlands, Austria, Switzerland and the UK [71].

Sales model

Many innovative and disruptive technologies do not enter markets via traditional sales channels. Tesla did not follow the traditional model of franchises that mainstream automotive companies follow. Tesla sold the Roadster though its own sales channels. Disruptive technologies can be complex; keeping the sales in-house prevents misinformation developing around a product. Poor sales and marketing advice in the early days of a market entry can potentially be damaging. By owning their own sales channels Tesla is able to offer customers compelling customer service. Tesla's sales channels achieve higher efficiencies and higher sales capture over traditional franchise models [67]. Currently this model is being

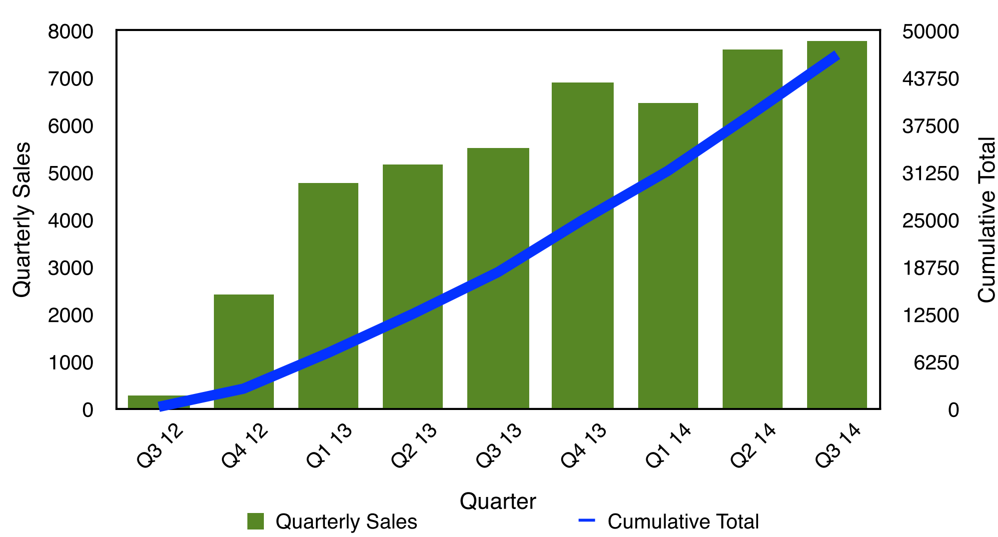

Fig. 8 – Tesla Model S Sales measured by number of deliverers from Q3 2012 to Q3 2014.

Table 6 – Running costs per year the Tesla Model S and its rival vehicles [39,59–62].

	Tesla Model S	BMW M5	Porsche Panamera diesel	Porsche Panamera hybrid
Purchase price (£)	73,700	73,505	69,222	88,967
Electric vehicle grant (£)	0	0	0	0
Battery lease (£ year^{-1})	0	0	0	0
Tax (£ year^{-1})	0	475	200	0
Combined cycle (MPG)	0	28.5	45.6	91.1
Consumption (kWh mile^{-1})	0.37	0	0	0
Electricity cost (£ kWh^{-1})	0.07	0	0	0
Fuel usage (L year^{-1})	0	295.789	184.87	92.54
Fuel cost (£ year^{-1})	0	1344.69	840.43	420.68
Fuel cost (£ L^{-1})	0	1.329	1.383	1.329
Fuel costs (£ year^{-1})	218.3	1787.09	1162.31	559.08
Running costs (£ year^{-1})	218.34	2262.09	1362.31	559.08

battled by US OEMs who have been successful banning Tesla from selling vehicles directly to the public in the state of Texas [72]. Tesla takes advantage of increased revenue share from vehicles sold; by selling the products directly, margins can be made smaller, this can lead to the purchase price of the technology being marginally lowered making the product more competitive in the market.

Threats

Tesla is experiencing some resistance from incumbents in the automotive sector. Currently in the US the National Automotive Dealers Association (NADA) and many state dealer associations are attempting to block Tesla's direct sales approach. The NADA are using State Legislation and Courts to block Tesla. They have been successful in the State of Texas and are making progress in two more states [11]. It is unclear if the intentions of these blockages are really to prevent direct sales or if they are to prevent Tesla from selling BEVs in these states. What is clear is that this will be damaging to Tesla. An additional threat is competition from other manufactures. As is common with new products other manufactures are now looking to enter the same market that Tesla operates in Ref. [21] with BMW recently entering the BEV sector with its i3 and i8 vehicles. US company Detroit Electric is also looking to launch a high performance BEV Roadster [73].

Conclusions

Academic implications

Based on our understanding of Tesla's market entry approach we suggest which encroachment pattern Tesla has been pursuing. It is clear that Tesla is not an example of immediate high-end encroachment where a product is introduced at the top of an existing market. Prior to the introduction of the Tesla Roadster there was no market for BEV sport cars. Tesla's market entry method is one new market high-end encroachment. New market high-end encroachment is where a product is sold only to new customers in new markets, products are improved along core attributes and add new ancillary dimensions targeted to consumers at the very high end of the market. It is important to understand what type of encroachment pattern a product is taking, as this will have implications on future product development and marketing activities [21]. Often it is hard to identify which category a new technology fits into, and often experts will put a technology in two different categories [21]. With Tesla it is could be debated whether the product is new market or new attribute high-end encroachment. It is the opinion of the authors that Tesla is an example of new market encroachment rather than new attribute encroachment. Compared to existing ICE automobiles the Tesla improved on core attributes, but also adds ancillary attributes. Core attribute improvements are high acceleration, high speed, bold looks and low running costs of Tesla vehicles, this combined with ancillary attributes of silent drive train, zero tailpipe emissions, convenience of never needing to visit a refuelling station and cost savings means that it is different to any ICE vehicle on offer. The vehicles also brand equity due to them being viewed as ‘cool’.

This paper represents an important addition to FCV literature. Marketing approaches and market entry strategies have been largely ignored by the industry. A previous study by the authors used case studies from other market sectors to guide FCV marketing. This paper holds greater relevance than these previous case studies as it uses a case study of a disruptive innovation from the automotive sector. To the best of the authors' knowledge this is the first study that uses a case study of a disruptive automotive technology to guide the market entry of FCVs. It is hoped that this will form the foundation of future research that can be used guide the successful market entry of FCVs.

Managerial implications

The study of Tesla Automotive clearly shows how it is possible for a high-end technology to enter markets via a market entry route of high-end encroachment. This gives hope to developers of FCVs, which are significantly more expensive than comparable ICE vehicles. These price premiums will not be an issue if core and ancillary attributes are improved allowing FCVs to enter market via high-end encroachment. But if FCVs do not have added value features over ICEVs their price premiums will be unacceptable to consumers.

Based on the findings of this study, automotive OEMs need to make significant changes to their market entry methods for FCVs. Current FCV offerings appear to be mass market ICE vehicles that have been modified to have FC drivetrains and hydrogen storage. They are visually indistinguishable to their

ICE counterparts on the interior and exterior and their performance in terms of speed, acceleration and range is also comparable. FCVs do not offer any core performance improvements; they only offer ancillary attributes of quiet operation and zero tail pipe emissions. These ancillary attributes alone are not enough to allow for high-end encroachment. Consumers cannot be expected to pay large price premiums for a FCV that is indistinguishable from an ICE vehicle that costs fractions of the price. Additionally Hydrogen infrastructure is not well developed, meaning that FCV adopters will find it inconvenient to access hydrogen refuelling infrastructure. Again this will not be acceptable if it is at a higher cost and without any added value. FCV developers should take note of Tesla's investment into BEV recharging stations. The success of FCV is heavily reliant on the roll out of a hydrogen-refuelling network. As automotive OEMs have such a significant stake in the sector they should also be encouraged to invest into developing a hydrogen infrastructure.

In order for FCVs to achieve high-end market entry FCVs will need both ancillary and core attribute improvements. These attributes could include higher speed, acceleration, range, comfort and looks or any other aspects that vehicle users currently place a high value on. Ancillary attributes will also be beneficial; FCVs have zero tailpipe emissions, silent drive and smooth drive. These ancillary attributes alone however will not be significant enough for the vehicles to achieve high-end encroachment; core values improvements must be present. FCVs need to be produced so that they have much improved core attributes compared to incumbent ICE vehicles, only then will smooth market entry be possible. FCV developers therefore need to develop radically different concepts from what we are seeing at present. In order to improve the relative advantage of FCVs the following should be addressed; Improved Performance (Speed & Acceleration), Improved Perceived Vehicle Safety & Improved Interior Features.

These attributes need to be designed into FCVs so that they offer higher levels over comparable incumbent vehicles. This will mean FCVs offer core attribute improvements and therefore will be more compelling to consumers and adoption of FCVs will be more likely. This is how FCVs should be marketed, not by producing FCVs that merely match the core attributes of ICE vehicles.

Future research

This study is limited in that it only makes use of historical data in order to make these conclusions and recommendations. This study is being expanded to include questionnaires, which will be targeted solely towards owners and users of Tesla BEVs. This future study will explore the exact reasons for the adoption of a Tesla vehicle and the motivations of its users. The findings will be used to make future recommendations on the appropriate market entry strategies for BEVs and FCVs. Future research is also required to address the problem of rollout of hydrogen infrastructure, as clearly FCVs will not enter markets in significant number if hydrogen infrastructure is lacking.

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