

RISE OF FUEL CELLS IN THE AUTO SECTOR (TOYOTA)

Declaration

The goal of the paper most likely involves research that has been aggregated and analysed in order to articulate conclusions and perspectives that add to existing research in the field of study. The convention of the paper is likely expected to be formal or academic, and the topic is beyond frivolous or superficial.

Acknowledgement

The current research helped me increasing my knowledge regarding the significance of hydrogen powered fuel cells and their application in the automobile industry. With a special emphasis on Toyota (and Honda), the research identifies the causes for the rising demand of fuel cells within the industry. This research has upgraded my knowledge and skills regarding the concept and knowledge behind hydrogen powered fuel cells and causes for Toyota considering its implementation in their automobiles. I would like to thank my academic guide to help me in completing the paper through sharing their knowledge and other relevant information. Such guidance has led to produce source of inspiration. They have shared valuable time and knowledge to complete tasks. Additionally, I would like to thank the participants for the survey, as well as the managers at Toyota and Honda for agreeing to respond to my interview and sharing their indispensable knowledge on the subject. Finally, I wish to offer my gratitude to my parents and friends for being supportive to me both financially and morally while collecting data from primary and secondary sources. After getting the support of all these people, I could successfully complete the paper.

Abstract

Introduction: This paper emphasises on the background of the advent of hydrogen-powered fuel cell technology and its application in the automobile industry. Additionally, a brief insight into Toyota Inc. along with the aim and objectives of the research has been presented. The aim of this research is to evaluate the major factors responsible for the increase in the use of fuel cells in Toyota motors. The objectives included investigating the importance of fuel cells in automobiles as well as the advantages and disadvantages associated with fuel cell usage. The rationale, purpose and significance of the paper have been presented along with the Scope and target audience for the paper.

Literature review: Existing literature on the importance of fuel cells in automobiles, along with the enhanced use of fuel cells and factors responsible for the same have been evaluated critically. Furthermore, the advantages and disadvantages associated with fuel cell usage and the rise of fuel cells in Toyota motors have been studied. Moreover, the gaps in literature have been identified and a conceptual framework has been presented as well.

Methodology: The methodology used for undertaking this research includes the use of a positivism philosophy, abductive approach and a descriptive design. A mixed methodology for the research, gathering and analysing quantitative as well as qualitative data has been deployed. The data has been chiefly collected from primary sources through carrying out surveys and interviews with the managers of Toyota and Honda to gain an insight into their perspectives for applying hydrogen fuel cell technology to the automobiles manufactured. Moreover, close-ended and open-ended questionnaires have been prepared for the survey and interviews respectively. Additionally, a probability sampling method has been implemented for the selection of the sample size for the survey, which was determined to be 84. On the contrary, non-probability sampling techniques, namely purposive sampling has been used for the collecting qualitative data, with a sample size of 2.

Results, Analysis & Interpretation of Data: It has been evident that most people are somewhat aware of the concept behind fuel cells and a few of their applications. However, despite the technology being environment-friendly and highly fuel efficient, participants stated that they would consider their options since this technology is not quite cost-efficient. The responses from the managers discussed the application of certain strategies to reduce the price to help the adoption of these automobiles.

Conclusion and recommendation: This chapter summarises the major findings and interpretations related to it. Additionally, relevant suggestions/ recommendations are made. The limitations experienced along with the future scope of the research have been discussed. Lastly, the overall research has been linked to the initially proposed objectives of the research.

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1.0 Introduction

1.1 Background of the research

Currently the world is looking for a solution to the pollution from emissions, as well as a cost-efficient fuel, which does not pertain to the existing non-renewable energy sources. Fuels which are easily accessible, available or can be easily prepared, as compared to other sources of energy are being prioritised (Alaswad, et al., 2016). *Toyota* has strength of over 340,000 employees in five continents and operating in more than 160 countries (Baroutaji et al., 2019). According to Cano, et al. (2018) fuel cells are capable of converting the chemical energy of hydrogen without the combustion process into electricity, by releasing water vapour as a by-product. With *Toyota* aggressively looking forward to targeting and capturing the global market for a newer form of substitute fuel with major applications in the automobile industry, it is to be investigated whether the world is ready for this technology and its overall feasibility for introduction to the larger audience (Hekkert and van den Hoed, 2017).

1.2 Research problem

The use of fuel cells in the manufacture of automobiles is a cutting-edge technology which multiple automobile manufacturers are taking into account. The particular technology in question is capable of providing a non-polluting solution to the contemporary fuels and is currently being used by Japanese automobile companies *Toyota* and *Honda* (Fang, et al., 2017, pp-239). In addition to that, it may be effective enough to reduce the dependence of nations on specific oil-producing economies. Regardless of the solutions that fuel cell technology offers, there are multiple limitations found to be distinctly associated with it. For instance, it is not cost-effective at all, and the availability of hydrogen for the development of the fuel cells can often be far-fetched. Despite the drawbacks, companies are focused on exploiting this new-found technology in the automobile industry. This paper aims at answering the problem as to the driving factors resulting in such determination from automobile manufacturers. Additionally, the major challenges in harvesting this technology are considered in this paper, along with potential solutions for the same.

1.3 Aim and objectives

Aim: The aim of this research is to evaluate the major factors responsible for the increase in the use of fuel cells in Toyota motors

Objectives:

- To evaluate the major factors responsible for the increase in the use of fuel cells in Toyota motors
- To investigate the importance of fuel cells in automobiles
- To assess the advantages and disadvantages associated with fuel cell usage

1.4 Research questions

The questions formulated for the research to be carried out are:

1. What are the major factors responsible for the increase in the use of fuel cells in Toyota motors?
2. How are fuel cells important for use in automobiles?
3. What are the advantages and disadvantages associated with fuel cell usage?

1.5 Rationale, significance and purpose of the research

As previously mentioned the world is apparently in dire need for renewable energy solutions to serve as fuels and for other purposes. The significance of this research can be attributed to undertaking a research related to the rise in the use of fuel cells derived from hydrogen, which is non-polluting and can be made available with a fair amount of ease. In addition to that, the substantial rise in the number of power plants for the production of fuel cells requires imparting any available knowledge on the subject (Alaswad, et al., 2016). Hence, the rationale for this research can be attributed to the search for an alternative fuel to promote globalisation and transactions, while helping the environment survive better. This paper serves the purpose of providing an insight for the use of fuel cells, as well as the advantages and shortcomings associated with the use of fuel cells for use in the automobile industry (Toyota).

1.6 Scope and target audience

The scope of this research paper includes a detailed investigation into the domain of fuel cells and the use of hydrogen, enabling the potential solution to be non-polluting. However, the paper also covers the disadvantages such as the expenses associated with the same and the on-going research into the matter. Additionally, the scope of application of this cutting-edge technology into the automobile manufacturing industry, particularly in Honda and Toyota has been considered. This paper is aimed at individuals interested in learning about the advent of the technology, along with its limitation, applications and the significance that it poses for the future. Moreover, this research paper can promote the onset of further knowledge left uncovered in this paper as well.

1.7 Methodology

The methodology used for undertaking this research includes the use of a positivism philosophy, abductive approach and a descriptive design. It needs to be stated that the researcher aims at deploying a mixed methodology for the research, gathering and analysing quantitative as well as qualitative data. The data has been chiefly collected from primary sources through carrying out surveys and interviews with the managers of Toyota and Honda to gain an insight into their perspectives for applying hydrogen fuel cell technology to the automobiles manufactured. Moreover, close-ended and open-ended questionnaires have been prepared for the survey and interviews respectively. Additionally, it needs to be mentioned that a probability sampling method has been implemented for the selection of the sample size for the survey, which was determined to be 84. On the contrary, non-probability sampling techniques, namely purposive sampling has been used for the collecting qualitative data, with a sample size of 2.

1.8 Structure/ outline of the study



Figure 1: Structure of paper

(Developed by author)

2.0 Use of Literature & Sources

2.1 Overview

Toyota is considered as a global market leader and is selling hybrid kinds of electric vehicles. Toyota Motor Corporation is a multinational automotive manufacturer. It has its headquarters located in Toyota city, Aichi in Japan (Cusumano, 2020). Toyota is also registered as a market leading corporation in hydrogen fuel cells vehicles. Founded by Kiichiro Toyoda in 1937 the corporation designs vehicles for the five brand categories. Toyota has been inclined towards implementing the use of research in robotics and artificial intelligence (Robledo, et al., 2018. p-167). Furthermore, the investment was done in Uber, in 2016. The transformation of the brand logo of the corporation was done from Toyoda to Toyota, given its resemblance from Japanese language which denotes good fortune and wealth.

With the corporation being among the leading brands in the market concerning the automobile sector, its extension towards a more efficient approach is commendable. Further, the drive towards adopting the use of hydro fuel was helping the corporation become a much reliable brand considering its adherence towards a sustainable approach. Given the efficiency of using hydrogen the limitation in the emission of carbon is achieved. This thereby influences the productivity rate of the automobile sector while limiting the use of resources (Saker, 2016). In addition to that, referring to the ability of the fuel cells to contribute towards efficiency of the automobiles, the fuel cells have been implemented into use by Toyota. This further stabilizes the position of the corporation in the future automobile market. This therefore brought into existence the Fuel cell vehicles (FCVs) and fuel cell electric vehicles FCEVs.

2.2 Importance of fuel cells in automobiles

Fuel cells

Fuel cells may be distinguished under the devices that potentially transform potential or reserved energy into forms of electrical energy. That is to say that it is a device that potentially generates electricity by a series of chemical reactions. There are however various kinds of fuel cell sizes that have been designed by inventors and scientists on the basis of their efficiency level. The

introduction of fuel cells in the vehicles was to be able to generate electricity to power start the motor (Jayakumar, Chalmers and Lie, 2017. pp-260). The main intention of implementing fuel cells into use for the designing of vehicles was to limit the emission of carbons and other harmful gases and maintain the air quality. There are various significant benefits with the use of the fuel cells in the automobile industry. The benefits may be registered as follows:

- In comparison to the basic diesel and gas engines, the fuel cells are much more efficient in use and may enhance the productivity level by limiting the use of resources investments.
- The internal combustion engines are known to be noisy; this makes them inconvenient for use in the indoor places. Replacing internal combustion engines with fuel cells would therefore make them ideal for use in hospitals and within buildings (Jayakumar, Chalmers and Lie, 2017. pp-260). The silent mechanism of the fuel cells therefore makes them suitable for use.
- The use of hydrogen fuelled cells helps to limit the pollution caused in comparison to the basic fuels that support carbon emission (Satyapal, 2017). Contradictorily the fuel cells eliminate water as a by-product of burning.
- The use of fuel cells can potentially eliminate the greenhouse gases, thereby sustaining the environment.
- Given the independent attitude of the fuel cells towards the fuels like gas and oil can support the automobile industry from withdrawing themselves from the conventional fuels (Saker, 2016). This therefore, controls the economic dependence of nations on the oil producing countries.
- For military purposes, fuel cells are considered potentially ideal for their use since they transmit low heat in comparison to the conventional fuels.
- The fuel cells provide much higher operating times over batteries. Given the capacity of the fuel cells, it makes them ideal for use (Tanç, et al., 2019. pp-10120).
- The maintenance for fuel cells is simpler than that of batteries since there are few parts of it involved (Whiston, et al., 2019. pp-4899).
- Unlike the batteries, fuel cells have no memory effect which makes them suitable for use in comparison to the conventional fuels.

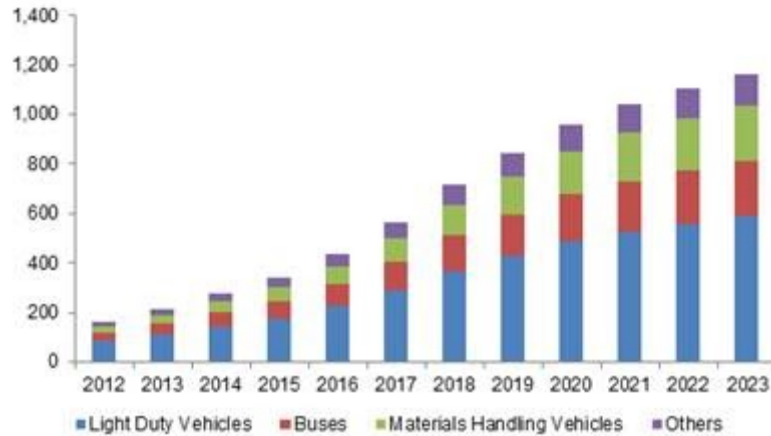


Figure 2: Asia Pacific to lead the global automotive fuel cell market landscape

(Source: Global Market Insights, 2020)

With the benefits of efficiency and maintenance ease, the automobile industries are highly impressed with the adoption of fuel cells in the designing of the vehicles in the automobile industry. Given the advantages of fuel cells over the internal combustion engines and other conventional sources, the automobile industry willingly adopts the fuel cells flexibility for making the vehicles more efficient to use (Rath, et al., 2019). With the intention of mitigating the environmental conservation, the future of fuel cells use are registered to be more promising with its renewable sources inclination over the carbon emitting ones (Dincer and Acar, 2017). With the advent of globalization, the inclination of the public towards a more efficient source of living would be attained by the use of fuel cells (Saker, 2016).

2.3 Enhanced use of fuel cells and factors responsible

Fuel cells are proven to provide potential benefits of implementing it to use in the automobile vehicle designing industry. The modification of the fuel cells is done on the basis of their electrolyte use. The fuel cells are designed on the basis of the factors such as fuel type requirement and range of temperature for the operational property of the cells (Jayakumar, Chalmers and Lie, 2017. pp-260). Depending upon the properties as such, the application of the fuel cells is taken into consideration for the suitability of the fuel cells.

Polymer electrolyte membrane fuel cells

Provision of high power density and other beneficial advantages such as limited dimension and reduced weight makes it suitable for use. The working scenario of this polymer fuel cell is determined by the availability of hydrogen, oxygen from air and water. Moreover, pure hydrogen is used for the fuelling properties of the cells (Sui, et al., 2017. pp-1808). Therefore, these kinds of polymer cells are ideal for transportation usage for buses, cars and other vehicles because of the minimal weight of the fuel cell. Additionally, the operation level of the fuel cells being consistent at low temperatures makes them suitable for use in the transportation sector.

Direct methanol fuel cells

This classification type of fuel cells is powered by pure methanol. This fuel kind is noted to have higher energy density than the hydrogen, because of the methanol used in designing them. However, methanol had a relatively lower energy density than that of the gasoline and diesel (Verma and Samanta, 2016, pp-227). Additionally, given the liquefiable property of methanol being similar to gasoline, therefore it is ideal for transportation and supply to the users (Rath, et al., 2019). Moreover, the application of methanol based fuel cells is a newer approach than the hydrogen based fuel application.

Alkali based fuel cells

The performance of the alkali based fuel cells are convenient to use as they can successfully put to use basic inexpensive metals as catalysts. Moreover, the alkali based fuel cells conduct a high level of performance due to the amplified rate of reactions occurring in the cells (Singh et al., 2018). The only drawback of the use of alkali based fuel cells is that they are prone to get itself poisoned by introduction to carbon dioxide. Minute presence of the carbon dioxide in air can greatly impact the alkali fuel cells and alter the rate of operations.

Phosphoric acid fuel cells

Phosphoric acid based fuel cells are expensive to use. They may be regarded highly efficient for the production of both heat and electricity. The efficiency rate may be estimated around eight 5%. However, when expected to make use of phosphoric fuel cells for generation of solely electricity, it may not be regarded as efficient (Tanç, et al., 2019. pp-10120). Moreover, the phosphoric fuels are registered to be less powerful in comparison to other classification of fuel

types. Therefore, they are generally huge and much heavier. Also, by the use of expensive catalysts such as platinum the phosphoric acid based fuel cells are grouped as expensive.

Molten carbonate fuel cells

This variety of fuel cells may be grouped under high temperature based fuel cells. Furthermore, they may be beneficial over phosphoric acid based fuel cells since molten carbonate cells are of high level temperature cells. This therefore, further significantly reduces the costs of the phosphoric and fuel cells. Furthermore, the offering of significant increase in the efficiency level by generating electricity (Staffell, et al., 2019. pp-463). An efficiency rate of over sixty percentages may be assessed by the use of molten carbonate fuel cells over the phosphoric ones. However, the only limitation of the molten carbonate fuel cells is the durability aspect of the fuel cells.

Solid oxide fuel cells

This type of fuel cells is comparatively ideal for use given a few potential benefits it claims. These fuels cells do not require use of expensive metals as catalysts to enhance the chemical reactions (Singh et al., 2018). This is so because the solid oxide fuel cells operate at a very high level of temperature that limits the need of expensive metals as catalysts. This therefore, reduces the costing of these fuel cells consequently.

Regenerative fuel cells

The regenerative fuel cells utilize natural resources such as hydrogen and oxygen for producing electricity (Rahman, et al., 2016. pp-137). Moreover, the by-products of these fuel cells are heat and water. Moreover, the use of solar power and other renewable resources makes it ideal for use (Tanç, et al., 2019. pp-10120). These cell types may be registered as ideally suitable to use given the utilization of renewable resources. However, the technology type being a rather new concept is therefore concentrated upon by NASA.

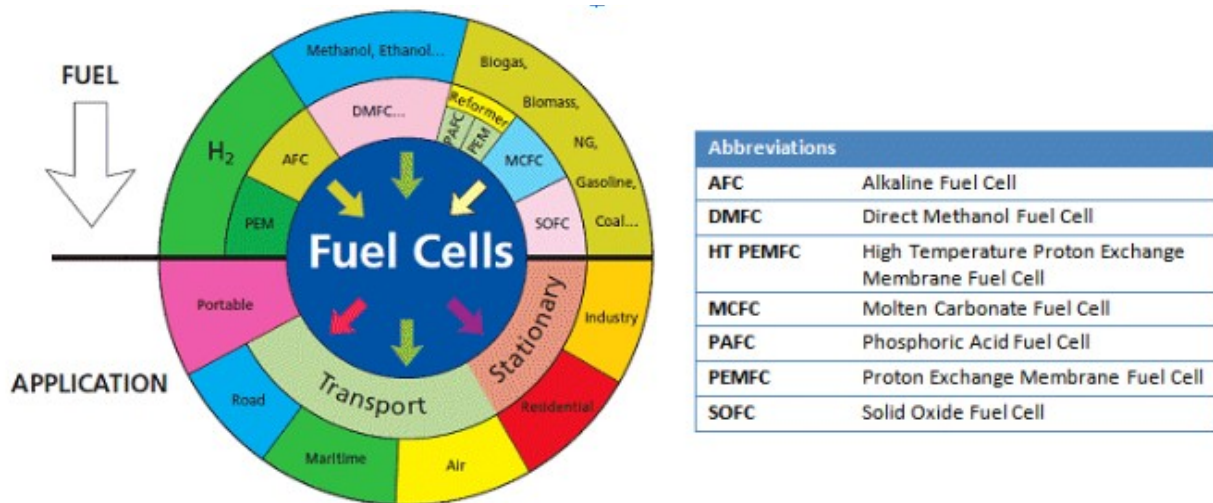


Figure 3: Fuel cell capacity and cost trends depicting alternatives to hydrogen based fuel cells

(Source: Chemistryviews, 2020)

2.4 Advantages and disadvantages associated with fuel cell usage

With the increased level of awareness among the public and the government authorities regarding the environmental preservation and sustainability, the concept and implementation of fuel cells has been put to use. With the inclination of the developing countries towards technological advancements and alternative applications of renewable resources, the fuel cell technology has come to rescue (Rath, et al., 2019). However, with the concept of the fuel cell technology being entirely a new concept, its application is therefore a bit of concern. The advantages and the potential limitations of using fuel cells are therefore concentrated upon to get an understanding of the same.

Advantages of using fuel cells

There are many significant advantages of implementing fuel cells in the automobile industry (Tanç, et al., 2019. pp-10120). The probable area of benefit of using fuel cells in designing vehicles is as follows:

Efficiency level: the efficiency level of the fuel cells are high and can be easily customized as peruse requirement (Staffell, et al., 2019. pp-463). Generally the energy efficiency level of the fuel cells is recorded to be under the range of sixty to 80%. However, the efficiency level of the fuel cells can be customized up to 80% when making use into a cogeneration system kind.

Cleanliness: the working procedure of the fuel cells are generally beneficial and environment friendly since it emits minimal to absolute no emission. The by-products of the fuel cells being water, heat and electricity therefore makes it much more efficient than the conventional fuels (Valente, et al., 2019). Additionally, these fuel cells kind of do not emit carbon dioxide, thereby helping preserve the environment.

Scalable property: the fuel cells may be stacked onto one another making them effective in limiting use of space (Wilberforce, et al., 2016. pp-16509). This further contributes to their advantage.

Silent: the fuel cells do not emit any kind of noise as compared to other conventional fuel sources. Moreover, referring to the stacking property of the fuel cells, limitation of moving parts therefore contributes to noise limitation.

Low maintenance: the maintenance of the fuel cells are much efficient than other conventional fuel. Despite the initial cost being higher, the maintenance involvement is low. Moreover, referring to the durability of the fuel cells over the batteries, the longevity of the fuel cells requires low maintenance.

Drawbacks of using fuel cells

There are very few limitations in using the fuel cells in the automobile industry. Given, the entirely new concept of the fuel cell technology, the popularity of the fuel cell has failed to gain expected recognition. This is because of the fact that there are a few drawbacks of the fuel cells that do not justify their economic competitiveness over other technologies. The predominant setback of the fuel cell use is the productivity challenges, hindrance in transportation and threat of flammable property and proper storage of the hydrogen gas (Valente, et al., 2019). Furthermore, the technology being entirely a new concept therefore demands a high level of investment into it for use. Also, the splitting power of fossil fuels into oxygen atoms and

hydrogen atoms poses a threat to the use. Moreover, since the working efficiency of the fuel cells are entirely dependent upon the fossil fuels, therefore arises a question on viability of the technology (Zohuri, 2019, pp-39). Subsequently, the lack of suitable infrastructure hinders the expansion of the fuel cell technology.

2.5 Rise of fuel cells in Toyota motors

With the advent of technological innovation in the automobile industry, the leading market brand of Japan, Toyota had taken commendable measures of introducing the fuel cell technology in the production method (Gogodze, 2019). The estimation of the huge influence in the fuel cells supply and demand by the year 20120 and later on a global aspect has led to the inclination of Toyota on assessing and adopting fuel cells technology. Given the environmental sustainability aspect and the intention to limit the carbon emission of the fuels, Toyota has taken serious interest in the fuel cell implementation and designing of their engines efficiently (Cadman and Payne, 2019). It has been evident that Toyota Corporation works on the principle of making decisions on a long term basis, therefore analyzing the expected hike in demand for the fuel cells; the implementation has been initiated by the corporation.

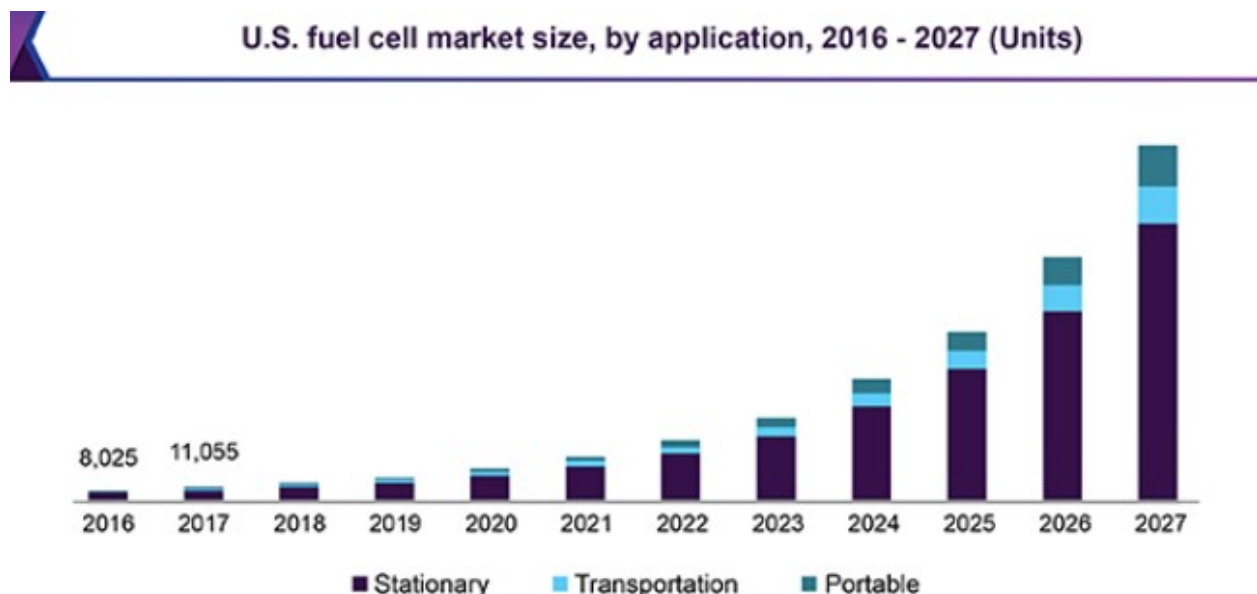


Figure 4: Fuel Cell Market Size & Share depicting the types of applications of fuel cells

(Source: Grandview, 2020)

As Toyota announced its 2050's environmental challenge, it is concentrating upon remedies to reduce the carbon emission by relying upon hydrogen based fuel (Cusumano, 2020). Moreover, the corporation is taking serious initiatives to spread the production awareness of fuel cells. As in the year 2017, Toyota commercially introduced Fuel cells buses and revised it by 2018, promising to provide more of such efficient buses for the Paralympics and Olympic games of Tokyo. In addition to that, with the strict implementation of rules for conserving the environment by the government, Toyota has put efforts in adhering to the basic governmental guidelines when designing automobiles while promising the buyers with an incredible vehicle experience (Cusumano, 2020).

2.6 Gaps in literature

The major gap in literature may be the inability to get opinions of more automobile industry managers implementing the Fuel cell technology used for the production of their potential vehicles. Time also proved to be a limiting factor in undergoing the research study. As with prolonged duration, the research could have been more promising. Also, in aspects of gaining insights on the working mechanism of the Toyota industry, limitation of articles talking about the Fuel cell use by Toyota was encountered.

2.7 Summary

The role and the significant implementation of the fuel cell technology could be termed potential enough if the integrating system opportunities would be clarified. In context to the previous years, it has been evident how approaches are being made to encourage the use of alternatives for the fuel (Kendall, 2018. pp-120). One such effort has been made by the Toyota Corporation to implement the fuel cell technology. Toyota being a market influencer is therefore making serious attempts to create a sense of awareness for the FC implementation while producing vehicles based on the technology.

2.8 Conceptual framework

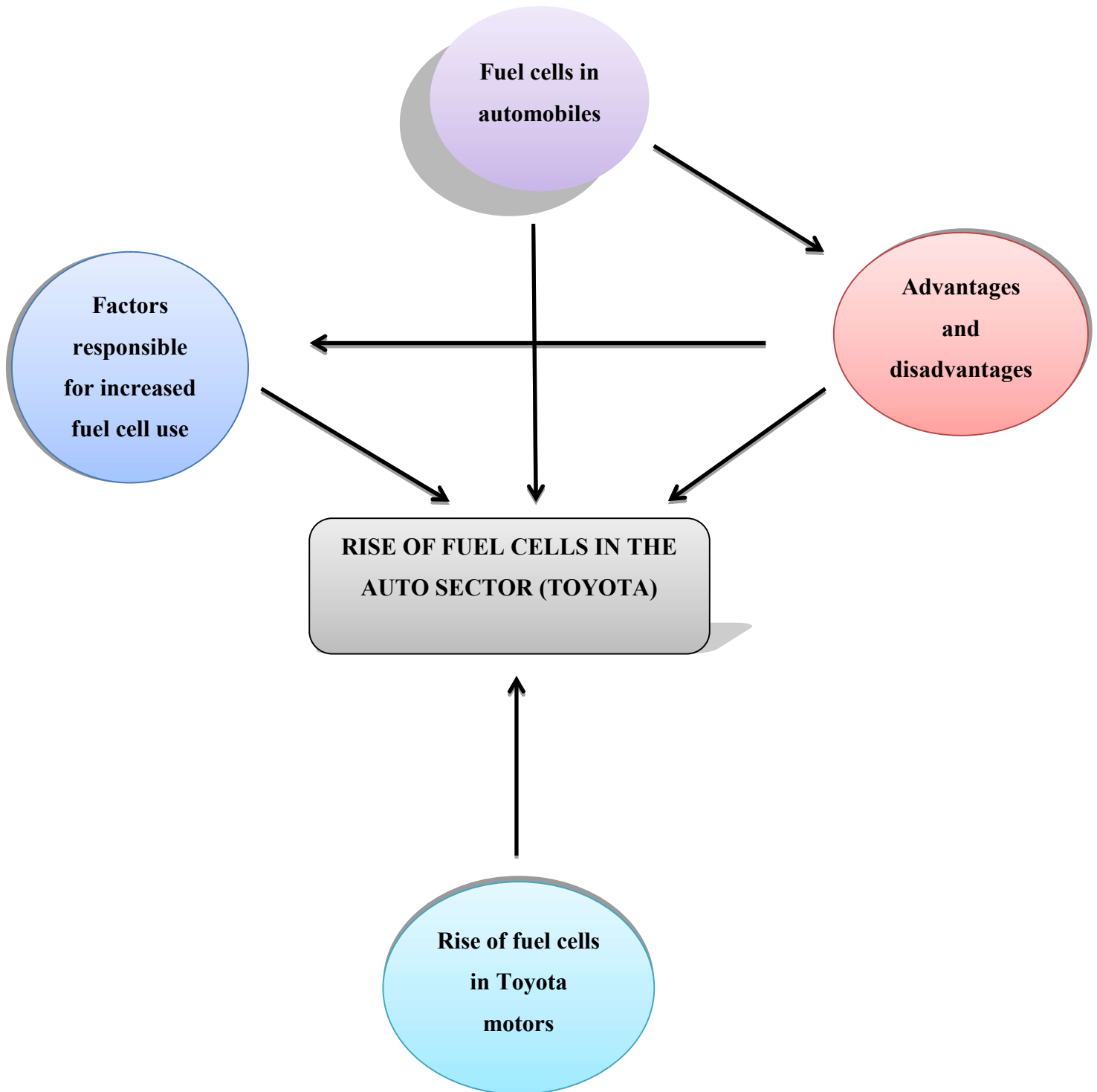


Figure 5: Conceptual framework

(Developed by author)

3.0 Research Design & Methodology

3.1 Overview

This research paper uses a mixed methodology considering the opinion of Ma (2012) regarding the use of both quantitative as well as qualitative methods for data analysis. In addition to that, the data is collected chiefly from primary sources, using questionnaires as the fundamental tool. However, data from secondary sources have been used for reviewing literature as well as for analysing the collected data to establish a link between the findings and the existing information and data. Figure 6 illustrates the concept of research philosophy, design, approach and more as discussed by Saunders, et al. (2015).

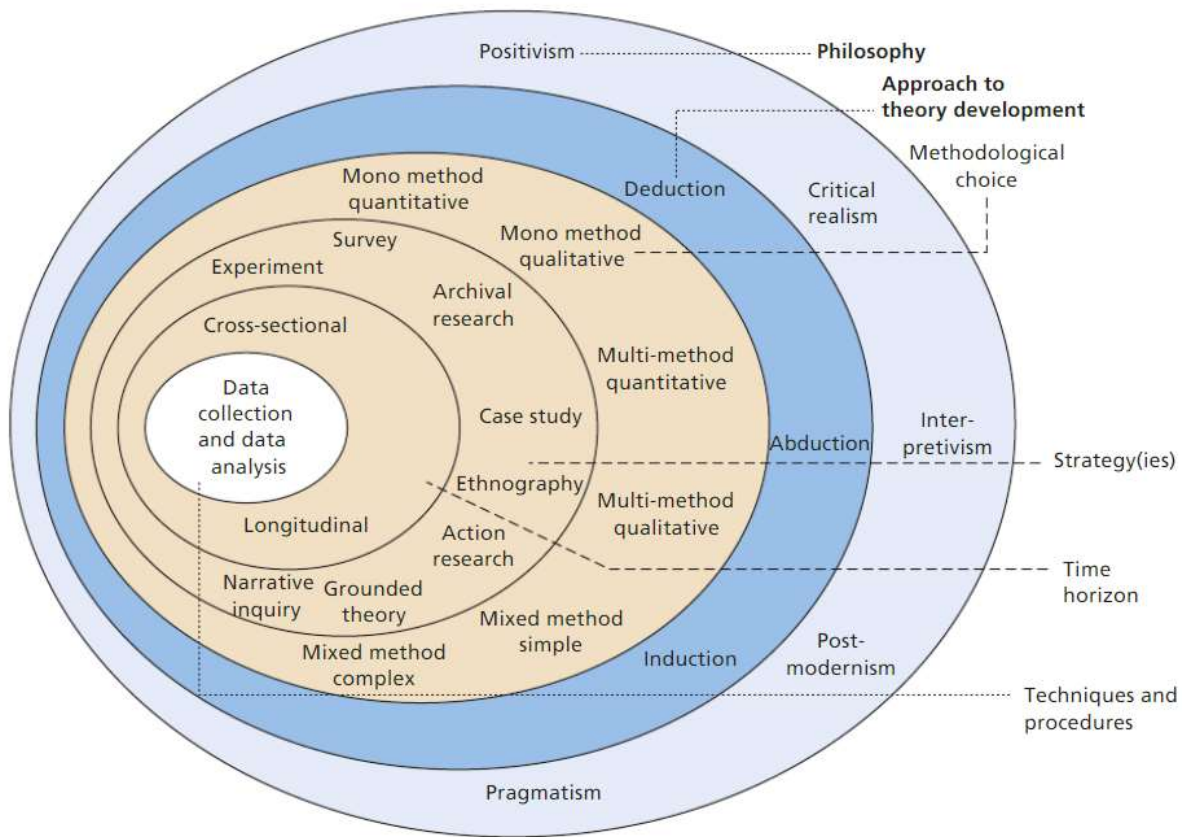


Figure 6: Research onion
(Source: Saunders, et al., 2015, pp-124)

3.2 Research philosophy

It needs to be mentioned in this context that a post-positivist paradigm or worldview has been adopted in this paper. Epistemological assumptions are evident in this paper as well. Since, this particular ideology is based on the concept that all observation is errant or fallible and all theories can be considered revisable (Panhwar, Ansari and Shah, 2017). This paper makes use of mixed methodology for data analysis, hence it may be stated that there are two best suited philosophies which can be implemented for this purpose. Positivism philosophy is widely regarded as the most suited and used philosophy for quantitative studies, while for qualitative studies, researchers are often noted to prefer interpretivism, which is more suited to the more humanistic approach deployed in these studies (Collis and Hussey, 2014). Furthermore, the elements of the data collected are open to interpretation by the researcher (Veal, 2017). However, since this paper deploys both methods of data analysis, the researcher has chosen to opt for positivism philosophy, since the researcher is responsible for collecting as well as interpreting the data objectively, which seems to be best suited to the type of research being carried out.

3.3 Research approach

According to Bell, Bryman and Harley (2018) abductive approaches are typically used to explain the “interesting” findings or “facts” which are investigated throughout the research. While deductive and inductive approaches fall prey to certain weaknesses. Deductive approach or reasoning is primarily criticised owing to its lack of clarity with respect to theory selection and hypothesis formulation. On the contrary, Saunders, et al. (2012) mentioned that inductive reasoning experiences shortcomings in the form of inadequate empirical evidence to develop a theory. Abductive reasoning, on the other hand, combines the positive facets of both the aforementioned forms of reasoning or approaches while eliminating their limitations in the process. In other words, even incomplete observations may lead to possibly correct conclusions, in case of deploying an abductive approach (Bell, Bryman and Harley, 2018). For the topic selected for this paper cannot be researched using hypotheses, while this research also does not seek to develop or propound a theory. Therefore both inductive and deductive approaches seem to be inappropriate in this regard. Hence, the appropriate approach considered in this context is abductive approach.

3.4 Research design

A descriptive design has been chosen for this research paper in order to substantiate the chosen research strategies to conduct surveys and interview the representatives of two major automobile companies using fuel cells in the manufacturing automobiles. The primary framework of research methods deployed for this paper indicates the overall process of data collection and analysis. Considering that there is no experimental set-up or correlational aspects to this particular research and the data is to be analysed and interpreted accordingly, a descriptive design is best suited for this paper.

3.5 Data type

3.5.1 Process, tools, strategy and techniques for data collection

The strategy for data collection has been decided to be a survey and interview. The questionnaire has been considered as the rudimentary tool for collecting the data for this research. Two distinct questionnaires, namely with close-ended as well as open-ended questions have been developed for the purpose of survey and semi-structured interview respectively. The data collection through the survey has been statistically analysed, interpreting patterns in the responses, with the help of MS Excel software. The data from the interview has been subjected to qualitative analysis, following a descriptive design.

3.5.2 Quantitative data collection (Primary sources)

The data to be gathered from primary sources would comprise automobile users, with a special emphasis for Toyota car users. The sample size is 84. Initially, the questionnaires were sent to 100 individuals based on their background of automobile usage. Only completed questionnaires were taken into consideration for the research. 91 questionnaires were returned, out of which 84 were found to be complete and were used for the purpose of this research. Close-ended questions were formulated in a questionnaire to derive quantitative data for analysis.

3.5.3 Qualitative data collection (Primary sources)

Telephonic interviews with managers of 2 automobile firms, namely *Toyota* and *Honda* have been carried out, since both brands use fuel cells for the automobiles manufactured by them. An

open-ended questionnaire has been designed for the purpose of interview, to gather qualitative data.

3.6 Sampling and sample size

It has been discussed previously that a mixed methodology has been deployed for this paper, while collecting and analysing qualitative and quantitative data. The sample size taken into account for both the cases are different as well as the sampling technique implemented. As discussed formerly, the survey for gathering quantitative data uses a sample size of 84, deploying a probability sampling method. However, for the interview with the managers of Toyota and Honda, the managers were selected using non-probability sampling techniques. Purposive sampling method was used for the selection of the sample size (2) for the interview. The fundamental purpose for this selection was the choice of organisations making use of fuel cells in the automobile industry. However, the survey was primarily carried out to identify and assess the knowledge of random individuals with the further objective to study their willingness or intention to implement the changes in their lives (Sharma, 2017). The overall aim was to use these sampling techniques to have a better chance at identifying and understanding the major factors driving the growth and rapid implementation of this technology in the automobile industry.

3.7 Limitations

In order to achieve something significant, it is necessary to overcome hurdles. One of the major limitations of this paper was the insufficient timeframe for the completion for this paper. Obtaining the appointments of the managers of *Honda* and *Toyota* required a significant time. In addition to that, the choice of implementing non-probability sampling did not provide the researcher with the accuracy of estimation regarding the extent of similarity as well as dissimilarity of the population parameters from the sample statistics (Vehovar, Toepoel and Steinmetz, 2016). Though the sample size for the survey can be deemed adequately large, the sample size for the interview is fairly small, as compared to standard interview sample populations. The lack of sufficient time, as well as the challenges associated with gathering appointments can be attributed to the same.

3.8 Ethical considerations

Firstly, for the survey as well as the interviews, “informed consent” of the participants have been considered. In addition to that, the dignity, privacy and anonymity of the participants for the research have been maintained. Compliance with the GDPR and the *Data Protection Act 2018* has been taken into account as well to protect the information and data of the respondents (Carey, 2018). Deception and exaggeration of the information provided by the participants have been avoided. Furthermore, misleading information to the respondents have not been provided. Voluntary participation of the sample population has been ensured. Discriminatory, offensive and otherwise unacceptable language has not been used. Lastly, the participants were asked to note that they were free to not answer a question if they did not want to.

3.9 Timeline

The research has been carried out over a period of 16 weeks or 4 months. As represented in Table 1, the Gantt chart illustrates the major activities and tasks undertaken during this period of time and the duration for each of the activities. The major activities performed include topic approval following its selection, research methodology decision, performing literature review and developing the open and close-ended questionnaires. The survey was carried out in the 6th and 7th weeks of the research, while the interview was conducted in the 8th and 9th weeks. The findings were discussed and analysed over the next 5 weeks from the 10th to the 14th weeks. The final weeks were dedicated to making the conclusive chapter and making necessary amendments.

Activities undertaken	Weeks															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Topic selection/ approval																



Table 1: Gantt chart/ timeframe
(Created by author)

4.0 Results, Analysis & Interpretation of Data

4.1 Overview

The chapter oversees the overall data interpretation and discussion of the collected quantitative as well as qualitative data from primary sources, through survey and interviews respectively. The quantitative data is represented in the form of pie charts to evaluate the response frequency to deduce the evident patterns.

4.2 Quantitative data collection and analysis

Quantitative data was collected with the help of questionnaires comprising close-ended questions. The questionnaires were electronically mailed to the respondents and the responses received were statistically analysed to draw a pattern for the intention of fuel cell-powered automobiles.

Question 1: Please select your gender:

Option/ response	Number of respondents	Total number of respondents	Response frequency
a. Male	41	84	49%
b. Female	38	84	45%
c. Other	1	84	1%
d. Would not like to disclose	4	84	5%

Table 2: Response to Q1

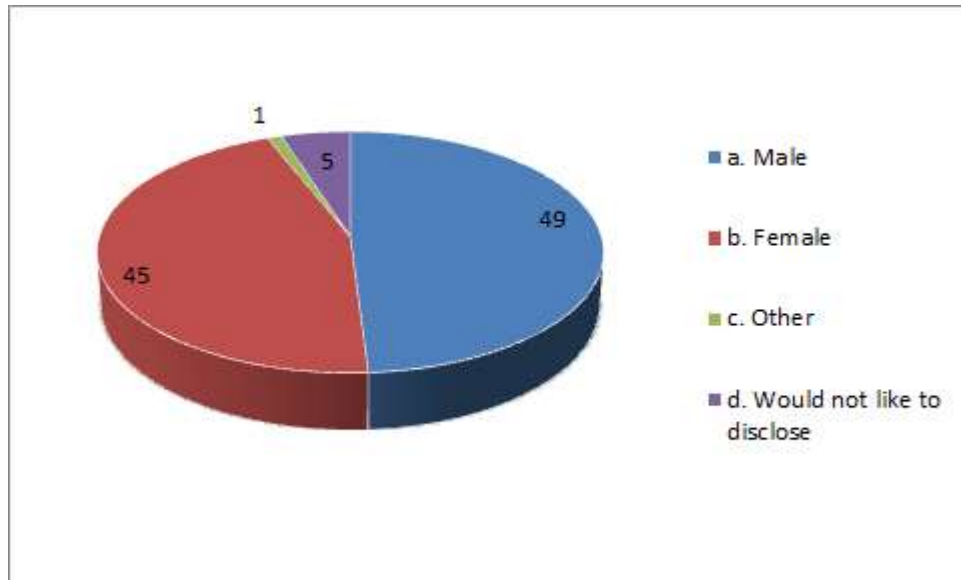


Figure 7: Statistical representation of Q1

A majority of the participants have been identified to be male while 45% are females. 5% of the participants stated that they would not like to disclose their gender. The question on gender was aimed at identifying whether the knowledge of hydrogen fuel cells is associated with a particular gender or whether gender had no substantial role to play in it.

Question 2: Please select your age group:

Option/ response	Number of respondents	Total number of respondents	Response frequency
a. 18-25	18	84	21%
b. 26-35	24	84	29%
c. 36-45	22	84	26%
d. 46-55	11	84	13%
e. 55+	9	84	11%

Table 3: Response to Q2

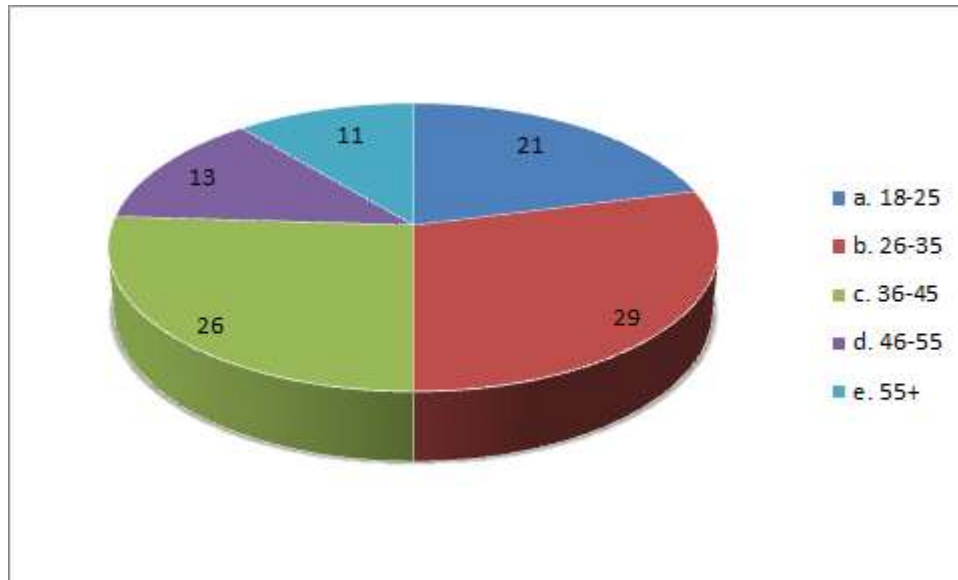


Figure 8: Statistical representation of Q2

Most of the respondents were found to be between the ages of 26 and 35, closely followed by the age group of 36-45. Furthermore, a much younger population aged between 18 and 25 had participated as well, with only about 24% of the participants aged 46 and above. Similar to the question regarding the gender of the participant, this question was aimed at evaluating whether a particular age group demonstrated the knowledge of hydrogen fuel cells better than the others. Since, this is a comparatively newer technology; it is possible that the age of the participant be related to their knowledge of the matter.

Question 3: Do you drive an automobile?

Option/ response	Number of respondents	Total number of respondents	Response frequency
a. Yes	36	84	43%
b. No	8	84	9%
c. Sometimes	14	84	17%
d. I borrow or rent automobiles from time to time	22	84	26%

e. Other	4	84	5%
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Table 4: Response to Q3

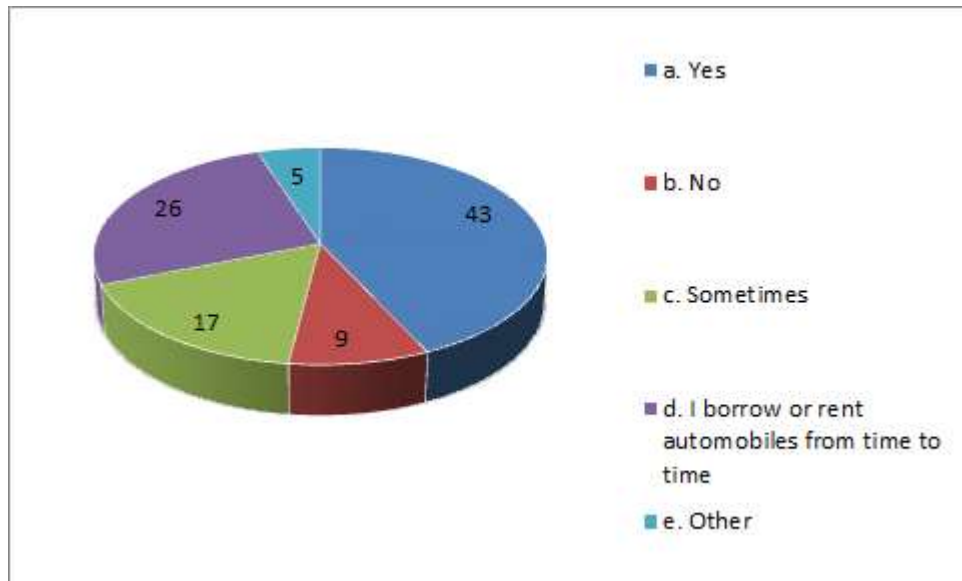


Figure 9: Statistical representation of Q3

43% of the participants mentioned driving an automobile, while 26% stated that they often rent or borrow vehicles as per their requirement. Furthermore, 17% stated they sometimes drive a vehicle, while 9% of the sample size mentioned that they do not drive a vehicle at all. This factor is possibly related to the knowledge and the choice of automobiles driven by the respondents.

Question 4: Which of the following brands do you drive or prefer?

Option/ response	Number of respondents	Total number of respondents	Response frequency
a. Toyota	33	84	39%
b. Honda	27	84	32%
c. General Motors	10	84	12%
d. Other	14	84	17%

Table 5: Response to Q4

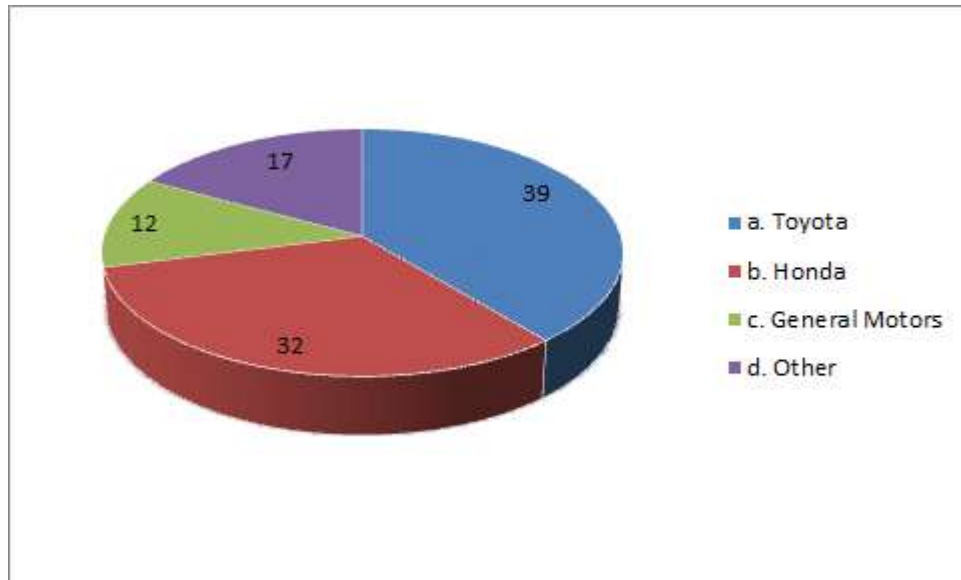


Figure 10: Statistical representation of Q4

A majority of about 39% of the respondents said that they drove or owned a Toyota car, while 32% mentioned having the ownership of Honda cars. It needs to be stated in this regard that Honda has also considered the use of fuel cells in their automobiles, along with General Motors, which is driven by approximately 12% of the sample population. 17% of the respondents mentioned driving another brand of vehicle.

Question 5: Please specify the reason for choosing the automobile brand:

Option/ response	Number of respondents	Total number of respondents	Response frequency
a. Fuel economy	20	84	24%
b. Environment-friendly	18	84	21%
c. Price	8	84	10%
d. Review/ reputation	10	84	12%
e. Style	9	84	11%
f. Reliability	13	84	15%
g. Other	6	84	7%

Table 6: Response to Q5

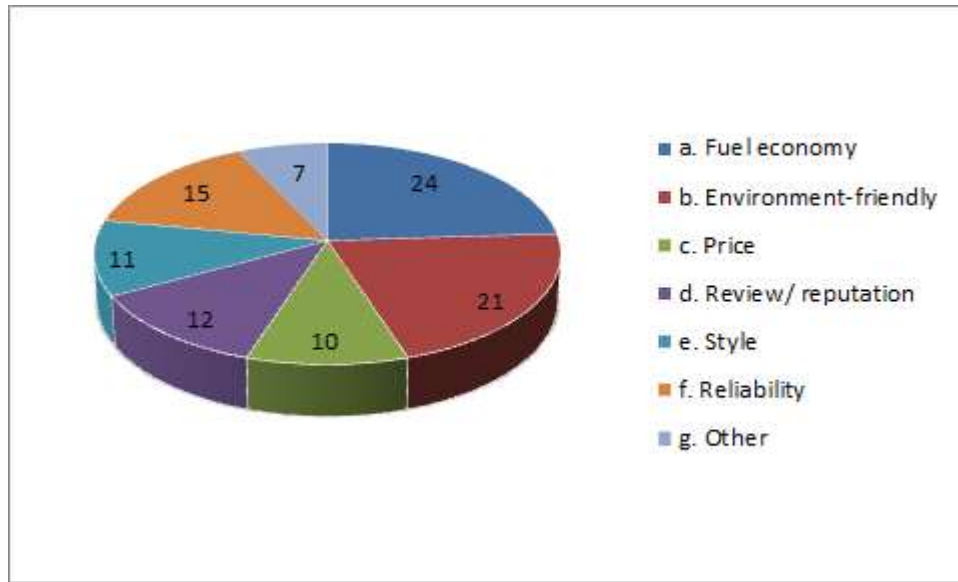


Figure 11: Statistical representation of Q5

Respondents stated varying reasons for opting for their respective choice of automobile manufacturers, such as fuel economy as voted by 24% of the participants. 21% stated that their choice of automobile should be environment-friendly, while 10% mentioned considering the price of the vehicle as an important factor as well. On the contrary, it became evident that 12% respondents depended on the reputation or the review of the car, while 11% cared about the style of the car as well. 15% of the participants mentioned that reliability was an important factor while 7% mentioned having other reasons. It needs to be stated that options such as fuel efficiency and environment-friendly are options related to advantages of fuel cell-powered vehicles, while price is also an important factor, since these automobiles are noted to be quite expensive.

Question 6: Do you understand the concept of a fuel cell?

Option/ response	Number of respondents	Total number of respondents	Response frequency
a. Yes	38	84	45%
b. No	18	84	21%
c. A little	20	84	24%

d. Other	8	84	10%
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Table 7: Response to Q6

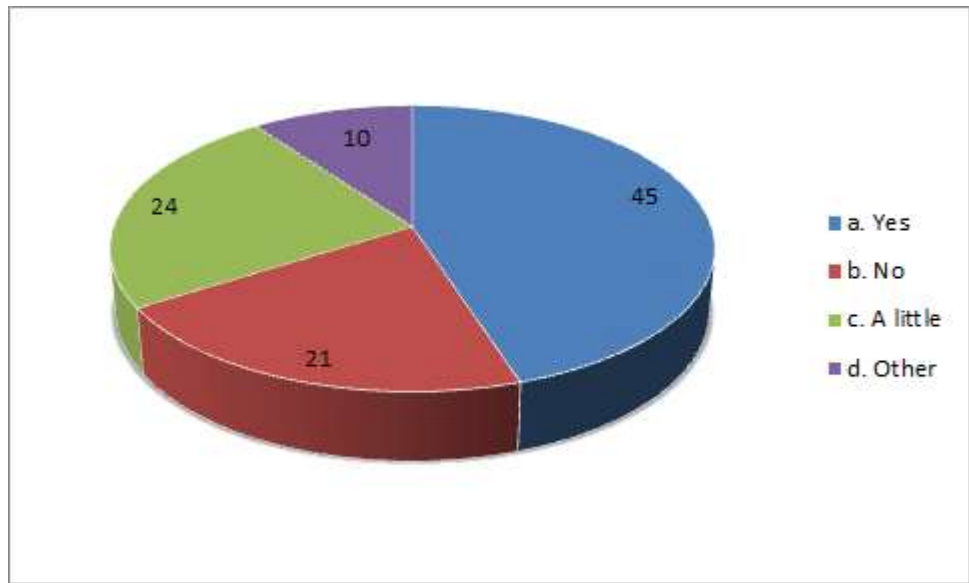


Figure 12: Statistical representation of Q6

45% of the respondents mentioned having an idea of fuel cells, while 24% had a little idea of the same. However, 21% mentioned not having the knowledge of this technology. As mentioned that the gender and age related questions were asked to find out whether these factors attributed to the knowledge of fuel cell technology. Considering the total of 69% having a little to significant knowledge of the technology, it can be stated that age or gender are almost inconsequential factors in this regard.

Question 7: Are you aware of hydrogen fuel cell use in automobiles?

Option/ response	Number of respondents	Total number of respondents	Response frequency
a. Yes	44	84	53%
b. No	21	84	25%
c. A little	10	84	12%
d. Not completely	7	84	8%

e. Other	2	84	2%
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Table 8: Response to Q7

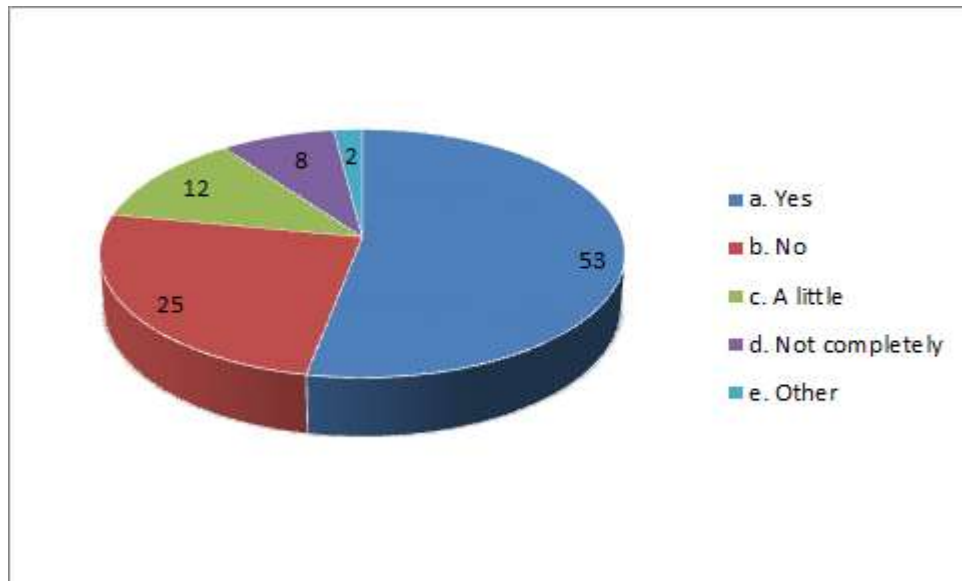


Figure 13: Statistical representation of Q7

A majority of 53% stated that they are aware of the use of fuel cells in the automobile industry, while 20% mentioned that they knew of it, but not entirely. However, 25% of the sample population mentioned that they did not know of it. This is indicative that the technology is fairly new and not many have the knowledge as well as the wide range of its applications and the advantages that come with it.

Question 8: Which of the following would you prefer in your chosen automobile?

Option/ response	Number of respondents	Total number of respondents	Response frequency
a. Higher efficiency	18	84	22%
b. Independence from oil or gas as fuels	17	84	20%
c. Environment-friendly	12	84	14%
d. All of the above	33	84	39%

e. Other	4	84	5%
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Table 9: Response to Q8

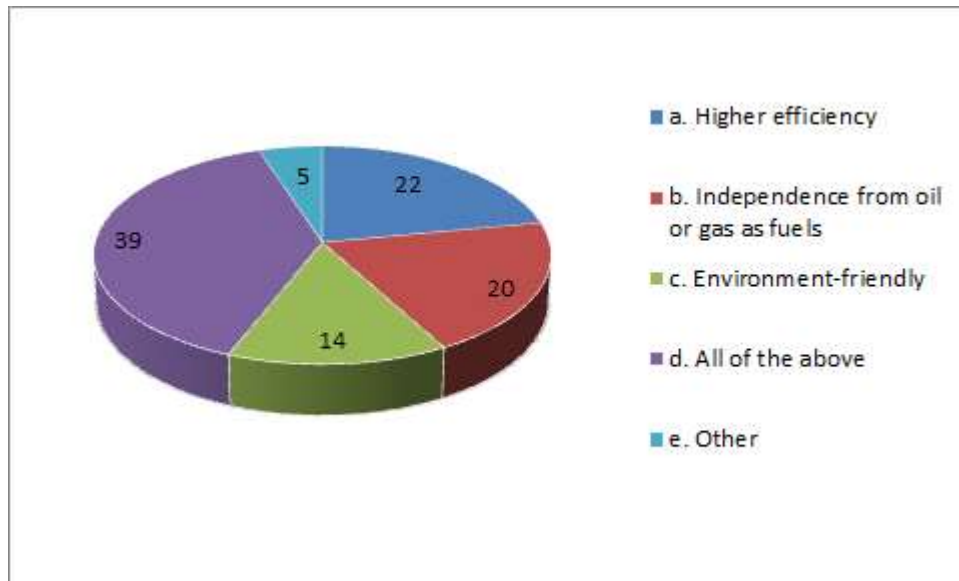


Figure 14: Statistical representation of Q8

22% of the respondents mentioned that they would look for better fuel efficiency. Another 20% mentioned that they would like to be independent of using oil and gas as fuels for their automobiles, while 14% stated being environment-friendly would be a good choice as well. Nevertheless, 39% of the participants mentioned that they would like to use all of the aforementioned responses for their automobiles. The choice of response provided to the participants indicates the advantages of fuel cell-powered automobiles. The response frequency generated is indicative of the intention of the respondents to adopt this newer technology.

Question 9: If your choice was to select one or all of the options in the previous question, would you mind paying a little more than the usual?

Option/ response	Number of respondents	Total number of respondents	Response frequency
a. Yes	52	84	62%
b. No	8	84	9%
c. A little	19	84	23%

d. Other	5	84	6%
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Table 10: Response to Q9

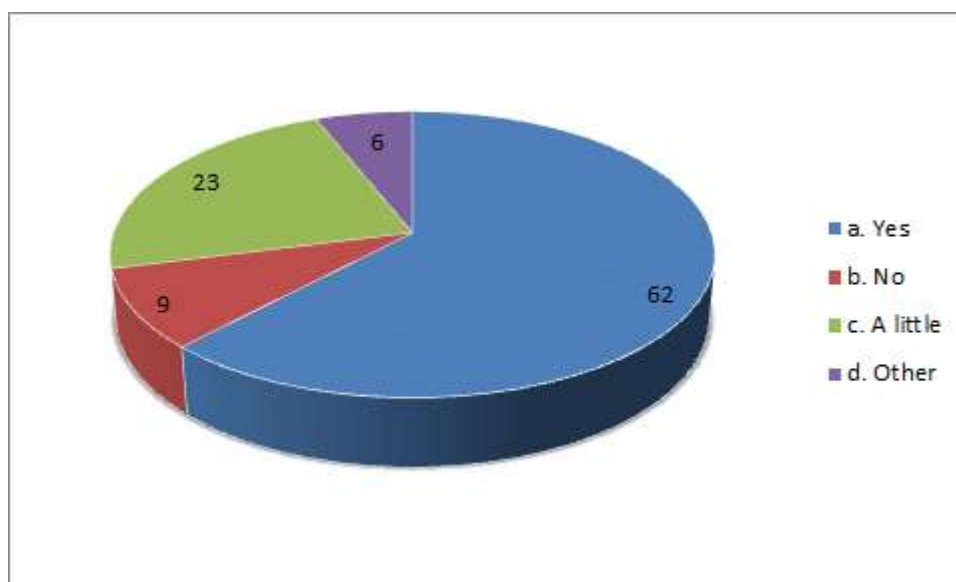


Figure 15: Statistical representation of Q9

62% of the sample size mentioned that they would not mind paying a little extra for enjoying the aforementioned benefits, while 23% seemed to debate their options, stating that they would mind a little perhaps. Regardless, 9% mentioned that would not pay extra for the benefits. This pattern of responses indicates that though individuals would like to adopt fuel cell technology, the budget and affordability of the same become a major challenge.

Question 10: Considering that now you are aware of the uses and advantages of hydrogen fuel cells, would you drive a conventional vehicle or fuel cell charged vehicle?

Option/ response	Number of respondents	Total number of respondents	Response frequency
a. Conventional vehicle (using oil or gas)	8	84	10%
b. Vehicle using fuel cell	47	84	56%
c. The technology sounds quite progressive, but is	12	84	14%

too expensive to be afforded			
d. I would like to consider my options	13	84	15%
e. Other	4	84	5%

Table 11: Response to Q10

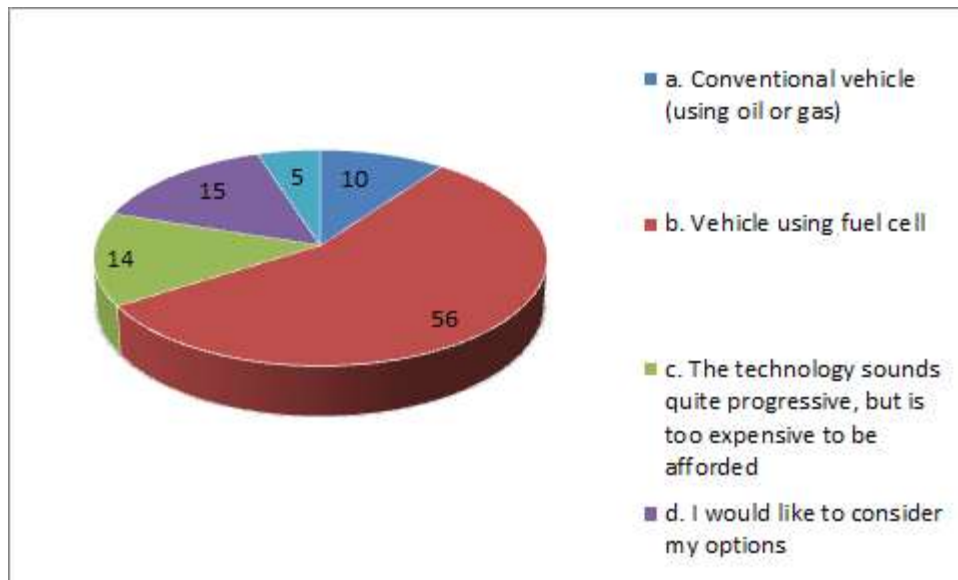


Figure 16: Statistical representation of Q10

Only 10% of the respondents mentioned that they would continue driving their regular vehicle. This is irrespective of the fact whether they are existing users of Toyota or not. However, the majority that is 56% of the population stated that they would switch to automobiles using fuel cell technology. Nevertheless, as discussed previously, the lack of cost-efficiency of the technology was considered by 14% of the participants, while 15% mentioned considering or debating their options thoroughly.

4.3 Qualitative data collection and analysis

Question 1: Your Company is noted to make use of fuel cells in the automobiles manufactured. Why did the idea occur to you in the first place?

Manager 1 (Toyota)	Manager 2 (Honda)
<i>The initial idea of implementing fuel cell technology in designing our vehicles came into mind by the initiative of the government in trying to conserve the environment. This therefore, brought in the revolutionary concept and 2050's environmental challenge.</i>	<i>Our company has always been driven towards contributing heavily for the environment. Keeping that objective in mind and supporting a sustainable society had driven Honda to make use of hydrogen based fuel cells and extract it from renewable sources.</i>

Table 12: Response to Q1

The respondents majorly put forward their opinion on the rise of fuel cells in their corporations. Additionally, they also mention the use of hydrogen based fuel cells as alternative to fossil fuels. Moreover, the Toyota manager is trying to contribute towards the expected revolutionary changes of the environmental challenge, 2050 as planned by the corporation. Toyota being a market influencing corporation is therefore making serious efforts to adopt innovative measures and set an example for the other automobile sectors. They further claim on the beneficiary uses of it and their contribution of the idea towards the sustainability of the environment.

Question 2: What are the major factors that pushed you to the use of fuel cells in manufacturing automobiles?

Manager 1 (Toyota)	Manager 2 (Honda)
<i>Apart from environmental conservation measures, the significant benefit obtained from the use of fuel cells make it an ideal choice. The fuel cells provide much higher operating times over batteries and transmit low heat in comparison to the conventional fuels. Moreover, the maintenance for fuel</i>	<i>Honda has always been inclined towards sustainable options. Fuel cell technology has been greatly contributing to us pursuing our objective. Moreover, low maintenance and low emission of fuel cells also drive us into using them.</i>

<i>cells is not much.</i>	
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Table 13: Response to Q2

Both the respondents greatly agree towards the significant benefits that are obtained on implementing the use of fuel cells. They further mention the low maintenance property, lower emission property of the fuel cell technology that attracts them towards the fuel cells. Additionally, the low emission property of the hydrogen based fuel cells leaving water and heat as a by-product is also a predominant factor.

Question 3: Considering that this technology is quite expensive, the affordability becomes limited. How do you plan on overcoming the same?

Manager 1 (Toyota)	Manager 2 (Honda)
<i>It is agreeable that fuel cell technology is comparatively costlier to that of the conventional sources. However, the maintenance and limited parts of the fuel cell saves extra expenses. Moreover, Toyota has always been a market influencer; therefore we are taking measures to find innovative methods to implement the technology at a significantly low cost.</i>	<i>We are making initial investments in the technology and given the benefits that it is highly contributing towards the environment and in reducing the maintenance cost, the idea is being pursued.</i>

Table 14: Response to Q3

The respondents agree that the fuel cell technology is costly. However, they are taking initiatives to implement the same, despite the setbacks. Also, both companies being environmentally driven are making use of this alternative, despite the costs. However, the maintenance and limited parts of the fuel cell saves extra expenses with the use of fuel cells. Toyota has always been a market influencer; therefore they are taking measures to find innovative methods to implement the technology at a significantly low cost.

Question 4: Hydrogen is not always readily available and the fuel cell design is mostly in its prototype stage. Is implementation going to be without a glitch?

Manager 1 (Toyota)	Manager 2 (Honda)
<p><i>Of course, there are several challenges in the implementation of the fuel cell technology. However, we have hired professionals who are looking into finding alternatives of this variety, like molten carbonate and phosphoric acid fuel cells. They are further assessing the viability of the alternatives for use.</i></p>	<p><i>The implementation of the fuel cell does have potential barriers, which we are constantly trying to overcome. We are planning to invest in the infrastructure of hydrogen plants for easier access and use. Given, the potential challenge we have hired professionals to help guide us through it.</i></p>

Table 15: Response to Q4

The managers of both Toyota and Honda responded that they have hired professionals for helping them through the implementation challenge. Toyota is evaluating the use of alternatives side by side. Toyota is further looking into finding alternatives of this variety, like molten carbonate and phosphoric acid fuel cells. They are further assessing the viability of the alternatives for use. While on the other hand, Honda is planning to set up hydrogen plants for the extraction of hydrogen to solve the issue.

Question 5: The use of fuel cells as discussed is quite environment-friendly. What other reasons can you give to switch to this technology?

Manager 1 (Toyota)	Manager 2 (Honda)
<p><i>Toyota has always been curious in expanding its approach towards the longevity of the corporation. Moreover, apart from the environmental perspective, the advantage of the fuel cell seems promising in helping the corporation</i></p>	<p><i>Apart from the environment friendly aspect, the technology is much efficient and promises revenue influence for the corporation. Moreover, given the benefits such as low maintenance property and higher fuel efficiency, therefore it drives the corporation towards adoption of</i></p>

<i>expand.</i>	<i>technology.</i>
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Table 16: Response to Q5

Both the respondent stated that the fuel cell technology has significant benefits in aspects of maintenance, and low emission offered by the hydrogen based fuel. Moreover, the by-products of hydrogen based fuel being water and heat has made it ideal for use. Additionally, Honda states that given the benefits such as low maintenance property and higher fuel efficiency; therefore it drives the corporation towards adoption of technology. Also, Toyota finds the fuel cell technology promising for the future.

4.4 Discussion

Introduction

With the implementation of the fuel cell technology into the automobile industry, the efficacy in the fuel consumption and limiting the carbon emission has been greatly achieved. However, there are certain areas of concern that must be concentrated upon by the automobile sector. This section therefore evaluates the discussion of the findings in respect to the fuel cell use. Further, the section successfully outlines the research theme on qualitative and quantitative approach.

Quantitative data analysis

In order to draw conclusions from the research and get a proper idea of the research researchers conduct a quantitative data collection process. In the quantitative data collection process researchers conduct an interview and survey for collecting the data respectively. In a survey process there has been a total 100 respondents selected and questionnaires have been provided to them.

Inclination towards vehicles

The data which has been taken from the quantitative research illustrate that most of the respondents are using vehicles. Further, most of the respondents are using Toyota vehicles and most importantly major respondents are intent to use economical fuel consumption vehicles

(Verma and Samanta, 2016). Therefore, it can be understood that people are concerned about the vehicles modernization as they want to use the cars which consume the least amount of fuel. Moreover, awareness about the environment is another main aspect which has been observed from the response of the participants. There is much literature that has argued that most vehicle making organisations were concerned about the environmental change factor and by taking this into consideration they also made fuel cell oriented cars (Saker, 2016). As Toyota one of the popular car making organizations is focused on making cars which can operate by fuel cell. Most importantly from the survey it has been evident that most of respondents are immensely aware about the fuel cell operated vehicle.

Preference of automobile brands and their reasons

From the above respondents it has been evident that most of the respondents used Toyota Company's vehicles; perhaps few respondents were satisfied by operating other company's cars. Moreover, it can be understood that most of the respondents were happy with Toyota's performance. The literature review illustrates that over the years Toyota brought the revolution within the car making industry by modifying the vehicles (Cusumano, 2020). Most importantly they also make their car by concerning the environmental fact. As they recently made a fuel cell oriented car which is an eco-friendly car with low amount of fuel consumption which is immensely attracted to the customers (Satyapal, 2017).

Awareness of fuel cell technology

The survey illustrates the major number of people who are aware about the concept of fuel. Further the respondents are also aware about the hydrogen fuel cell use in automobiles. Moreover, respondents' preference of using cars also illustrate that people are most likely to use higher efficiency cars with independence from or gas as fuels. A huge number of respondents also use the environment friendly car which can easily illustrate that people are more likely to use environmentally friendly cars. From the literature review perspective it can easily be identified that car making companies focused on the customer's preference and they are willing to build a maximum number of eco-friendly cars to target the maximum numbers of cars (Verma and Samanta 2016). Moreover, Toyota makes the efficiency of using hydrogen and limiting the

emission of carbon thereby influencing the productivity rate of the automobile sector while limiting the use of resources (Saker, 2016).

Aspects that drive the interest of consumers towards fuel cell implied automobile industry

After collecting the response of participants it can be understood that more than average people are concerned about the environmental change and they really want to protect the environment. At the same time they also take initiative by purchasing the fuel cell car or intend to purchase the fuel cell cars. Moreover, from the literature perspective it can easily understand the energy efficiency level of the fuel cells are recorded to be under the range of 60% to 80% (Verma and Samanta 2016). However, the efficiency level of the fuel cells can be customized upto 80% when making use into a cogeneration system. The working procedure of the fuel cells are generally beneficial and environment friendly since it emits minimal to absolute no emission. The by-products of the fuel cells being water, heat and electricity therefore makes it much more efficient than the conventional fuels (Saker, 2016). These factors drive customers to purchase fuel cell cars.

Extent of support towards fuel cell as an environment friendly alternative

In respect of the preference question of cars participants responded that they want to use the fuel cell oriented car. Further, after data collection of surveys it can be easily understood that people in recent time are concerned about the environment as well they want higher efficiency cars (Saker, 2016). Moreover, the fuel cell cars provide both of the factors which bring drive on the customers for purchasing the fuel cell cars. From the literature review perspective it has been also seen that there are many advantages that fuel cell cars have which help to bring drive on the customers for purchasing fuel cars (Valente, et al., 2019).

Qualitative data analysis

Telephonic interviews with managers of 2 automobile firms, namely Toyota and Honda was carried out, since both brands use fuel cells for the automobiles manufactured by them. An open-ended questionnaire had been designed for the purpose of interview, to gather qualitative data. The section therefore links between the response of the managers and their correlation with the opinions of the existing literatures.

Implementation of fuel cell technology in automobile sectors

As per the statements of the Honda and Toyota managers, it is clearly understood that the environment sustainability has been considered as the predominant factor in influencing the automobile industry in implementation of the fuel cell technology. As per the opinions of (Tanç, et al., (2019), it has been evident that fuel cells running on hydrogen is relatively beneficial in terms of limiting the carbon emission. It is clearly deduced by findings that, Toyota has taken serious interest in the fuel cell implementation and designing of their engines efficiently. Since fuel cells run on hydrogen therefore it is comparatively a better alternative for preserving the environment (Verma and Samanta, 2016). Supported by Satyapal (2017), the use of fuel cells can potentially eliminate the greenhouse gases, thereby sustaining the environment.

Factors promoting fuel cell implementation

The findings clearly denote that there are certain factors that greatly contribute towards the implementation of the fuel cell technology in the automobile industry (Saker, 2016). Depicted by the interview with the managers of Toyota and Honda, it is evident as to how there are significant benefits that are obtained on implementing the use of fuel cells. Further mentioned by the managers on low maintenance property, lower emission property of the fuel cell technology that attracts them towards the fuel cells. This is further supported by Verma and Samanta (2016), which clearly suggests that the low emission property of the hydrogen based fuel cells leaving water and heat as a by-product is also a predominant factor.

Challenges in implementation of fuel cell technology

With the implementation of the fuel cell technology,, there are certain challenges that are encountered. Clearly stated by the statements of the automobile industry, it is evident as to how there are issues related to the costs when opting fuel cells. Supported by the visions of Tanç, et al., (2019), fuel cells being run on hydrogen requires infrastructure supporting the hydrogen plants that would ease the process of obtaining hydrogen from natural resources. Moreover, guided by the visions of Saker, (2016), the fuel cell technology being entirely a new concept requires thorough insight on the methods of implementation in the automobile sector.

Future scope of the fuel cell technology and potential challenges

The fuel cell technology being a new innovation requires thorough evaluation on the implementation process. However, with context to the futuristic approach of the technology it is definite that the ability of the fuel cells to contribute towards efficiency of the automobiles, the fuel cells has been implemented into use by Toyota (Cusumano, 2020). This therefore can be supported by the opinions of Satyapal (2017), which suggest that fuel cells are a futuristic scope in the automobile industry. Given the potential threat to the environment with the over emission of the carbon the fuel cell technology implementation seems promising from the environmental perspective (Robledo, et al., 2018).

Predominant factors promoting applicability of fuel cell technology

The findings suggest that the interviewed managers are willing towards the implementation of FC technology given the significant benefits over the conventional fuel sources. Moreover, as per Satyapal (2017), with the inclination of the developing countries towards technological advancements and alternative applications of renewable resources, the fuel cell technology has come to the rescue. The managers state that the fuel cell technology is highly efficient to use and requires low maintenance properties as supported by the opinions of Robledo, et al., (2018). Therefore, given the potential benefits that the FC promises on aspects of efficacy and productivity with minimal to now noise and air polluting agents' emission, the technology stands competitive for the future times to come.

4.5 Summary

Despite the fuel cell technology using hydrogen being a cutting-edge technology, the aspect of a significant expense seems to be a major challenge for the average consumer to adopt the same. However, the major benefits such as fuel efficiency, non-polluting and independence from oil and gas as regular fuels seems to be the driving factor for people intending to adopt the technology.

5.0 Conclusion & Recommendations

5.1 Conclusion

With the increasing awareness of the government and the industry managers towards aiming to contribute sustainability of the environment and help conserve it, the fuel cell use technology has been brought to existence. The fact that states fuel cells must be regarded as among the most reliable forms of alternative energies, they are being considered widely. In addition to that the ease of accessibility and comparatively lower costs of this alternative fuels are therefore suitably opted. The paper further stresses on the need for the sustainable management drive and its influence on the need for emergence of alternative energy on a thermodynamic aspect. The paper further tries to enwrap all the essential attributes that are needed to be aware of when applying the Fuel cell technology into use.

The role and the significant implementation of the fuel cell technology could be termed potential enough if the integrating system opportunities would be clarified. In context to the previous years, it has been evident how approaches are being made to encourage the use of alternatives for the fuel. One such effort has been made by the Toyota Corporation to implement the fuel cell technology. Toyota being a market influencer is therefore making serious attempts to create a sense of awareness for the FC implementation while producing vehicles based on the technology. The paper also succeeds to provide the fabrication perspectives in the paper by highlighting the various types of fuel cells that are in existence. The potential drawbacks and advantages have also been mentioned to get a thorough understanding on the mechanism of fuel cells.

5.2 Linking with objective

Objective 1: The primary objective of the paper was “to evaluate the major factors responsible for the increase in the use of fuel cells in Toyota motors.” This objective has been attained by referring to the environmental aspects and the demands of the government to aim sustainability of resources for a longer period of time. Moreover, the principle of Toyota motors to opt for longer sustainability approaches are being spoken about justifying their serious interest towards the fuel cell technology.

Objective 2: The second objective of the paper was “to investigate the importance of fuel cells in automobiles.’ This objective has been fulfilled by highlighting the significance of the fuel cell use in enhancing the efficiency of automobiles. The aspects such as energy efficiency, durability and cost genre of the fuel cells have been compared to that of the conventional fuel to help draw an idea of switching the attitude of the automobile industry to the FC technology.

Objective 3: The final objective of the research paper was “to assess the advantages and disadvantages associated with fuel cell usage.” This aspect of the fuel cell technology has been potentially achieved by highlighting the various significant advantages of the fuel cell. Furthermore, the drawbacks and the limitations of the fuel cell technology use have been covered in the paper.

5.3 Recommendations

In context to the influx of hydrogen based fuel cell technology in the automobile industry, there are a few aspects that must be taken into consideration for the proper utility of the technology. Moreover, in context to the limitation of the production of hydrogen for the use of fuel cell technology there are various measures that may be put to use. The approach of the production technology must be concentrated upon critically to find solutions with the prolonged wait of extracting hydrogen from fossil fuels.

Recommendation 1: Use of thermo chemical techniques such as making use of heat to potentially convert biomass to produce hydrogen may be effective. Moreover, the usage of sunlight and enzymes upon bacteria and green algae can prove effective in splitting itself into hydrogen for use.

Recommendation 2: In context to the flammable property of hydrogen and the difficulty in storing the gas, require viable techniques for the storage. Use of metal hydrides may prove their efficiency as they are evident in absorbing and retaining hydrogen for prolonged periods of time. Moreover, the extraction of hydrogen from the metal hydrides in times of use can be manipulated.

5.4 Future scope and limitations of the study

The paper entirely focuses on the aspects that sound promising in reference to the use of fuel cell technologies as an alternative to the conventional fuel sources in the automobile industry. With the advent of modernization, the influx of technological advancements has been amplified in recent times. This therefore has promoted the overproduction of vehicles that do contribute towards the degradation of the environment's health. Therefore, with the intention of regulating the repercussions of the vehicle's production, the use of fuel cell technology seems promising. Moreover, referring to the versatility and the environmental friendly attribute of hydrogen driven fuel cells, the study upon this technology is essential. This paper would therefore help assist the seeking personnel in getting a deeper insight on the fuel cells and design their approach towards implementation wisely. However, there are a few limitations of the study that limits in gaining a wider perspective on the theme. Setting up meetings with the interviewed managers was challenging and were very time restricted, given the activities happening in the corporation. Also, efforts were made to hinder any sensitive questions that would make the managers uncomfortable. This therefore, limited in gaining a thorough insight on the working process adopted by the two interviewed automobile sectors.

Moreover, the fuel cell technology entirely concept is therefore not deeply stressed to research and use in the automobile industry. Only renowned brand industries are taking initiatives to research on the technology and find solutions to overcome the implementation challenges. Concluding, given the potential inclination of the world on a global perspective towards attaining innovation for improving efficiency in the working mechanism, the automobile industry is estimated to have a bright future with the implementation of the fuel cell technology. In addition to that, the environmental friendly approach of the world makes this research paper much validated for the future researchers working on fuel cell technology research.

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Appendix 1: Questionnaire for survey

Question 1: Please select your gender:

- a. Male
- b. Female
- c. Other
- d. Would not like to disclose

Question 2: Please select your age group:

- a. 18-25
- b. 26-35
- c. 36-45
- d. 46-55
- e. 55+

Question 3: Do you drive an automobile?

- a. Yes
- b. No
- c. Sometimes
- d. I borrow or rent automobiles from time to time
- e. Other

Question 4: Which of the following brands do you drive or prefer?

- a. Toyota
- b. Honda
- c. General Motors
- d. Other

Question 5: Please specify the reason for choosing the automobile brand:

- a. Fuel economy
- b. Environment-friendly
- c. Price
- d. Review/ reputation
- e. Style
- f. Reliability

g. Other

Question 6: Do you understand the concept of a fuel cell?

- a. Yes
- b. No
- c. A little
- d. Other

Question 7: Are you aware of hydrogen fuel cell use in automobiles?

- a. Yes
- b. No
- c. A little
- d. Not completely
- e. Other

Question 8: Which of the following would you prefer in your chosen automobile?

- a. Higher efficiency
- b. Independence from oil or gas as fuels
- c. Environment-friendly
- d. All of the above
- e. Other

Question 9: If your choice was to select one or all of the options in the previous question, would you mind paying a little more than the usual?

- a. Yes
- b. No
- c. A little
- d. Other

Question 10: Considering that now you are aware of the uses and advantages of hydrogen fuel cells, would you drive a conventional vehicle or fuel cell charged vehicle?

- a. Conventional vehicle (using oil or gas)
- b. Vehicle using fuel cell
- c. The technology sounds quite progressive, but is too expensive to be afforded
- d. I would like to consider my options

e. Other

Appendix 2: Questionnaire for interview

Question 1: Your company is noted to make use of fuel cells in the automobiles manufactured. Why did the idea occur to you in the first place?

Question 2: What are the major factors that pushed you to the use of fuel cells in manufacturing automobiles?

Question 3: Considering that this technology is quite expensive, the affordability becomes limited. How do you plan on overcoming the same?

Question 4: Hydrogen is not always readily available and the fuel cell design is mostly in its prototype stage. Is implementation going to be without a glitch?

Question 5: The use of fuel cells as discussed is quite environment-friendly. What other reasons can you give to switch to this technology?