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Deducing of an Automobile Design for an Electric Vehicle (EV): Perspective of Technological Acceptance Model (TAM)

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Abstract: Research looks at the integration of the EV in the Ghanaian market from textual analysis and the Technology Acceptance Model (TAM) point of view to aid in an EV design. This information systems theory models how users come to accept and use a technology. The model use purposive random sampling of stratums from various transports stations and public drivers by considering; Perceived usefulness (PU) and Perceived ease-of-use (PEOU). In the study, it was observed that about 76% of the respondents said they were willing to use an EV if they are available in the Ghanaian market whilst 24% said they will not use and EV. There was also textual analysis of the existing EV to develop a proposed EV which will forgo the major challenges like the frequent charging and avoid the use of fuel completely. Therefore, the research is to seek an alternative EV which avoids the use of continuous charging of batteries, fuel, power density problems and poor life time performance. It was noticed that about 33% of the respondents said their reason for willing to use EV was to save cost, 25% stated for comfort, 18% were also will for the purposes of no fuel use and 13% for EV will be least expensive. Therefore, the research concluded that, for a EV to be acceptable, it has to have the characteristics of being cost efficient, environmental cleanliness, good performance and convenience in usage.

Keywords: Technology Acceptance Model (TAM), Electric Vehicle (EV), Automobile, Proposed EV, Engine Comparison, Operating Cost Analysis

1. Introduction (Background)

Electronic Vehicles (EVs) have being around since 1834 [8]. However they have not been put into commercial use compare with combustion engines. These notwithstanding there are tremendous positive roles awaiting them in the future with the current trend of advancing electrical systems emerging across the world. For instance, there has been a shift of most railway systems from internal combustion engine to electrical ones. This has achieved high accuracy of speed and dynamism making transportation quiet easier.

Electric Vehicles (EVs) should have been better with modern technologies but this is not the case. It is still faced with the problem of external charging for a shorter period of usage and the low speed associated with it.

The EV has seen a lot increasing developments since its inception with many countries. Annual sales of light-duty plug-in electric vehicles in the world's top markets between 2011 and 2015 shown in figure 1.

In five years, global sales of highway legal light-duty plug-in electric vehicles have increased more than ten-fold, totaling more than 565,000 units in 2015. Plug-in sales in 2015 increased about 80% from 2014, driven mainly by China and Europe [1]. Both markets passed in 2105 the U.S. as the largest plug-in electric car markets in terms of total annual sales, with China ranking as the world's best-selling plug-in electric passenger car country market in 2015 [3][1]. Since 2011, cumulative global sales totaled about 1.27 million plug-in cars and utility vans by the end of 2015.

Aside all the advancement in the EV field there is a limitation to the adaptation of it large global scale

[1] A total of 295,322 plug-in electric vehicles have been sold up through 2014, accounting for passenger cars (includes now off-the market vehicles, the Fisker Karma, Tesla Roadster, Mini E, Coda sedan, BMW ActiveE – and incremental contributions by vehicles not normally tracked), light-duty vans and trucks, and heavy-duty trucks.

acceptance. However, this research has implored the Technological acceptance Model (TAM) to come out with a proposed EV that will eliminate the existing EV challenges. The next section discussion the various dimensions of the proposed EV as supposed to the existing automobiles.

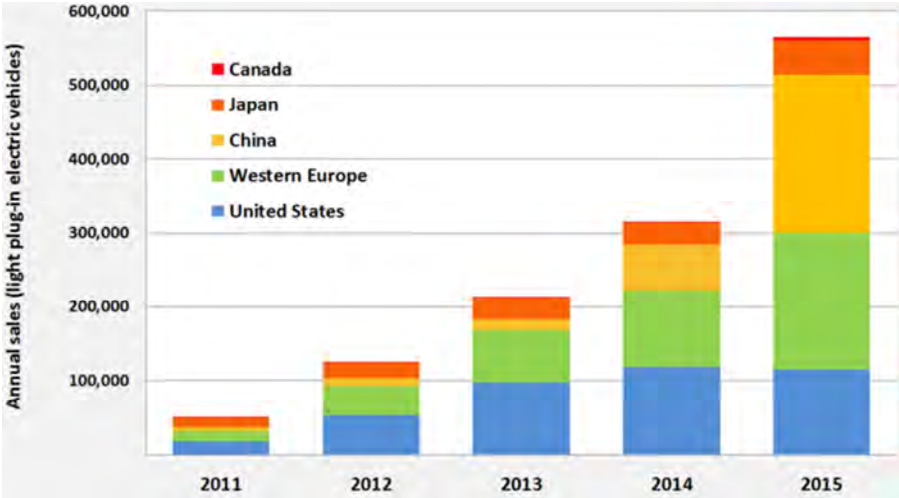


Figure 1. *Global annual sale of light-duty plug-in EV between 2011 and 2015, source: Argonne National Laboratory [1].*

1.1. Technology Acceptance Model (TAM)

The technology acceptance model (TAM) is an information systems theory that models how users come to accept and use a technology. The model suggests that when users are presented with a new technology, a number of factors influence their decision about how and when they will use it, notably:

a Perceived usefulness (PU) This was defined by Fred Davis as "the degree to which a person believes that using a particular system would enhance his or her job performance".

b Perceived ease-of-use (PEOU) Davis defined this as "the degree to which a person believes that using a particular system would be free from effort" [5].

Bagozzi, Davis and Warshaw say:

Because new technologies such as personal computers are complex and an element of uncertainty exists in the minds of decision makers with respect to the successful adoption of them, people form attitudes and intentions toward trying to learn to use the new technology prior to initiating efforts directed at using. Attitudes towards usage and intentions to use may be ill-formed or lacking in conviction or else may occur only after preliminary strivings to learn to use the technology evolve. Thus, actual usage may not be a direct or immediate consequence of such attitudes and intentions. [9]

1.2. Proposed EV Engine Compared with Other Engine Designs Including Existing EVs

The EV engine designed by the study has been compared with other engines such as the combustion engine and the existing EV engines to elicit the advantages and the benefits of the designed engine over its counterparts.

Table 1. *Comparison of Proposed EV to internal combustion and existing EV.*

comparing the Proposed Engines design with other forms		
Existing EV (Grid connected Charging)	**Researched designed EV (no external plugging)**	**Internal combustion Engine Systems**
Fueling: Batteries and Chargers (Infrequent replacement of battery pack and battery fluid)		Ignition: Distributor points caps and rotors. Ignition coil Spark plugs (periodic ignition system tune ups)
Electrical: Motor and Controller (Infrequent replacement of motor brushes for only dc motor)		Cooling: Radiator, Water pump, Cooling hoses, Thermostat, Sensor and overflow jars (periodic cooling system flushing and replacement of coolant or antifreeze)
Drive: Transmission, Drive shaft, Differential, Brakes, Wheel/tires, Steering, and Fluids (Periodic systems maintenance and replacement of fluids, brakes and tires)		Fueling: Carburetor, Fuel injectors, Fuel pump, Fuel lines/hoses, Gas tank, Fuel filter and Air filter (periodic fuel system maintenance and replacement of air/fuel filters)
Energy: External plug to grid connected for electrical power (provision of energy for drive)	Energy: No external plug to grid connected for electrical power (provision of energy for drive)	Mechanical: Block/heads, Crankcase/oil pump, Pistons/rings, Gears/chains, Shaft/rods Gaskets/belts, Alternator/starter (Periodic overhauls and replacement of oil and oil filters)
Operation: for each specific distance drive there should be a stop charging at an electric station. This cause occasional charge of battery water.	Operation: the vehicle drive does not need stop and charge processes as the system depends not on batteries but on continues internal charging system.	Drive: Transmission, Drive shaft, Differential, Brakes, Wheels/tires, Steering, and Fluids (Periodic systems maintenance and replacement of fluids, brakes and tires)

From table 1, it is evidenced that the electric vehicle is very simple and more reliable. They are also more environmentally friendly than the internal combustion engines. This is so because there are no known emissions produced by EVs.

Additionally, the proposed EV will need minimal periodic maintenance. Compared to the existing EVs which use its battery for charging the system and also running the system while in operation, the proposed EV will only need the battery to start the system but do not need it to run the system operation. Hence, there would be minimal use of the battery and battery water.

Moreover, it will use significantly lesser time per mile to operate than the existing EVs. Because the existing EVs are recharged externally, the operation apparently comes to a stop before the recharging takes place. This takes a considerable time do recharge but the proposed EV will not be externally recharged.

Finally, the proposed EV will help to take away from the road a lot of combustion engines when the owners of such vehicles decide to convert them to the electric engines. This noble action will help to remove one polluting car from the road and add one nonpolluting electric vehicle.

1.3. The Research Gap

The study has identified some challenges associated with both the existing EVs and the internal combustion engine. Internal combustion engine emit substances that are detrimental to the health of the environment [19], [10]. Therefore, internal combustion technology is in contravention with ongoing efforts in the world to clear or reduce to the barest minimum emissions that are harmful to the environment. Also, the existing EVs are faced with the challenge of charging and recharging the battery after it has covered a certain mileage. That is the battery falls after it has performed a certain distance. However, the main limitations facing the existing EV technology are discussed under the following headings:

a Energy and power density
b Battery charging
c Lifetime performance

1.3.1. Energy and Power Density

The exact amount of energy that a battery bank contains translates to the vehicle's range of distance travel at a time. Therefore, the less the energy the less the distance travelled. In the same vein, the power is how fast the energy can be removed or dissipated when the vehicle is in use. This has a direct effect on the acceleration of the vehicle. This is because; the acceleration of the vehicle is dependent on how fast the energy is dissipated from the battery. For these two reasons, the existing EVs are constrained by the weight and the space of the car to contain more of the weighty battery banks to generate enough power.

However, the proposed EV will not need such volumes of battery banks to power it. It will significantly need less number of battery banks to power it.

1.3.2. Battery Charging

The issue of the range of distance covered is one of the key limiting factors of electric vehicles. For instance, most existing EVs distance travelled before recharging is about 40 miles. However, it is obvious that drivers are not enthused by the ultimatum of stopping to recharge their batteries during period of cruising after the power battery has run out or they have travelled the maximum distance before recharging. Even though, a number of different technologies have emerged to resolve this challenge, the challenge still persists. These include: plug-in hybrid (PHEV) and extended range electric vehicle (EREV) which can fall back on the existing liquid fuel infrastructure at the sacrifice of some efficiency and fuel costs [13].

However, the proposed EV will only need a battery to kick start the engine and switch to a well-defined mechanism that does not depend on the battery again for its energy to operate.

1.3.3. Lifetime Performance

Each charging and a discharging cycle is a complete life in a battery's lifespan [7]. Each battery has its own chemical properties which are different from other batteries. Therefore, the different chemical properties affect its usable life. For instance, advanced lithium ion chemistry exhibits small cycle degradation rates up to 1000 cycles with deep discharge capability whiles current car batteries technology in automotive applications is likely to last up to 5 years. Therefore, the driving performance of electric vehicles diminishes over the lifetime of the vehicle because it is the sole source of energy for the car. Therefore the proposed EV does not depend on batteries for its continuous operation.

1.4. Why the Proposed Electric Vehicle (EV)

The research gap/challenges identified with the existing EVs have been addressed by the prosed designed EV. This proposed EV has also considered the negative financial implications of both combustion engines and the existing EVs and the discomfort of charging and recharging of the existing EVs on customers. Additionally, aside the thorough consideration of the proposed EV on the negative financial implications of the combustion engines, the proposed EV is environmentally friendly and technologically apt. The economic, environmental and technological implications of the proposed EV are considered in more detail below.

1.4.1. Economical (Operating Cost Analysis)

The existing Electric Vehicle only consumes electricity. In between charge-ups there are no consumables to worry, except watering of the batteries occasionally. According to the Ford Ranger Vehicle pickup conversion the average consumption is about 0.44kWh per mile.

From ECG (2014) the prevailing tariff in commercial

(*Non-Residential) consumption* charged per month for the lowest range (0-300 will be translated into

$$\frac{0.44kWh}{m} * \frac{GH¢0.6304}{kWh} = 27.7376\ pesewas\ per\ mile$$

This does not include charging cost and $3.3\ (12.474p) cents\ per\ mile$ for battery replacement.

Table 2. *Non-Residential.*

Tariff Category (GH¢/kWh)	Effective October 2014, Billing Cycle
0-300	0.6304
301 – 600	00.9947
601+	60.46

Source: Ghana Electricity Company of Ghana [14]

Comparing this existing EV to the gasoline powered internal engine, which consumes gasoline, ignition, cooling, fueling and exhaust systems requires filters, fluids and periodic maintenance. Nowadays the air pollution and economic issues are the major driving forces in developing electric vehicles (EVs) [4].

The average of $20\ miles\ per\ liter\ or\ 0.05\ liter\ per\ mile$ is at $GH¢2.749\ per\ liter$ for fuel that translates to:

$$0.05\ liter/\ mile * GH¢2.749/liter = 0.13745\ (13.745\ pesewas)/mile$$

Consumables and periodic maintenance must still be added.

Assuming the cost: $GH¢48.4\ per\ month$ (oil change average over three month, fuel additives aligning and balancing tires) and annual mileage is $12000\ miles\ per\ year\ this\ becomes$:

$$GH¢48.4 * 12month \left(\frac{580.8}{year}\right) \div \frac{12000miles}{year}$$

$$= 0.0484(4.84\ pesewas)/mile$$

Adding the two make it $18.585\ pesewas/mile$ operating cost for gasoline powered vehicle versus $27.7376\ pesewas\ per\ mile$ for existing EV conversion and may vary depending on the driver.

This is almost 100% the cost of the existing Electric Vehicles (EVs).

The operating cost analysis of the proposed Electric Vehicle (EV) is approximately insignificant. The system is to have no cost of charging per mile and it eliminates the approach of existing EV occasional battery water change.

Automobile drives are of much input to the socio-economic dispensation in the country. This ranges from government to public sector. All industries are for automobiles.

This automobile drive will help solve the immense hardship of the problems it come a long with. The initial will be appreciable with less reduced burden the other automobiles come with. This technology uses no fuel for it drive hence the continuous expenditure of formal ones will be no more.

a Low maintenance cost
b No fuel
c Low cost of transportation

1.4.2. Environmental Safety

The proposed EV does not emit any known substances which are detrimental to the health of the environment. EVs are generally emission-free and the proposed EV is no exception. With the increasing number of vehicles imported and registered in the country annually [12], the construction of the EV is a visible proof of our commitment to the maintenance of a green and healthy environment.

1.4.3. Technological Advancement

Even though EVs have been around since 1834 (Leitman and Brant, 2009) with a number of technological attempts to overcome its major challenge of charging and recharging of its battery, none of the technologies have been able to overcome that. This proposed technology have been able to overcome that completely through it's continues internal charging system.

2. Materials and Methods

2.1. Perceived Acceptability of Proposed EV by Vehicle Users

According to this research design, the technology can be used in all places with its target as an automobile drive. The application is broken down into three main fields which include:

a Long journey drive.
b Town drives for both public and private sectors.
c Electrical power generation.

In other to explore the various vehicle technology and the factors affecting the automobile industry in Ghana, the research looks at the players. It assesses how the EV will influence the industry and recommendation to help the research comes out with a well-fitting and acceptable technology for the Ghanaian vehicle users.

In view of this, various transport stations were contacted with their mechanics, drivers and mates. The route for the research data collection is show in figure 2.

The data collection begun with O. A. Travels and Tours, it was the closest station to Kumasi Polytechnic (research center) and has organized transport systems. It was also used as initial preparatory data collection for preceding centers. The research field agent was then divided into three groups. The three groups then converge at the O. A Travels & Tours workshop at Afrancho-Kumasi.

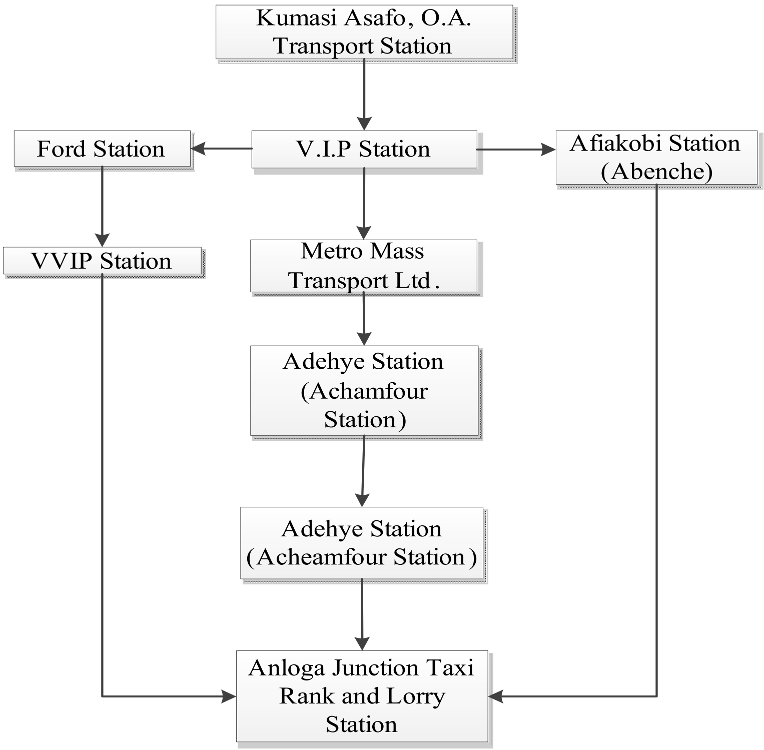


Figure 2. *Research data collection zones and their allocations.*

2.2. Data Collection Method

The research uses research schedules and field interview approach in the data collection.

Under the research schedules, eighty-six (86) data was collected using both close and open ended formats out of the one hundred and twenty (120) administered through non-probabilistic sampling. Attached in the appendix A is the sample of the research schedule used for data collection.

The field interview is purposively chosen. The O. A Travels & Tours workshop was the place where the interview was conducted. The interview was structure according to question pertaining to the operation of existing vehicle, choices, recommendation of structural composition and recommendations for the Proposed Electric Vehicle.

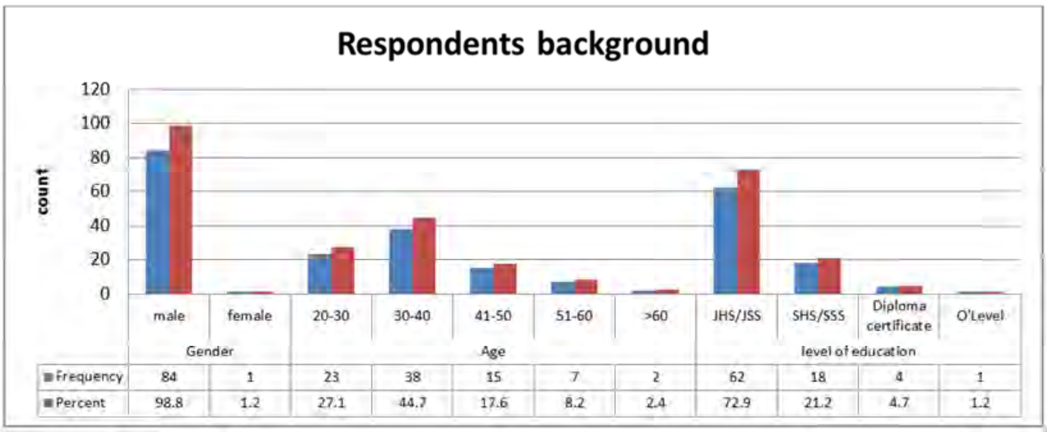
3. Findings

3.1. EV Technology Acceptability Study

The main of objective of the study was to assess the acceptability of EV to the consumers. These were commercial transport owners and operators in the market.

3.2. Background Characteristics of Respondents

The study assessed the background characteristics of the respondents. It was found that 98% of the respondents were males. It was also found that almost 73% 0f the respondents had up to JHS level of formal education with about 2.4% been about 60 years as shown in figure 3.



	Gender		Age					level of education			
	male	female	20-30	30-40	41-50	51-60	>60	JHS/JSS	SHS/SSS	Diploma certificate	O'Level
Frequency	84	1	23	38	15	7	2	62	18	4	1
Percent	98.8	1.2	27.1	44.7	17.6	8.2	2.4	72.9	21.2	4.7	1.2

Figure 3. *Respondents' gender, age and educational levels.*

3.3. Respondents Transport Companies/Unions

Of the respondents studied, it was clear that 44% to do not belong to any known company. Also, about 22% belonged to VIP whiles only 1.4% each of the respondents belonged to the Ford Company, Cool family, and Ghana Express.

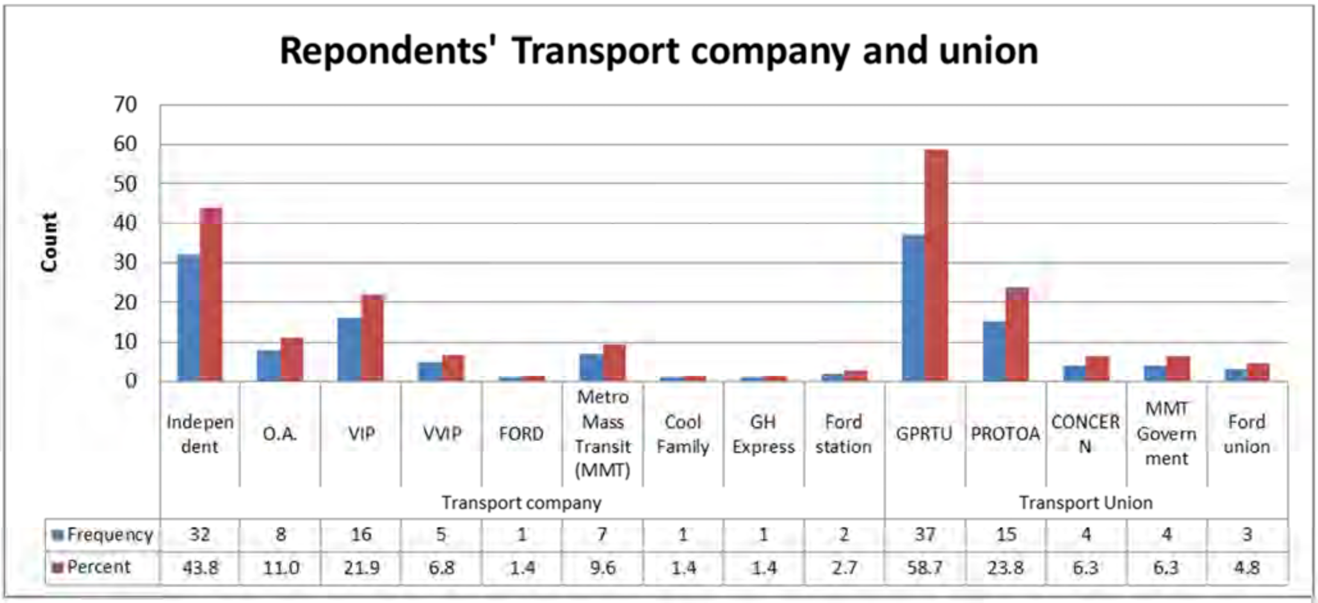


Figure 4. *Names of company and belonging transport unions.*

In the same vein, about 59% of the respondents belonged to the GPRTU as a union while's only about 5% belonged to the Ford union as shown in figure 4.

3.4. Respondents' Perceived Choice of Brand and Brand Used

The study sought to understand respondents perceived brand choice and brand been used.

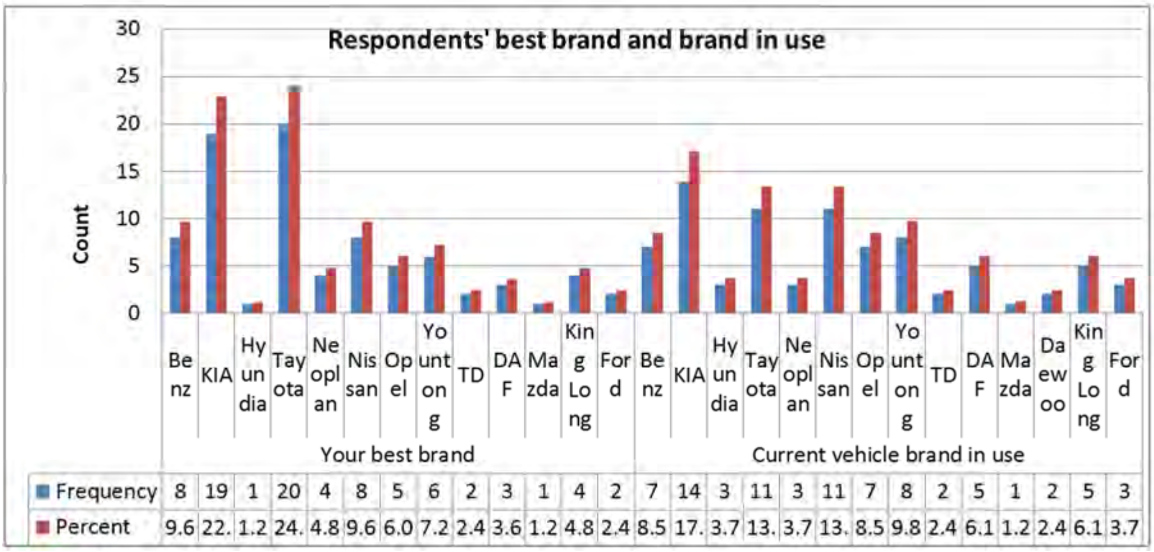


Figure 5. *Respondents' best brand and the current brand in use.*

3.5. Respondents' Reasons for Preferred Brand Choice and Current Brand

The respondents adduced some reasons for the preferred choice of vehicle in figure 5(a) and the reason of current brand in use figure 5(b).

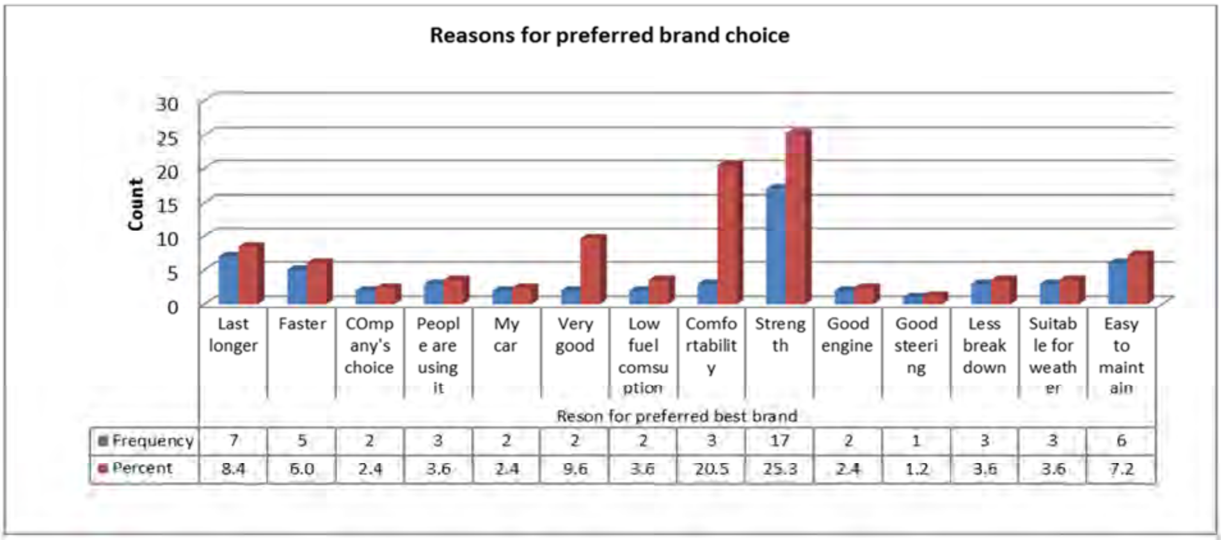


Figure 5. *(a) Reasons for preferred brand choice.*

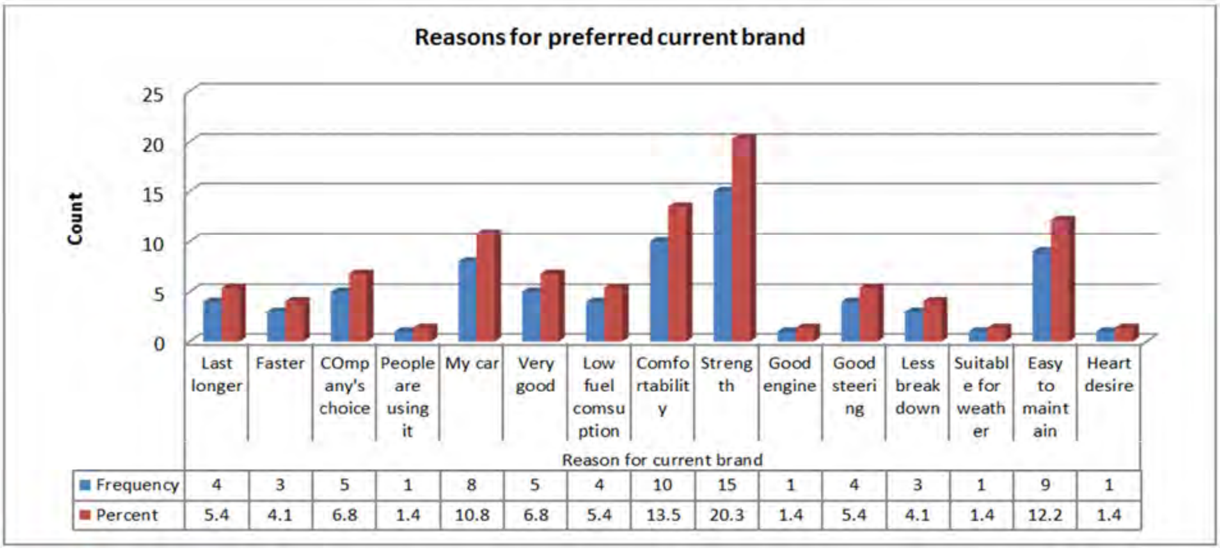


Figure 5. *(b) Reasons for choice of current brand.*

3.6. Willingness to Use EV

The study assessed the willingness of the respondents to use Electric Vehicle.

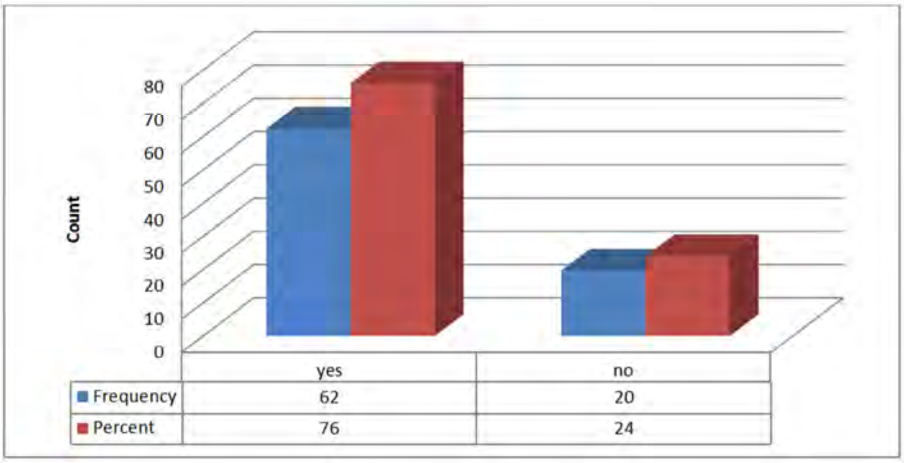


Figure 6. *Willingness to use EV.*

3.7. Reasons for Willing to Use EV

The study assessed the reason for respondent's willingness to use the Proposed EV

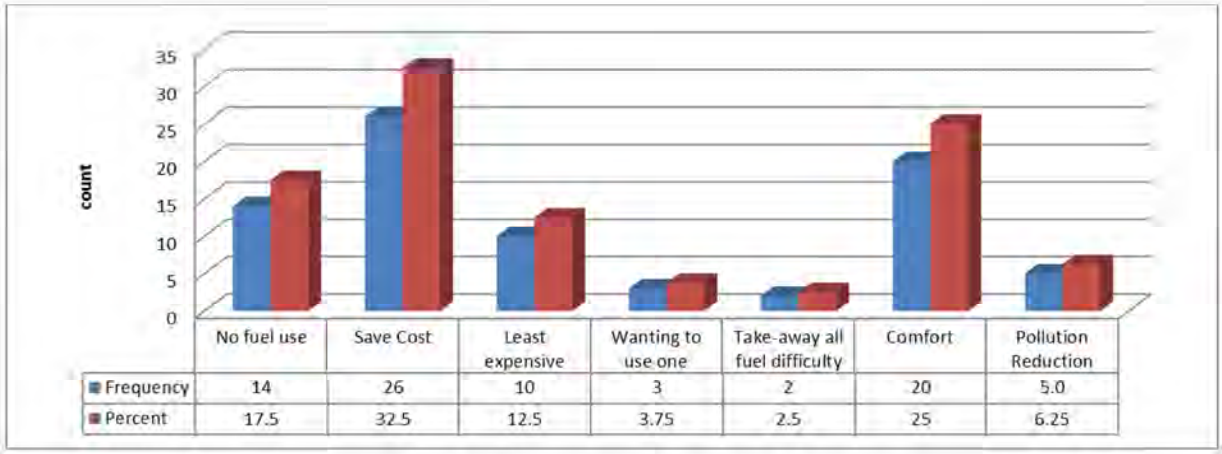


Figure 7. *Reasons for wanting to use EV.*

3.8. Expectations of Respondents' to the EV

The study also assessed some recommendations given by the respondents for the purposes of what they expect to see from the Electric Vehicle.

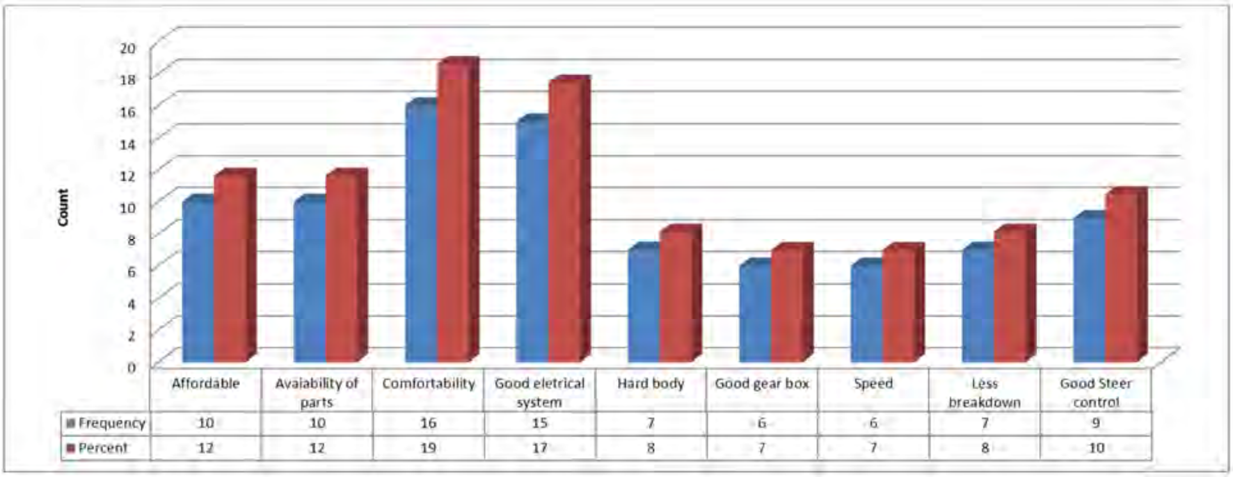


Figure 8. *Recommendations from the respondent on the EV.*

4. Discussion

The discussion in this research work has been divided into the five (5) main sections dependent the views of the field findings to be factored into the future design of the Proposed Electric Vehicle (EV).

4.1. Respondents' Perceived Choice of Brand and Brand Used

In the brand of vehicles currently used by the respondents in the market, it was found that 17% used KIA whiles a little over 13% were found to be using Toyota and Nissan vehicles in the market It was observed that about 23% and 24% of KIA and Toyota respectively were perceived as the best brand of vehicle for commercial use whiles 1.2% each of Hyundai and Mazda were perceived as best choice of brand.

4.2. Respondents' Reasons for Preferred Brand Choice and Current Brand

About 21% and said their preferred choices are comfortable whiles 25% said their preferred choices are strong shown in figure 5 (a). That is both the engine and the body of the vehicle are strong and rugged. Of their reasons for current choice of vehicle in use, a little above 20% stated that their reason is based on the strength of the car whiles about 14% stated comfortability as their reason for current use of brand vehicle as shown in figure 5 (b).

4.3. Willingness to Use EV

It was observed that about 76% of the respondents said they were willing to use an EV if they are available in the Ghanaian market whilst 24% said they will not use and EV.

4.4. Reasons for Willing to Use EV

In all six main reasons were given. It was noticed that about 33% of the respondents said their reason for willing to use EV was to save cost, 25% stated for comfort, 18% were also will for the purposes of no fuel use and 13% for EV will be least expensive as shown in figure 7.

In the same context of respondents EV willingness, about 4% were for the reason of wanting to use one, with about 6% for purpose of pollution reduction and about 3% of the respondents willing to use the EV because it will take-away all fuel difficulties

4.5. Expectations of Respondents' to the EV

It was observed that about nine major recommendations were given. About 19% of the respondents said the EV should be of god comfortability, about 17% of the respondents recommended good electrical system for the EV and about 10 expecting the EV would be affordable. From the recommendations of the development of the EV, about 12% respondents suggested there should be availability of part, with about 10% stating the EV should have good steer control and about 8% of the respondents recommending hard body and less-breakdown respectively. Furthermore, about 7%the respondents said they would like to have an EV with better speed and good gear box as presented in figure 8.

5. Summary of the Proposed EV Deduce from Technological Acceptance Model (TAM)

With the increasing use of automobile drives in the world, the search for better, efficient and environmentally friendly technology will surely be the solution to the problem associated with combustion engines. The advantages and benefits with the use of EV from TAM survey are summarized in figure 9.

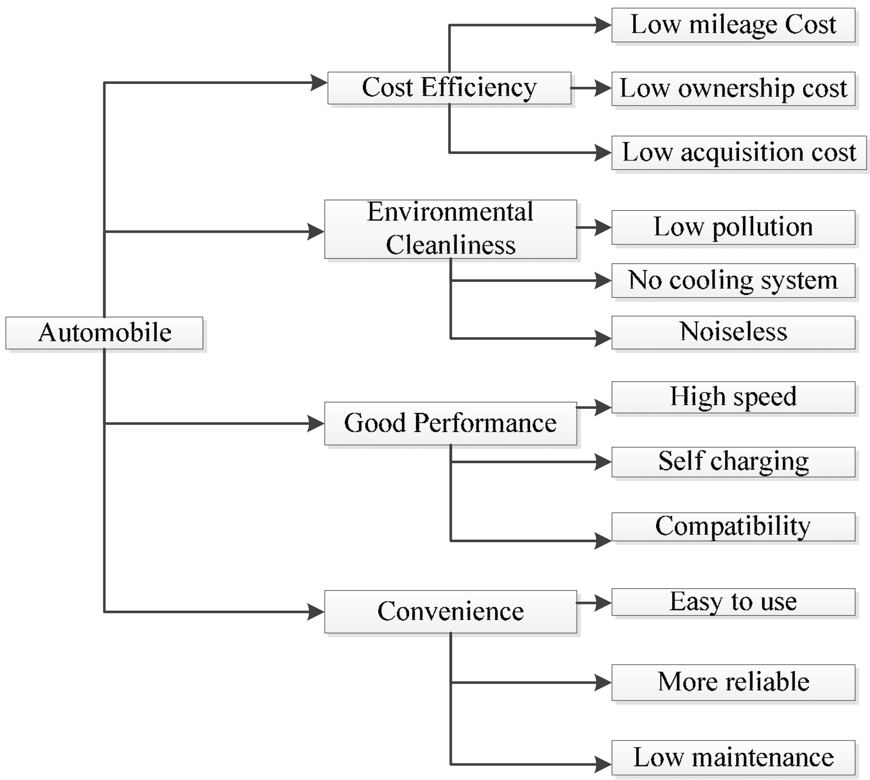


Figure 9. *Automobile magnetic drive characteristics preview.*

Field Technology Application

According to this research design, the technology can be used in all places with its target as an automobile drive. The application is broken down into three main fields which include:

a Long journey drive.
b Town drives for both public and private sectors.
c Electrical power generation.

Future Studies

The expected future studies will be bow to implement the proposed design from the Technological Acceptance point (TAM). Therefore there will be a look at how the system composition can be identified and put into experimental setup.

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Biography

Mamudu Hamidu is currently a PhD Engineering Candidate at Accra Institute of technology/Open University of Malaysia (AIT/OUM). He is working on vehicle tracking and reporting system using combined wireless technology as an area of research. He holds Master’s degree in Information Systems from University of Coventry, UK and a Bachelors of Engineering Degree (BEng) in Electrical/Electronic Engineering from Accra Institute of technology (AIT), Ghana. He is a lecturer and researcher at the Electrical/Electronic Engineering Department of Kumasi Technical University (formerly Kumasi Polytechnic), Ghana.