

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

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Abstract

Electric vehicles (EVs) have been around since 1834. However, they have not been put into commercial use as against combustion engines. That notwithstanding, there are tremendous positive roles awaiting them in the future given the current trend of advancing electrical systems across the world. This 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. From the information systems theory models, users come to accept and use a technology by considering; Perceived usefulness (PU) and Perceived ease-of-use (PEOU). In this 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 an EV. There was also textual analysis of the existing EV in order to develop a proposed EV which will avoid the major challenges associated with the old system.

Keywords: *Technology Acceptance Model (TAM), Electric Vehicle (EV), Automobile, Proposed EV, engine comparison, Operating cost analysis.*

Introduction

Electronic Vehicles (EVs) have been around since 1834 (Leitman and Brant, 2009). However, they have not been put into commercial. This notwithstanding, there are tremendous positive roles awaiting them in the future with the current trend of advancing electrical systems across the world. For instance, there has been a shift of most railway systems from internal combustion engine to electrical ones. This has help achieve high levels of speed and dynamism making transportation quite easier. Electric Vehicles (EVs) should be 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 in many countries. Annual sales of light-duty plug-in electric vehicles in the world's top markets between 2011 and 2015 are shown in Figure 1A in the Appendix.

In five years, global sales of highway legal light-duty plug-in electric vehicles have increased more than ten-fold, totaling more than 565.00 units in 2015. Plug-in sales in 2015 increased about 80% from 2014 figures, driven mainly by China and Europe (*Argonne National Laboratory, 2016*). In 2015, both markets surpassed 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 (*Cobb, J. , 2015; 201¹*). Between 2011 and 2015 cumulative global sales totaled about 1.27 million plug-in cars and utility vans (*Argonne National Laboratory, 2016*)².

Aside the advancement in the EV field, its usage is limited in globally. However, this research explores the Technological acceptance Model (TAM) to come out with a proposed EV that will eliminate the existing EV challenges. The next section discusses the various dimensions of the proposed EV as supposed to the existing automobiles.

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. These include;

- 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”.
- 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” (Davis 1989).

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 relative advantages and the benefits over its counterparts.

Table 1: Comparison of existing EV to Proposed EV and Internal combustion

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)

¹A 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.

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 will be from batteries; maximum of three)	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 when developed will eliminate most of the challenges faced by the existing EV and the internal combustion engines. 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 to 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.

The Research Gap

The study has identified some challenges associated with both the existing EVs and the internal combustion engine. According to Kylander et al. (2003) and Lustig et al. (1999) internal combustion engines emit substances that are detrimental to the health of the environment. Therefore, internal combustion technology is in contravention with ongoing efforts in the world to 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. The main limitations facing the existing EV technology have been discussed under sections 1.3.1 to 1.3.3

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 than three batteries to power it.

Battery Charging

The issue of the range of distance covered is one of the key limiting factors of electric vehicles. For instance, for most existing EVs the distance travelled before recharging is about 40 miles. However, it is obvious that drivers are not enthused by having to stop to recharge their batteries during periods of cruising after the power battery has run out or before they have travelled the maximum distance. Even though, a number of different technologies have emerged to resolve this challenge, the challenge still persists. Some of the proposed approaches to dealing with this challenge are: 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.

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.

Lifetime Performance

Each charging and a discharging cycle is a complete life in a battery's lifespan. 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 while 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. The proposed EV does not depend on batteries for its continuous operation.

Why the proposed Electric Vehicle (EV)

The research gap/challenges identified with the existing EVs have been addressed by the proposed designed EV. This proposed EV takes into consideration 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, 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.

Economical (Operating cost analysis)

The existing electric vehicles only consume 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

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

This does not include charging cost and for battery replacement. Comparing the existing EV to the gasoline powered internal engine, which consumes gasoline, ignition, cooling, fueling and exhaust systems requires filters, fluids and periodic maintenance.

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

$$0.05 \text{ liter / mile} * \text{GH¢}2.749/\text{liter} = 13.745 \text{ pesewas) / mile}$$

Consumables and periodic maintenance must still be added.

Assuming a cost of GH¢48.4 per month for oil change average over three month, fuel additives ligning and balancing tires and considering an annual mileage of 12000 miles per year this becomes:

$$\text{GH¢}48.4 * 12 \text{ month} \left(\frac{580.8}{\text{year}} \right) \div \frac{12000 \text{ miles}}{\text{year}} = \frac{4.84 \text{ pesewas}}{\text{mile}} \quad \text{Adding the two make it}$$

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.

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

Automobile are very important to the socio-economic development of the country. The proposed automobile drive will help solve the immense hardship of the problems are associated with the old models. This technology when developed will provide low maintenance cost, no fuel use, and low cost of transportation.

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 (DVLA, 2010), the construction of the EV is a visible proof of our commitment to the maintenance of a green and healthy environment.

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. The proposed technology will be able to overcome the charging challenge completely through the continuous internal charging system to be developed.

Materials And Methods

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; long journey drive, town drives for both public and private sectors, and electrical power generation.

In order to explore the various vehicle technology and the factors affecting the automobile industry in Ghana, the research also looks at the players in the market. It assesses how the EV will influence the industry and makes recommendation to help the researchers come out with a well-fitting and acceptable technology for the Ghanaian vehicle users. In view of this, various transport stations were contacted where the mechanics, drivers and mates were engaged. The route for the research data collection is show in Figure 3A in the Appendix..

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

Data collection Method

The research used 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 a sample of the research schedule used for data collection.

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

Findings

EV technology acceptability studio

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

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% of the respondents had up to JHS level of formal education with about 2.4% been about 60 years or older as shown in Figure A4 of the Appendix.

Profile of Respondents

Of the respondents studied, it was clear that 44% do not belong to any known company. Also, about 22% belonged to VIP while only 1.4% each of the respondents belonged to the Ford Company, Cool family, and Ghana Express. In the same vein, about 59% of the respondents belonged to the GPRTU as a union while only about 5% belonged to the Ford union as shown in Figure A4.

Respondents' reasons for preferred brand choice and current brand

The respondents adduced some reasons for the preferred choice of vehicle. Figure lists the reason of current brand in use.

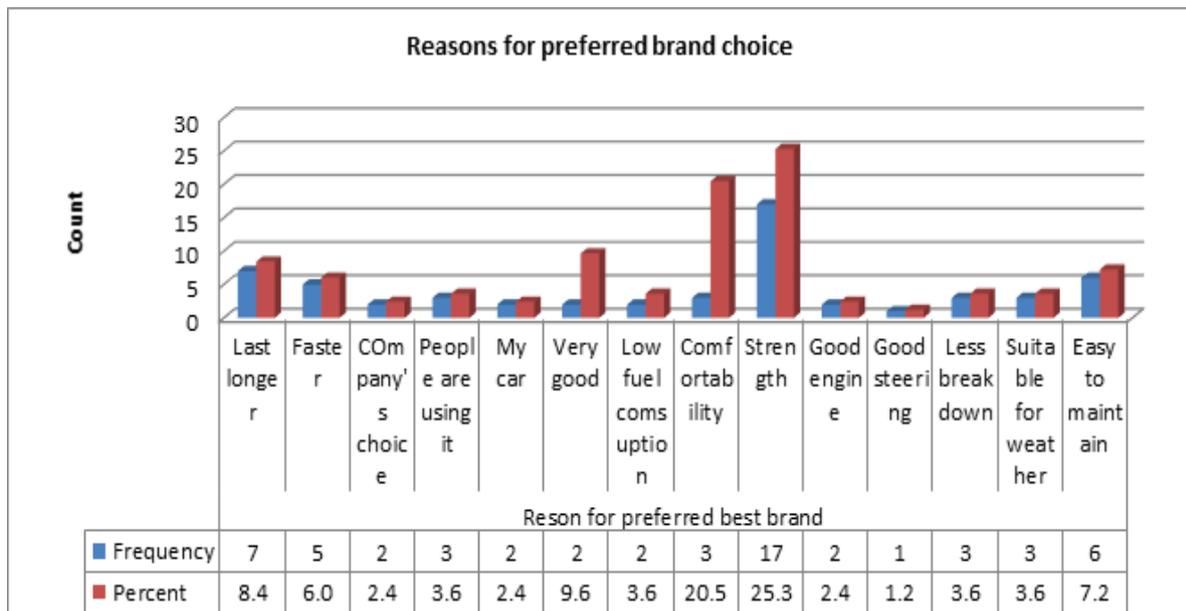


Figure 1: Reasons for preferred brand choice

Respondents' perceived choice of brand and brand used

The study also sought to understand the respondents perceived brand choice and brand been used. Figure 2 shows the results from the respondents.

Willingness to use EV

The study assessed the willingness of the respondents to use Electric Vehicle. The results are shown on Figure 3

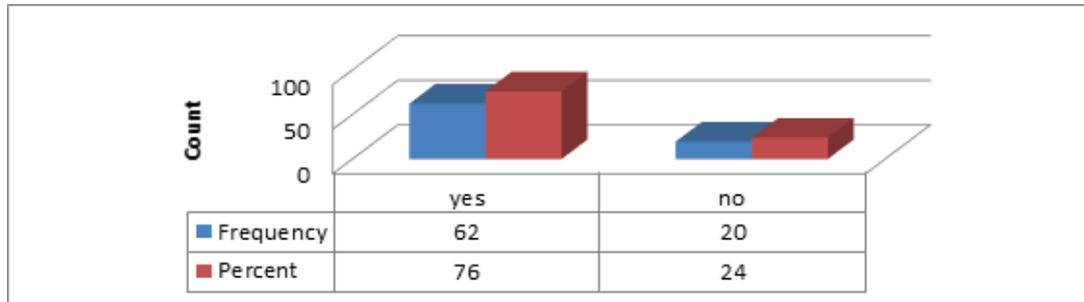


Figure 3: Willingness to use EV

Reasons for willing to use EV

The study further assessed the reason for respondent’s willingness to use the Proposed ER. The outcome is shown on Figure 4.

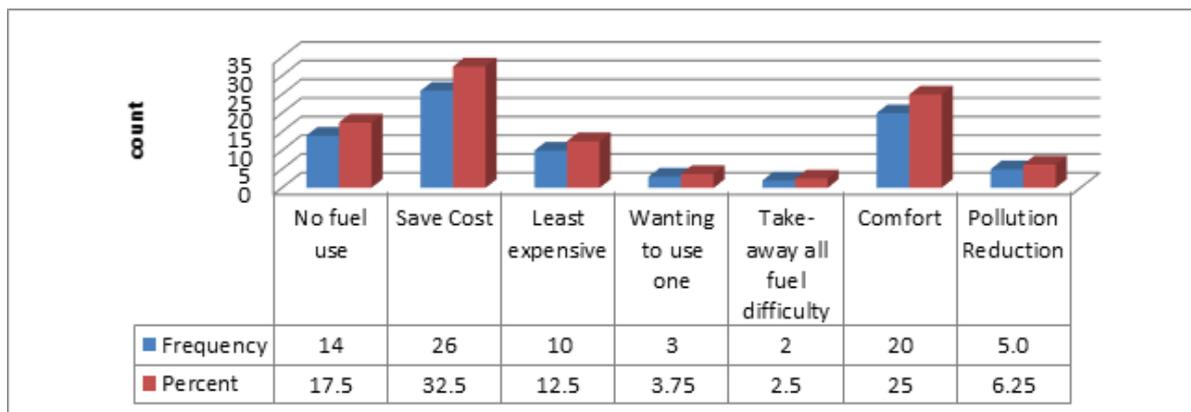


Figure 4: Reasons for wanting to use EV

Expectations of respondents’ to the EV

The study also assessed some recommendations given by the respondents regarding what they expect to see from the Electric Vehicle. The results are shown on Figure 5 below.

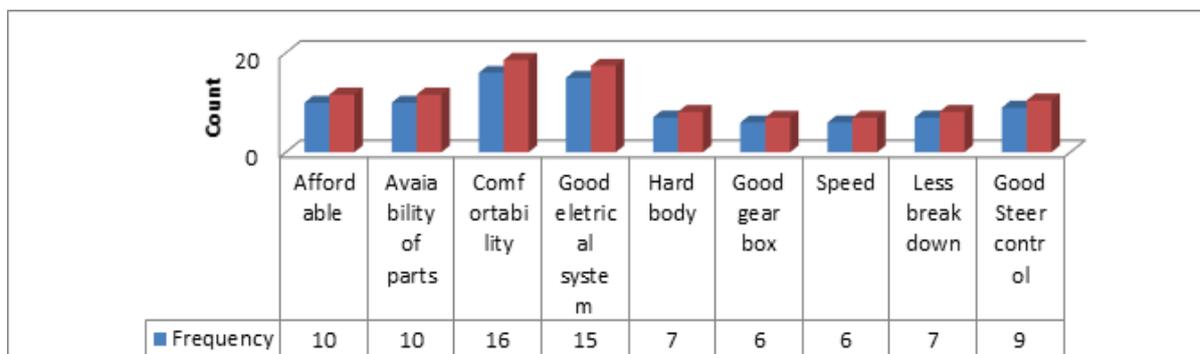


Figure 5: Recommendations from the respondent on the EV.

Discussions

Respondents' perceived choice of brand and brand used

Regarding the brand of vehicles currently available on the market, it was found that 17% of the respondents used KIA while a little over 13% were found to be using Toyota and Nissan vehicles (see Figure 1). 23% of the respondents perceived KIA as the best commercial vehicle while 24% perceived Toyota as the best commercial vehicle. 1.2% of respondents considered Hyundai as the best brand while another 1.2% held Mazda as best choice of brand.

Respondents' Reasons for preferred brand choice and current brand

About 21% of respondents said their preferred choice is comfortable while 25% said their preferred choice is strong (see Figure 2). Strength in this case referred to the body and engine of the vehicle. Regarding the reasons for current choice of vehicle in use, a little above 20% stated that their reason is based on the strength of the car while about 14% stated comfort as the reason for current choice of brand vehicle.

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 while 24% said they will not use an EV.

Reasons for willing to use EV

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% will use EV because it does not require a fuel and 13% will use it because it is not expensive (see Figure 7). Further, about 6% said they will use it because it does not pollute the environment while about 3% of the respondents were willing to use the EV because it will take-away all difficulties associated with acquiring fuel for use.

Expectations of respondents' to the EV

About 19% of the respondents said the EV should be comfortable to use, about 17% of the respondents recommended good electrical system for the EV and about 10% expect that the EV would be affordable. Again, about 12% respondents suggested that there should be availability of spare parts, with about 10% stating the EV should have good steer control and about 8% of the respondents recommending that it should have a hard body and not breakdown often. Furthermore, about 7% the respondents said they would like to have an EV with better speed and a good gear box.

Summary survey results

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 the TAM survey are summarized in Figure A6 of the Appendix.

Field technology application

The technology of the EV is applicable to other areas of industry, however its target is as an automobile drive. The application is broken down into three main fields which namely, long journey drive, town drives for both public and private sectors, and electrical power generation.

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Appendix

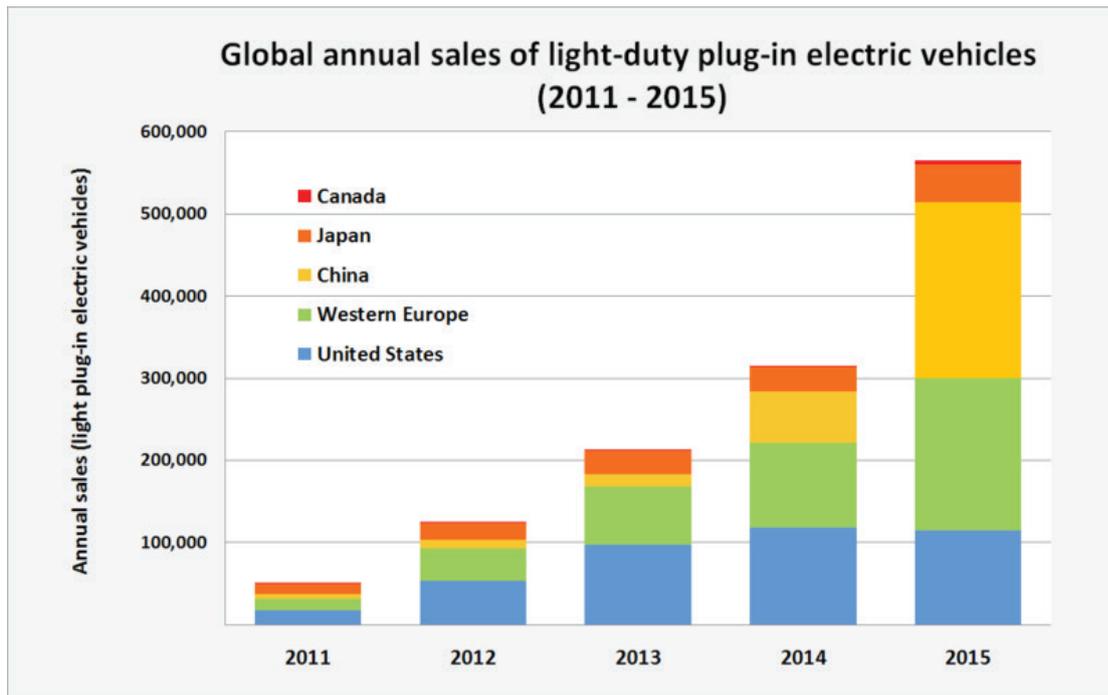


Figure 1A. Global annual sale of EV between 2011 and 2015, source: Argonne National Laboratory, United States Department of Energy (2016)

Table A2. Non-Residential Tariff

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 (ECG, 2015)

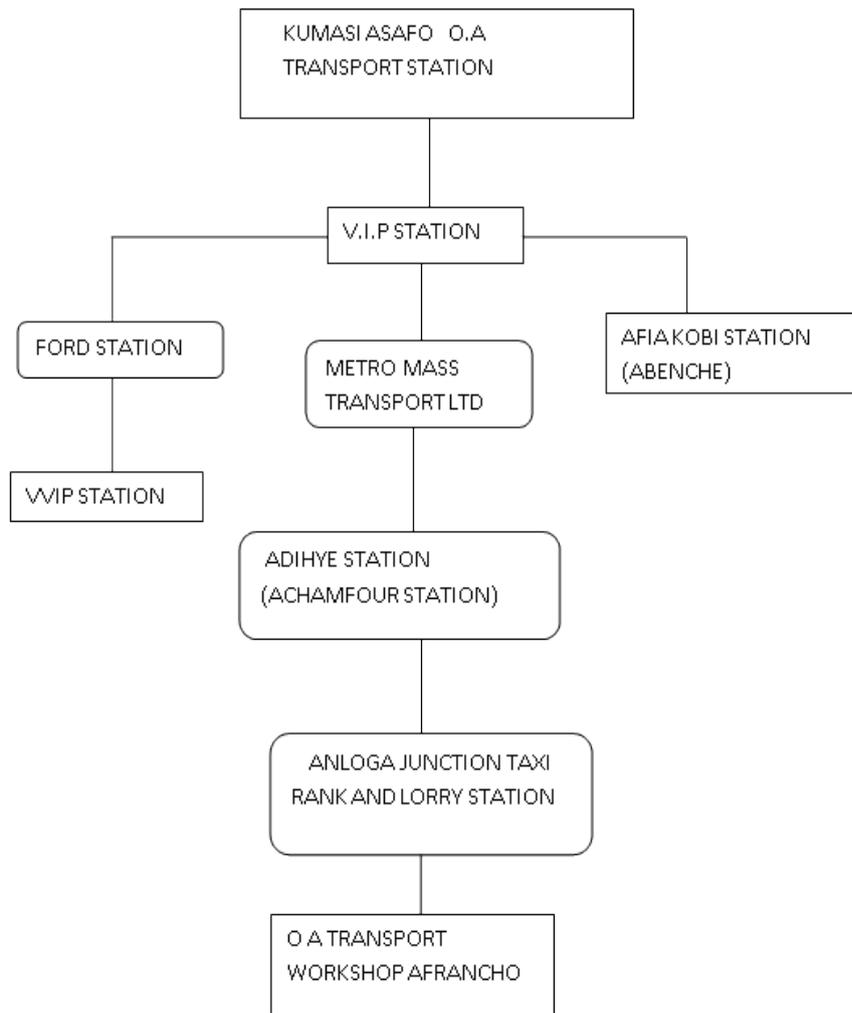


Figure A3. Research data collection zones and their allocations

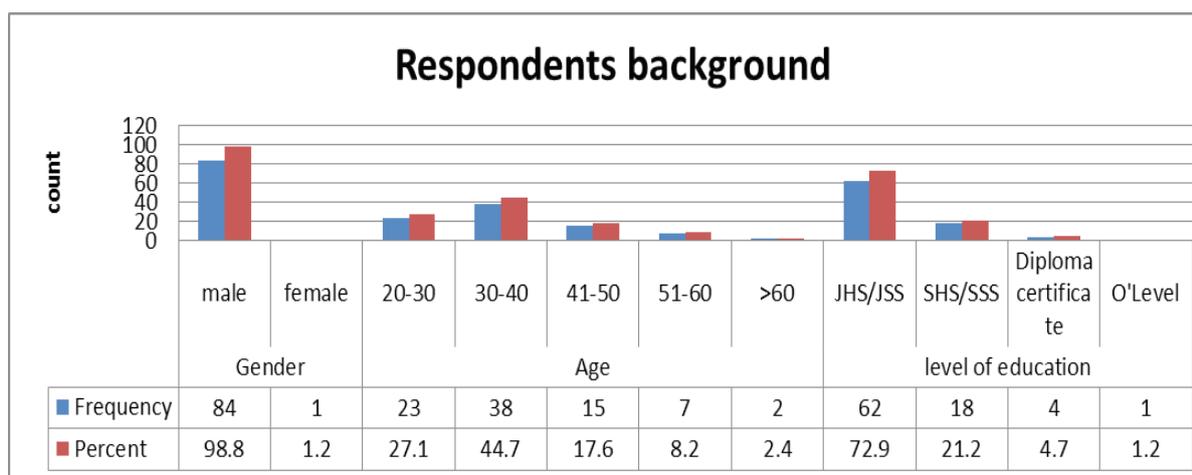


Figure A4. Background characteristics of respondents

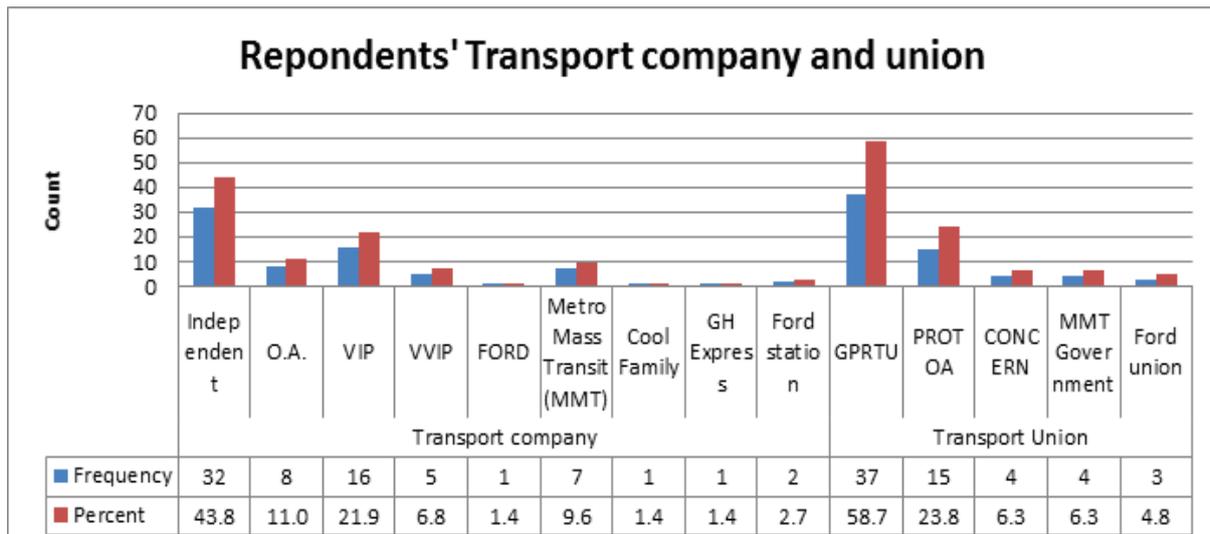


Figure 5A. Background characteristics of respondents

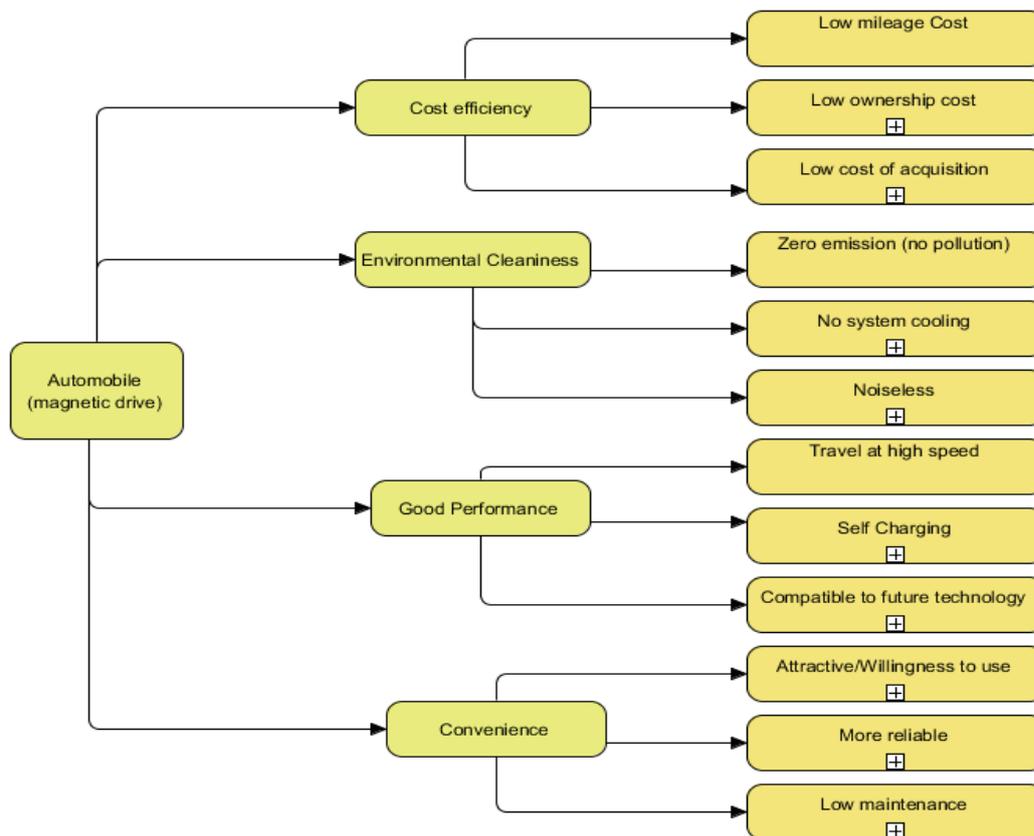


Figure 6A. Automobile magnetic drive characteristics preview.