CHAPTER 1

SCOPE FOR HYBRID ELECTRIC VEHICLES IN INDIA

Urbanization has caused many affects on public life. Presently, the daily activities are mainly dependent on vehicles. So the density of vehicles in city areas is increasing day by day. Mainly, many of these vehicles are all dependent on non-renewable energy resources like petrol and diesel. These resources are extinguishing day by day and may not last long. People are also taking war in certain countries because of oil crisis with political instability. With all these factors, it’s seen that the prices of oil going high day by day making the common man’s life unbearable.

Design and development of automobile was not carried in a single day. With several hands in picture, the present automobiles are on roads. As vehicles have become the phantom in human life, its design, development and existence plays a major role in present generation.

Since the invention of wheel in ancient age, the development of automotives is one of its boons to mankind. Throughout the generations, different vehicular architectures were designed with several propulsion techniques, with efficient utilization for several applications. Categorization includes steam engines, internal combustion engines and electric vehicles.

1.1 STEAM ENGINES

Steam engines are external combustion engines with a history of 2000 years. Rankine cycle is the principle behind steam engine operations. Coal was used majorly as fuel source. The fuel is burnt and the heat energy liberated is being used for carrying thermodynamic process, in which the means like water is converted into steam and made to pass through pistons in carrying out mechanical work. It requires huge boilers to carry out this process of propulsion. Initial generation of steam takes much time and construction of boiler is voluminous with heavy load on board. The pressure generation and steam generation made these steam engines to be applicable
only for heavy locomotives rather than small vehicles. Figure 1.1 shows steam engine locomotive which was on rails until 1988 preserved in German Railway museum [48].

![Steam Engine Locomotive](image)

Figure 1.1: Photo of steam engine which was on rails until 1988

1.2 INTERNAL COMBUSTION ENGINES

As the external combustion engine was not much portable in utilization, internal combustion engines (ICE) were developed to overcome the drawbacks of external combustion engines. The internal combustion engine is a type of engine where the fossil fuels like petrol or diesel is burnt mixing with air in a closed environment. The heat energy in burnt gases after expansion propels the vehicle by getting converted into mechanical energy. Compactness and light weight makes the internal combustion engine more durable, getting used in smaller vehicles. Instant starting of the vehicle, less noise, nominal vibrations, easy handling makes the internal combustion engine vehicles more reliable in today’s world. Figure 1.2 and Figure 1.3 shows the Internal Combustion Engine and ICE operated four-wheeler vehicle [3].
Because of maximum speed and torque offered by internal combustion engine, its design, development and application made them the unbeatable god in automobile sector providing the propulsion for majority of the vehicles on roads presently in world.

As the applications of internal combustion engine vehicles increased day by day, its density in urban areas is causing environment pollution because of toxic emissions. The fuel consumption is also increasing day by day depending on the utilization of ICE vehicles for relevant needs by the people.

Reduction in fuel consumption and toxic gas emission becomes the major challenge in design and development of present internal combustion engine operated conventional vehicles. The new variants ICE designs are making any personnel to get attracted into it because of its reliability and its trustworthy characteristics. The non-
renewable energy resources utilized by ICE are extinguishing day by day and may not last long for our future generation. Since this ICE vehicle usage cannot be minimized presently, an alternative propulsion source technique or supportive propulsion technique is required for reducing the fuel consumption of the vehicle.

Hydrocarbons, Nitrogen Oxides and Carbon Monoxide are the exhaust pollutants emitted by internal combustion engines when the fuel petrol or diesel is burnt. These pollutants cause several diseases like heart problem, blood pressure, irritations in any part of the body, lungs disorders and many more. These pollutants will also affect the animal species habitats. As every organism is interconnected with one another directly or indirectly, the effect on one will surely makes an impact on another. The environmental pollution caused by ICE vehicles like acid rains, ozone layer depletion, air and noise pollutions will affect the habitat not to live life peacefully.

With energy conservation and environmental concern, world should look towards the electric vehicles (EV) and hybrid electric vehicles (HEV) in future. Also several optimization methodologies have to be followed by several manufacturers designing fuel efficient environmental friendly vehicles not leaving these reliable internal combustion engines. As the sales of internal combustion engine vehicles are growing at a higher rate, “By 2020 annual demand for cars and light trucks will reach 103 million units. Of these, only 3 million will be either all-electric vehicles or plug-in hybrids. A further 6 million will be hybrid vehicles with an electric drive in addition to their internal-combustion engine. In other words, a good 100 million new vehicles powered by internal-combustion engines will be sold in 2020” [49]. But as the natural resources like petrol and diesel are consumed day by day, by 2020 it will have limited supply worldwide.

1.3 ELECTRIC VEHICLE

Any vehicle with electric propulsion can be branded as electric vehicle. As electric motors are the major element in providing vehicle propulsion, depending on the energy source utilized in driving this electric motor, the classification involves,
battery operated electric vehicles (BEV) and fuel cell operated electric vehicles (FLEV).

Earlier in the eighteenth century, at first these electric propulsions were meant only for large locomotive movements. Because of high torque establishment by these motors and smooth speed controlling mechanisms, its applications were categorized on high tractive power requirements. A patent was issued in mid 18\textsuperscript{th} century for propelling the locomotives on rails with current through it in England [43].

With the relevant application of electric motors on small passenger vehicles in the mid of eighteenth century, its applications were made available for public as electric cars for transportation. These electric cars became the competitors for ICE driven vehicles in the aspects of environmental friendly issues like zero-emissions, less noise, easy driving and smooth operation with lesser vibrations.

With the wide application and distribution of electricity in nineteenth century, invention of rechargeable batteries found the application with electric motors in electric vehicles. People found themselves more comfortable in riding these electric cars within the city by charging their batteries when required. But, the same people preferred ICE operated vehicles over electric vehicles when it came to long distance transportations.

Many innovations occurred in improving the technology of electric vehicle which was in high demand at that time. For example, Ferdinand Porsche, founder of the sports car company by the same name, developed an electric car called the PI in 1898. Thomas Edison, one of the world’s most known inventors, thought electric vehicles were the superior technology and worked to build a better electric vehicle battery. Even Henry Ford, who was friends with Edison, partnered with Edison to explore options for a low-cost electric car in 1914 [58].

As of the increasing prices of the oil in the timeline, in order to avoid the dependency of a country on other for oil resources, countries like US managed to carry out the advancements in the electric vehicle and hybrid electric vehicle giving more scope for its research also taking up the invention towards alternate fuels. In the
same time, many automakers began designing and developing alternative fuel vehicles, including electric cars. For example, a prototype was developed by General Motors for an urban electric car that it displayed at the Environmental Protection Agency’s First Symposium on Low Pollution Power Systems Development in 1973, electric delivery jeeps was produced by American Motor Company in United States Postal Service used in a 1975 test program. Even NASA helped to increase the profile level of the electric vehicle when its electric lunar rover became the first manned vehicle to drive on the moon in 1971 [20].

Even with much advancement in timeline of electric vehicles, they have shown failure against ICE driven vehicles. Its restricted top speed, less distance coverage per charge of batteries became the major parameters of failure in attracting the people towards it.

Presently with environmental concern, go green concepts were introduced for re-design, development and application of electric vehicles with major research on batteries, power electronic devices and electric motor applications by framing regional regulations by many countries. As of cost issues, these branded green electric vehicles failed to compete again with ICE driven vehicles.

Many ICE automobile manufacturers like TESLA, NISSAN, CHEVROLET, BMW, and HONDA invested a lot in design and development of electric vehicle, more efficient in minimizing the previous drawbacks of higher cost, less drive per charge and less top speed.

The failure of electric vehicles in the time line will not make it completely non-applicable. Giving some examples, Leaf by Nissan, Chevy Volt by Tesla, Prius by Toyota and many more are electric vehicles manufactured by some countries this date. The electric vehicle sales guide for the year 2014 from different manufacturers is presented in Figure 1.4 [27].
1.3.1 BATTERY CONSTRAINTS IN ELECTRIC VEHICLES

The energy source for these electric vehicles, batteries, were more taken into consideration throughout for research activities. So that improvement in energy source might increase the value of electric vehicles with respect to more drive per charge. Some of the batteries which found the application in electric vehicles involve

- Lithium ion batteries
- Nickel Hydride batteries
- Zebra batteries
- Lead Acid batteries

The Lead-acid batteries are chemical batteries including hydrogen and sulphur. These batteries found more applications in automotive sectors as rechargeable batteries lasted with about three to four years of life time. Figure 1.5 shows the Lead-Acid batteries available presently in market.
Nickel hydride batteries are pretty old batteries, treated to be efficient against lead acid batteries. These batteries are issued with fast charging and slow charging status managements in its applications. Figure 1.6 shows the usage of Nickel-iron batteries against Lead-Acid batteries for Ford. Figure 1.7 shows the present Nickel-iron batteries available in the market.

Figure 1.6: Henry Ford advertised Nickel iron battery against lead acid in his trials

Figure 1.7: Nickel Hydride battery
Zebra batteries failed in holding the charge for much longer time. Zebra batteries contain molten sodium as electrolyte in its operation. Because of its poor charging and charge with-hold issues, these batteries found non-applicable. Figure 1.8 shows the present Zebra battery packs available in the market.

![Zebra battery pack](image)

Figure 1.8 : Zebra battery pack

Lithium ion batteries are the costliest batteries available with ninety percent efficiency in its charging and discharging issues. These batteries also found application in mobile phones, laptops and other portable electronic applications. With Cobalt oxide as cathode and graphite as anode, these batteries lasts for four plus years. Phosphate variant batteries will give service for 10 plus years, but too costly to invest on. Figure 1.9 shows the present Lithium-ion battery available in the market.

![Lithium-ion battery](image)

Figure 1.9: Lithium-ion battery
1.3.2 CHARGING CONSTRAINTS OF BATTERIES IN ELECTRIC VEHICLES

Full charging time of batteries depend on type of battery being used in the electric vehicle. An average of five hours is required even today for charging lead acid battery fully.

Giving examples, the charging of electric vehicles are done in domestic service areas like house and office. The AC supply type provided will be converted to relevant DC supply type for charging purpose. Also DC supply stations are established in countries like United States and United Kingdom for reducing the charging time of batteries. Figure 1.10 shows the charging of electric vehicle through charging stations.

![Figure 1.10: Electric vehicle being charged in charging stations](image)

General opinion given on electric vehicles feels that, the usage of charging time by it is more which makes them non-convenient in usage. They have to charge the batteries overnight, office time, whenever they want to roam within the city limits. If the battery gets depleted fast, then the vehicle will become non-usable. So the consumers of electric vehicles have to be foresighted in charging the batteries for using the electric vehicle when required.

1.4 HYBRID ELECTRIC VEHICLES

HEV is a combinational vehicle from both internal combustion engine propulsion system and electric motor propulsion system. These types of vehicles are
built to overcome the drawbacks of only electric motor propelled vehicles and for fuel economy or for better performance in only ICE driven vehicles.

In 1901 Ferdinando Porche built Lonher porche mixte hybrid, which was the first HEV. Then the Toyota Prius was released in Japan in the year 1997 which became the first mass produce HEV in the world. Toyota utilized Nickel-Hydride battery for driving the electric motors [55].

![Figure 1.11: Toyota Prius](image1)

Regenerative braking methodology is implemented in charging of batteries converting the mechanical braking losses into electrical energy. Development of plug-in hybrid electric vehicles (PHEV), made them to operate also in ICE and also to get charged from charging outlets to propel with electric motor. Figure 1.12 shows the Chevrolet Volt, PHEV developed by Chevrolet in 2011.

![Figure 1.12: Chevrolet Volt](image2)
With the advancements in hybrid electric vehicle sector, Toyota has made milestone in selling seven million units of its HEV Prius since first unit was bought by a Japanese driver in 1997 [31]. Figure 1.11 shows the Toyota Prius car manufactured by Toyota.

Usage of hybrid electric vehicles not only reduces the air pollution in the environment, also helps in conservation of natural resources. As the combination of ICE and electric motor propels the whole vehicle, the efficiency towards better performance and fuel conservation can be achieved by optimizing the ICE usage in the drive time. The stated drawbacks of electrical vehicles can also be overcome

- Instant charging
- Reduced top speed
- Much distance coverage per charge
- Inconvenience and non-reliable
- Foresightedness
- Battery depletion issues

Also these HEVs can be driven in only ICE mode, only electric motor mode and combination of both ICE and electric motor mode which gives an ample of options for the consumer in this regard.

Also the HEVs are more costly compared to EVs or ICEs. Reducing the weight of the vehicle is still a challenge for the automakers in this regard. It only reduces the rate at which fuel burning takes place in ICE as of additional propulsion or supportive propulsion given by electric motor. Designing of powertrain creates more constraints in synchronizing ICE and electric motor for efficient propulsion of the vehicle.

1.5 MARKET OF ICE VEHICLES

The Indian market of automobiles majorly involves internal combustion engine propelled vehicles over electric vehicles which are divided into following sectors.
Two wheeler vehicles categorized as gear and gearless vehicles. These vehicles are propelled by internal combustion engine using petrol as main fuel. Normally motor cycles will lie under geared type of two wheeler vehicles whereas mopeds and scooters will lie under gearless type of two-wheeler vehicles. These types of vehicles can carry two people for small or medium distances. Figure 1.13 and Figure 1.14 shows some Gear and Gearless two-wheeler vehicles on-road in our country presently.

![Figure 1.13: Geared motorcycle](image1)
![Figure 1.14: Gearless scooter](image2)

Three wheeler vehicles categorized as passenger vehicles and goods carrying vehicles. These types of vehicles are geared type of vehicles with internal combustion engine for propulsion using petrol or diesel as main fuel. These types of vehicles are most suited for carrying five persons termed as commercially hired vehicles with certain materials to be transported for small or medium distances. Figure 1.15 and Figure 1.16 are some examples of three-wheeler vehicles on-road in our country presently.

![Figure 1.15: Passenger carrier three wheeler](image3)
![Figure 1.16: Goods carrier three wheeler](image4)
Four wheeler vehicles categorized as passenger vehicles and utility vehicles. These vehicles are manufactured in both geared and gearless variants. Passenger vehicles are commercial vehicles to be hired for transportation which involves cabs, cars, mini-bus. Utility vehicles involve goods carriers and mini trucks. All these vehicles are propelled by internal combustion engine with petrol or diesel as main fuel. These types of vehicles can carry five to fourteen persons depending on its utility suitably for medium or long distances. Figure 1.17 and Figure 1.18 are some examples of four-wheeler vehicles on-road in our country presently.

![Passenger car](image1.png)  ![Passenger utility vehicle](image2.png)

Figure 1.17: Passenger car  Figure 1.18: Passenger utility vehicle

Heavy vehicles are geared vehicles with very higher rated internal combustion engines used to serve as passenger vehicles also as goods carrying vehicles. Passenger carrying vehicles like buses are commercial heavy vehicles which can carry 40 to 60 persons through long distances. Goods carrying trucks are commercial and can carry goods in tones through long distances. Figure 1.19 and Figure 1.20 are some examples of Heavy motor vehicles on-road in our country presently.

![Passenger bus](image3.png)  ![Truck](image4.png)

Figure 1.19: Passenger bus  Figure 1.20: Truck
In the above categorization four-wheeler vehicles are more technically concentrated against three-wheelers and two-wheeler vehicles. But two-wheeler vehicles are more market concentrated in our country. Profitability in automobile sector depends on brand, services offered, cost and trustworthy attributes. Market leaders are those who are high in these attributes.

In the financial year 2014, 16.9 million two wheeler vehicles were sold with a growth of 4 percent in motorcycles and growth of 22 percent in mopeds and scooters compared to previous financial year whereas three wheeler vehicles dropped by 11 percent. There was a tough competition and industrial freight between the manufacturers in commercial and heavy vehicles segment which badly dropped by 20 percent. Increase in fuel prices, less interest rates, more import taxes these declining in sales volume can be found. It’s been expected about 7 percent to 10 percent rise in sales volume for the next financial year as fuel prices are being reduced by 10 percent since few months [21].

Demand in automobiles is related to economic growth of the country. In India vehicle percapita is 41 (among 1000) as of 2011. The number of registered vehicles in millions was released by Indian department of statistics and program implementation as shown in the Figure 1.21, number of motor vehicles registered versus year. It’s being analyzed from 1951 to 2011 for the growth rate in registered vehicles in the country. As stated, as of march 31st 2011, Delhi had the largest number of registered motor vehicles followed by Bangalore, Chennai, Hyderabad and Pune [25].
1.6 ELECTRIC VEHICLE MARKET IN INDIA

Against the internal combustion engine vehicles the electric vehicles market is less rated in India because of its service lags and of high cost issues. About 4000 cars have been sold in a decade and about 30000 cars of Mahindra Reva, pure electric can be sold [19]. The daily usage of vehicles by the people made this electric vehicle a failure. It’s more charging time, less speed per charge and less top speed made the consumers to avoid the electric vehicles in our country. Also the power crisis in our country is also one of the major reasons which make these chargeable electric vehicles non-usable.

There are many two-wheeler electric manufacturers in India like Hero, Ampere, Green Electric and Eco vehicle. There is no competition in four wheel electric vehicle as only the REVA is being produced by REVA Electric Car Company Pvt. Ltd. The latest variant of the car is the REVA-i model which was initially intended to be exclusive to the Indian market but is now distributed in UK, Greece,
Cyprus, Norway, Iceland, Spain and Germany. Figure 1.22 and Figure 1.23 are some examples of two-wheeler electric vehicles on-road in our country presently.

![Ampere V60 Electric two wheeler](image1)

![Hero Optima Electric two wheeler](image2)

Other announcements made in the field of EVs in India, according to EAI [18]

- E4 - Mahindra and Mahindra’s four seat model (this was initially slated to be released by 2010, but yet it’s not on roads.
- Oreva Super - Clockmaker, Ajanta Group plans to release a low cost electric vehicle.
- TATA group announced that it has started development on an EV in late 2009.
- Hero Electric – an electric car slated to be released in 2013.
- Tara Tiny – developed by Tara International as a competitor to the TATA NANO, is priced at about $2450.

![Reva](image3)

![Reva-i](image4)
The REVA was produced by REVA Electric Company from 2001 to 2007. It was powered by 400Amp motor controller to a DC motor rated at 4.8KW. Eight lead acid batteries were used each of 6V, 200Ah in 2008, a new variant of REVA was introduced named as REVA-i. It uses AC drive system with a maximum output of 80Km/h where REVA was limited to 40km/h. It uses 350Amp, 3-phase AC motor with eight 6V lead acid batteries. Each battery is of 200Ah. REVA in India was sold about 4600 models till 2013. REVA-I variant was released in 2009 with Li-ion batteries onboard. It was claimed by the maker a rate of 40Paise/Km in India with this new variant [41].

1.7 STUDIES ON CONSUMER BUYING BEHAVIOUR TOWARDS ELECTRIC TWO–WHEELER

In India major vehicles on the roads are two-wheeler vehicles. Compared to four- wheeler vehicles, presently two-wheeler vehicles are more reliable in saving time, ICE powered and fuel efficient with petrol as fuel. But two-wheeler vehicles are limited for two persons traveling according to motor rule in India. With the present traffic situation much people prefer two-wheelers to travel depending on their needs compared to four wheeler vehicles. Four wheeler vehicles are preferred occasionally to travel into ceremonies, marriage and long distances, where whole family of an average of four people can comfortably travel. Buyer behavior relies on psychological, physical, social behaviors of potential customers as they become aware of evaluate, purchase and tell others about the product and its service. Consumer buying decision process comes into action with the following stages

- Problem Identification: This process starts when the buyer identifies the need for the product and the service it provides. This is triggered by the environment, the circumstances of the customer. These frequent stimuli have to be identified that spark the interest in the product category.

In India generally any major city comprises of more middle class families. These families are salaried, running small business, working for daily wages etc. Normally one vehicle will be present in any home in this type of situation. This vehicle may be used by any member of that family to move
around according to their needs. Sometime two to three persons should move around in the same vehicle when whole family needs the ride for their need. That is moving for any movie, wedding, cultural or traditional occasions, the vehicle has to take full load of the family at that time. And in these situations where the people should keep up time for their work and needs, consumer will think a lot about these factors, with foresightedness towards the fuel consumption of the vehicle. In middle class families four wheeler vehicles are seen rarely. Keeping middle class families in mind who are maximizing the sales of two-wheeler vehicles in India this study is conducted.

- **Information Search:** The consumer will collect information about various brands of automakers that are into two-wheeler section. Consumer will see for the features matching his needs for using it. Taking an example, a college student will collect the information for a motor bike two-wheeler which should be powerful in initial pickup and should be passionate and should achieve maximum speeds comparatively. A person who is into small business expects features like carrying small amount of goods, family traveling in the vehicle comparatively. Consumers based on their needs they will survey for brands and features available in the market to get updated before buying the two-wheeler vehicle. This information will be collected by the consumer through various means like family, friends, advertisements, sales persons, mass media, rating organizations, surveys conducted, handling and examinations etc.

- **Evaluation of alternative:** The process used by all the consumers in buying situations will be different. They look for satisfying their needs along with beneficiary solutions from the product of purchase. The manufacturer should understand the consumer attitude, his willingness, and circumstances around him with the needs which are to be satisfied. As there is competition between the brands, consumers may go for the alternatives as there is choice set present in the market.
• **Choice of purchasing decision:** As the information about various products in the market is present with the consumer, it will be prioritized giving preferences according to his needs and circumstances.

• **Post Purchase Behavior:** The consumer may experience large gap between the featured product and experience which may lead to dissatisfaction about the product. The consumer dissatisfaction may cause serious negative impact on market about the product causing risk to the manufacturer. The consumer may also dispose the product because of dissatisfaction.

1.7.1 **CHARACTERISTICS OF CONSUMER**

General Characteristics of consumers involve

- It involves physical and mental activities which consumers undertake to get the products and services as well as to obtain satisfaction from them.
- It involves observable activities over the market, over various brands, features and specifications for prioritizing and prescribing the products.
- Consumer attitudes will be complex in understanding and keep on changing with time. So the manufacturers should update themselves regarding the consumer behavioral attitudes.
- Some behaviors are affected by internal factors such as psychological, traditional and cultural, perception, fear and environmental aspects.

Keeping in mind the consumer decision attributes and consumer characteristics, constraints regarding the electric two-wheeler sales have been framed in this study. This study is limited to Bangalore city in Karnataka, India. This study objective involves

- Measuring the consumer buying behavior towards electric two-wheeler compared to any ICE two-wheeler.
- In order to find the consumer satisfaction towards the electric two-wheeler vehicle considered.
This study is organized as a consultant to an electric scooter manufacturing company which is into production of electric scooters in market.

1.7.2 RESEARCH METHODOLOGY ADOPTED IN THE STUDY

Marketing research is the function which links the consumers with the marketers to identify and define market opportunities, taking suitable actions and understanding the consumer behavior defining the external and internal risks. The information is being collected and the collected information is being analyzed for getting better results in future. There are many ways of tackling the problem. The research design may include

- Explanatory type
- Descriptive type
- Casual type

Explanatory data focus on defining the present problems and identifying the solution for them. They mainly depend on secondary data rather than primary data. Primary data may be deduced and considered also for analysis. Descriptive data focus on defining the present problem in depth and scientific analysis of it is required in framing the solution for it. Casual research focus on stating the relationship bondage between the two or more variables in the present environment.

Data collection method involves various ways. It is the process the researcher has to follow with certain instruments or materials referred to the environment. Questionnaire is one of the data collection methods which involves

- Open-ended questions- to know the upmost information in the mind of the correspondent.
- Dichotomous questions- to make the correspondent to say either ‘yes’ or ‘no’.
- Multiple answer questions- to make the correspondent to answer more than one answer.

Sampling plan followed here for the survey conducted is as follows

- Correspondents are the consumers of electric scooters manufactured by the Company and utilizing its service within Bangalore city.
• The sampling size considered is 25 respondents.

A set of questionnaire is prepared for the survey conducted with the consumers, given in Appendix A.

1.7.3 DATA INTERPRETATION AND ANALYSIS

First the consumer class is categorized with twenty five respondents as shown in the table 1.1. Figure 1.26 represents the pie-chart with respect to table 1.1.

Table 1.1: Respondents categorized into consumer class

<table>
<thead>
<tr>
<th>OCCUPATION</th>
<th>NO. OF RESPONDENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
<td>08</td>
</tr>
<tr>
<td>Business people</td>
<td>04</td>
</tr>
<tr>
<td>Officials</td>
<td>03</td>
</tr>
<tr>
<td>Other professions</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
</tr>
</tbody>
</table>

Figure 1.26: Sales of electric vehicles based on Customer class

It can be seen that officials and business people are avoiding the electric vehicle. Whereas, the students and other professionals are purchasing these electric scooters for fulfilling their needs. From the questionnaire, officials and business
people came out with these issues to look about the electric scooter which are as follows

- Officials can’t find much time in charging the vehicle instantly. On full charge, the vehicle is expected to run for 40-45 Kilometers. Charging of the batteries require minimum of 6 hours in driving the distance specified, if they are into executable jobs they couldn’t expect the vehicle according to their needs. That is they can’t run over the city limits with one charge of the vehicle. They face the real problem when batteries are not being charged because of power cut on certain days which makes the vehicle unusable.

- The business people are finding difficulty in transporting goods to certain places in these types of vehicles. The initial pick-up and maximum torque offered by the vehicle on goods with person load cannot be tolerated by the vehicle and battery gets depleted very fast for a shorter distance. So they find electrical scooters are not reliable for business class work which involves certain roaming with benefits.

- Students feel they have much time in charging the batteries. But they are not satisfied with the propulsion of the vehicle whenever higher gradient is encountered. Also carrying one more person, rider with pillion is just very difficult to travel for medium distances. Single person can efficiently travel for certain shorter distance within city limits.

- Other professionals refer to the class who occasionally use two wheeler vehicles for travelling. They alone travel only near to their homes and find much time in charging the batteries.

The above points mention the reliability of the vehicle with respect to consumer class. It is to be noted that, all twenty five correspondents are having minimum one ICE driven scooter or motorbike with them along with this electric scooter.
The various sources that motivated the twenty five correspondents to go for an electric scooter is given in the table 1.2, Figure 1.27 represents the pie-chart with respect to table 1.2. It should be noted that all sources carry energy conservation topic for marketing.

Table 1.2 : Motivation expressed by consumer class in buying the electric scooter

<table>
<thead>
<tr>
<th>Sources</th>
<th>Number of correspondents got motivated</th>
</tr>
</thead>
<tbody>
<tr>
<td>News paper</td>
<td>05</td>
</tr>
<tr>
<td>Television and mass media advertisements</td>
<td>06</td>
</tr>
<tr>
<td>Events regarding energy conservation</td>
<td>12</td>
</tr>
<tr>
<td>Friends</td>
<td>02</td>
</tr>
</tbody>
</table>

Figure 1.27: Various source of Motivation for public in purchasing Electric Vehicle.

It can be seen that about 50 percent of the correspondents bought their electric scooter as they are more concerned regarding the environment and energy conservation.
The consumer satisfaction towards the electric scooter is shown in table 1.3. Figure 1.28 represents the bar graph considering certain parameters for reference.

Table 1.3 : Consumer preference for parameters of electric scooter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Excellent</th>
<th>Good</th>
<th>Average</th>
<th>Poor</th>
<th>Very poor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>8</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>Maintenance</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>Durability</td>
<td>0</td>
<td>3</td>
<td>9</td>
<td>10</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>Style</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>5</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>Easy-Driver</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>3</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Mileage</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>9</td>
<td>8</td>
<td>25</td>
</tr>
</tbody>
</table>

Figure 1.28: Graph showing the various attributes plotted as per correspondent hits

This above parametric data collection shown in table 1.3 indicated that many consumers are feeling dissatisfaction in the electric scooter towards price, maintenance, durability and mileage. These points are enough to suggest the following points
• The consumers are dissatisfied with the electric scooter they bought for their needs because of their less durability and more maintenance.
• They are general in experiencing the point that their needs are still not met completely with the product they own with respect to speed, pickup and load management.
• Price of the electric scooter is too high compared to ICE propelled two wheeler vehicles. An electric scooter of the company considered costs about 44,000/- INR approximately where ICE vehicles range starts from 32,000/- to 1, 50,000/- INR.
• Maintenance is a big issue for them. Service stations for their electric scooter are not many in the city. Also there is scarcity in availability of parts.
• With respect to durability, more than one person cannot travel in the electric scooter according to their usage. The battery gets depleted fast because of more loads. Often the electric scooter comes to service because of City road conditions. The battery used is Li-ion, 4-battery set, each of 12V and 20Ah. Battery lasts for 2 years at maximum and costs about 18,000/- INR about 41 percent cost of the new electric scooter.

1.7.4: SWOT (Strengths, Weakness, Opportunity and Threats) ANALYSIS

**Strengths:**

• Stylishly designed
• Easy driving
• Sales got increased by motivating people towards energy conservation and minimizing environmental pollution

**Weakness:**

• Very costly
• Not suitable for busy professionals like officials and businessmen
• Requires instant charging of the batteries
• Less durability
• More maintenance often requires servicing
• Less availability of parts for the vehicle
• Less mileage per charge and
• Batteries will not last long, and too costly to replace.

**Opportunities:**

• Compete wisely with design modifications with ICE market.
• Conversion of electric vehicle into hybrid electric vehicle so these drawbacks can be minimized.
• Designed vehicle should be more customer friendly along with energy conservation.

**Threats:**

• ICE vehicle manufacturers are more into two wheeler market and competition between them will make the consumer to think more in buying an electric scooter.
• No major ICE manufacturer is perusing any research of hybridizing electric vehicle, neither the electric scooter manufacturers.
• People are more concerned about mileage, durability, and maintenance-free, immediately accessible and service oriented vehicles in the vehicle market.
• No Government schemes are being implemented in motivating the consumers to go for electric vehicles.
• Hybrid electric two-wheeler and electric two-wheeler vehicles are very new to Indian market.
• Patience in consumers is less towards electric vehicle battery charging.

1.8 **HYPOTHESIS AND PROBLEM FORMULATION**

This phenomenological approach of study conducted and analyzed leaves the following questions in mind, Can the two independent propulsion sources, ICE and electric motor can be utilized as Hybrid Electric-ICE two-wheeler vehicle to get complete propulsion of the vehicle such that, incorporating the features of ICE driven vehicle and overcoming the drawback of present electric vehicles in supportive to following aspects
More fuel efficiency
More Reliability
More Durability
More driving per charge of batteries
Suitable for all class of customers in the universe
Easy driving and safety
Less maintenance and less servicing issues
Design and development of both customer and eco-friendly scooter
As both the sources are sharing the torque or tractive effort, the drawbacks of each source can be easily minimized.

As two-wheeler vehicles are more in India. Its usage according to needs of the consumers is increasing day by day, designing and developing fuel efficient Hybrid Electric-ICE two-wheeler vehicle has to be built in supportive to the above said points.

1.9 OBJECTIVES

- Carrying out a detail study on types of hybrid electric vehicles (HEV) and its design.
- Analyzing urban driving cycles and its characteristics for convenient and efficient design.
- Appropriate selection of electrical motor and control strategy for the vehicle performance based on driving cycle analysis.
- Designing and developing the suitable hybrid electric vehicle and analyzing for fuel efficiency.

The motivation for taking up the research work deriving the above said objectives are as follows

1.10 MOTIVATION

- A step towards energy conservation and environmental protection.
- A promising approach for an eco-friendly and emission free environment.
A challenging attitude of studying and designing multiple energy sourced vehicles.

By viewing the present pollution status of India it is the time to alert ourselves also others for building a better tomorrow by switching to electric/hybrid electric vehicles.

1.11 LITERATURE SURVEY

[1] Lei Wang, Yong Zhang, Chengliang Yin and Ximing Zhang published the technical paper “Design and Simulation for a Series-Parallel Hybrid Electric City bus,” in IEEE proceedings, 2009, describing the improvements in fuel economy of series-parallel hybrid bus as compared to that of conventional city bus. The simulation was conducted through CRUISE and MATLAB for the design. The results showed that, the fuel consumption can be reduced by 26 percent by following the series-parallel hybrid architecture.

[2] A. Khanipour, K. M. Ebrahami and W. J. Seale published “Conventional Design and Simulation of an Urban Hybrid Bus” in World Academy of Science, Engineering and Technology Transactions, 2006, describing the study, design and development of series hybrid bus validating the fuel efficiency and emission requirements. The simulation platform used was ADVISOR, a Matlab / Simulink platform. The validation of fuel efficiency was performed on standard driving cycle with observation of fuel consumption reduction by 40 percent in their design.

[4] Yamin Gao and Mehrdad Ehsani published “Hybrid Electric Vehicle: Overview and State of the Art,” Proc. IEEE, 2005 describing the various configuration of hybrid electric vehicles along with planetary gear implementations. The strategy of battery current consumption is also explained in the paper. Also stated the applications of various configurations depending on type of vehicle. Series configuration more suitable for heavy vehicles, Parallel and Series-Parallel configuration are more suitable for light vehicles.

[5] Vidyadhar Gulhane, M.R. Tarambale and Y.P Nerkar published “ A Scope for Research and Development Activities on Electric Vehicle Technology in Pune City” Proc. IEEE, 2006 describing, the various vehicle manufacturers are doing research on electric vehicles, its design with respect to electric motor, motor controller and the Government media in supportive to it. This paper also describes the disadvantages of electric vehicle usage in its reliability and also durability in India.


[7] Chris Mi, Abdul Masrur, and David Wenzhong Gao, Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives. This book describes the various HEV architectures, hybridizing the present automobiles, Simulation of HEV, Military vehicle hybridization, power electronics in controlling the motor, electric machines and its characteristics and many more concepts relevantly.