Final Thesis

AUTOMATION OF ELECTRIC VEHICLE AND DEVELOPMENT PROSPECTS

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### Abstract

This thesis introduces the basic principle of operation for electric vehicle. Through analysing its impact on environment and combining the reality and application, making a prospect concerning electric vehicles’ sales market.

In introduction of operative principle for electric vehicle, firstly are all vehicles’ types illustrated. Then through examples, its necessary components and automation control system are explained.

In aspect of environment, real explanations and examples are given which indicate the benefits of electric vehicles.

The last part is about the markets of electric vehicles. The whole marketing segmentation is analysed by its beneficiary, utilization rate all over the world, also including PESTLE and competition analysis.

### Keywords

EV, BEV, HEV, SHEV, PHEV, CHEV, FCEV, ABS, ASR, Tesla, Google car, SWOT, PESTLE.
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1 Foreword

I am a student who has studied in Savonia University of Applied Sciences for 3 years in Industrial Management. During my study period, I am always in high spirits in Principal Lecturer Harri Heikura’s lectures concerning automation control system and utilization of new energy sources. I think they represent the application and development of vehicle and technology in the future, which is the main reason why I chose such a topic to study. I firmly believe I can get new knowledge and information from it.

During the process, PhD. Harri helps me to modify and define the main orientation and necessary content according my final thesis proposal from the start. When I finished half of the content, PhD. Harri checked it and gave suitable advices, then he showed me the next step and what I needed to supplement. Then with the achievement of rest part, PhD. Harri pointed out what should be corrected and what was the right format. After several stages of correction, my final thesis passed then I did a presentation in front of two supervisors. It is a milestone in my study life.
2 Target of thesis

The purpose of the thesis was to study electric cars and their principle of automation system, effect on environment, carrying out market research and forecasting of future.

At the beginning, the thesis introduces the theoretical background of electric vehicle, through studying its operating principle, application of all kinds of sensors, the difference of engine between gas-online and electric vehicles, and the whole automation process to enhance understanding.

In the thesis, relationships between environment and application of electric vehicles through some aspects including greenhouse effect, carbon dioxide emission, air pollution, water pollution and so on are analyzed. To some extent, its appearance will arouse people’s awareness of protecting the environment.

The Thesis also illustrates people’s attitude and market prospects through finding out electric vehicles’ marketing situation and analyzing electric vehicle’s production, production management, quality, procurement process, investment, risks, sustainable development and other factors from scientific viewpoint of development for example PESTLE analysis and SWOT analysis.

In conclusion, the thesis gives a real example about application of electric vehicles in the world.
3 Theoretical background

The electric car is a new type of vehicle powered by vehicle power supply, with the work of motor driven system, conforming to the requirements of road traffic and safety regulations.[1]

3.1 Operating principle of electric vehicle

The biggest difference between electric vehicle and internal combustion engine car is power generation system. Electric vehicle except consists of the driving motor, power supplying, speed controlling device and so on other devices are basically the same as the internal combustion engine car.[2]

3.1.1 Basic concept for electric vehicle

Electric vehicle consists of electric drive and control system, mechanical system, driving force transmission system, and other working devices. According to components of electric car, electric drive and control system are the core factors.

3.1.2 Category of electric vehicles

Category of electric vehicles contains battery electric vehicle (BEV), hybrid electric vehicle (HEV), and fuel cell electric vehicle (FCEV) respectively.[3]

3.1.2.1 Battery electric vehicle (BEV)

Battery electric vehicle is driven by motor and the driving power that mainly comes from the on-board rechargeable battery or other energy storage devices. Most vehicles are directly driven by motor. A number of motors install in the engine compartment. Even some battery electric vehicles utilize four wheels as rotors to support power. For all battery electric vehicles, the difference is storage of power. [4]

Advantages: Technology is relatively simple and mature, the vehicles can be charged as long as there is electricity supply.

Disadvantages: Energy storage per unit in battery is too low, and battery price is pretty high. So the purchase price is more expensive. In aspect of cost, the penetration of electric car depends on battery’s lifetime or local price of petrol and electricity.
3.1.2.2 Hybrid electric vehicle (HEV)

Hybrid electric vehicle means getting power from on-board storage energy like following two ways \(^6\)

1) Fuel consumption;
2) Rechargeable/energy storage devices.

Then according to the power system structures, it can be divided into the three categories:

1) Series hybrid electric vehicle (SHEV):
The driving force of the vehicle only comes from the motor. The feature is work of engine drives generator. It generates electric power and flows through motor to control driving. In addition, power battery can also offer power to the motor to drive the car separately.

2) Parallel hybrid electric vehicle (PHEV):
Driving force comes from the motor and the engine at the same time or separately. Structure feature is parallel drive system can be used as power source for engine or motor lonely, or use motor or generator as a power source to drive the car.

3) Mixed type hybrid vehicle systems (CHEV)
This kind of hybrid electric vehicle both has series connection and parallel connection driving mode. This Structure can work in series connection and parallel connection hybrid mode respectively.

Advantages:
1) Under the working of hybrid, when car needs high-power and internal combustion engine cannot afford it, battery can supplement it. Also, when load of car is low, the surplus power can be used to battery charging. Because of working of internal combustion engine sustainably, battery can be charged continuously, which means hybrid electric vehicles are the same as normal car.
2) Because of the existence of battery, it can be easily recycle energy when braking, downhill and idling.
3) In busy city, it can shut down internal combustion engine then driven by the battery lonely to achieve "zero" emissions.
4) Hybrid electric vehicle, with the internal combustion engine, can solve such difficulty easily as energy consumption of air conditioning, heating, defrosting and others.
5) It can utilize the existing gas station rather than investing new one.
6) It can help battery to keep in good working condition, without overcharge, over discharge, prolonging its lifetime and reducing the cost.

Disadvantage: The vehicles cannot save fuel when they drive long distance with high speed.

Figure 2: Hybrid electric vehicle [7]
3.1.2.3 Fuel cell electric vehicle (FCEV)

Fuel cell electric vehicles utilize fuel cell as a power source. Chemical reaction process of fuel cell does not produce harmful product, therefore the fuel cell electric vehicles are pollution-free. Conversion efficiency of fuel cell energy is 2 ~ 3 times higher than the internal combustion engine, so from the aspects of energy utilization and environmental protection, it is an ideal pollution-free vehicle. In order to get the necessary power and meet the requirements of vehicle use, a single fuel cell must be combined into a set of fuel battery. [8]

Compared with traditional vehicles, fuel cell vehicles have following advantages.

1. Zero emissions or approximate zero emissions.
2. Reduce possibility of water pollution causing by oil leak.
3. Reduce the emissions of greenhouse gases.
4. Improve the fuel economy.
5. Improve the efficiency of the engine combustion.
6. Stable operation and no noise.

![Figure 3: Fuel cell electric vehicle](image)

3.2 Sensors of electric vehicle

A sensor is an object whose purpose is to detect events or changes in its environment, and then provide a corresponding output. In car industry, manufacturers add those different sensors into vehicle to detect its integrated state.
3.2.1 Concept for vehicle sensor

Recently in electric car industry, sensors are widely used in the engine, chassis and body systems. They play a very important role in battery electric vehicle especially.\[10\] At present, a common household car has about one hundred sensors. Compared with it, a luxury car has more than two hundred sensors. Sensors can detect information such as physical quantity, the amount of chemicals or others, and convert them into electrical signals. Depending on effects of different sensors, these signals can be classified as temperature, pressure, flow, position, gas concentration, velocity, brightness, dry humidity, distance and etc. Once a sensor fails, the corresponding device cannot work properly or stop working. Therefore sensors are the key parts in car control system. Microcomputer control system cannot be achieved without any sensors.

3.2.2 Category of on-board sensors

According to function, electric car sensors can be roughly divided into two categories:

1) One is display sensors that illustrates parts of electric car’s current state. Drivers can read the information from these sensors.

2) The other is control sensors that is used to control the vehicle’s running state.

3.2.3 Historical background of on-board sensors

In 1960s, only the engine oil pressure sensor, oil amount sensor and water temperature sensor were installed in the car. They are connected to the instrument or light.

After 1970s, with the appearance of catalytic converters, electronic ignition and fuel injection device, people added relevant sensors to control exhaust emissions and automobile power system.\[11\] In 1980s, anti-lock braking system and airbag improved the safety of cars. Nowadays, some on-board sensors can detect all kinds of fluid temperature and pressure for example air inlet temperature, airway pressure, cooling water temperature and fuel injection pressure. Some sensors can ensure the speed and position of each part for example travel speed, throttle percentage, angle
and speed of the camshaft, crankshaft, transmission, the location of the exhaust gas recirculation (EGR) valve. Others can measure the engine load, detonation, fire and oxygen content in the exhaust gas, ensure seat position, measure wheel speed, super elevation of highway surface and tyre pressure in the anti-lock brake system and suspension control device. The airbags, which are used to protect in the front of the crew, need to be added more crash sensor and acceleration sensors to improve accuracy.

With the technological development, researchers began to use obstacle avoidance sensor to judge and control vehicle’s lateral acceleration, instantaneous velocity and the required torque of each wheel, which makes braking system become a core component in vehicle stability control system.

3.2.4 Example of on-board sensors

1) Odometer sensor

Odometer sensor is usually installed on differential mechanism or axle shaft to measure cylinder number of wheels. The signal is detected by Hoare or photoelectric sensors. The purpose is using odometer count to effectively analyze and judge the speed and mileage of the car. Due to the fact that wheels and axle shaft have same angular velocity, wheel’s radius is also already known, so sensor can calculate the actual distance and show it on the instrument panel. In order to reduce motoring torque and force of friction on transmission shaft, manufacturer designs two bearings on it.

Now according to detection of gear operated to obtain data rather than detecting original dynamic signal for sensors. Gearbox is also changed. Plug of odometer sensor is usually installed on the gearbox which can be found when you open the hood.

2) Oil pressure sensor

Oil pressure sensor is used to detecting how much engine oil left in the sump, and convert it to special forms which we can easily understand. The sensor can remind driver how much engine oil there is left, or how long we can drive, even warn driver that engine oil needs to be added.
3) Water temperature sensor

There is a semiconductor thermal resistor inside of the sensor, whose temperature is inversely-proportional to the resistance. It is usually installed on the engine cylinder or water jacket of cylinder head. Water temperature sensor has contact with cooling water so that it can measure the temperature of engine cooling water. According to the change of the temperature, the sensor will generate a signal, and electric control unit (ECU) utilizes the signal as correction number to control fuel injection and ignition. All results for each process will be showed on instrument panel then driver can know the car’s running state or how long the car keeps working.
4) Air flow sensor
Effect of the sensor is measuring air flow of engine. Through processing air flow will be converted to electrical signal output and will be passed to ECU. As we know forward impulse of car comes from fuel combustion, volume of air flow is the key that supplied by ECU which can control injection time and ignition time. So air flow sensor can help us to operate accelerating and decelerating preferably. [15]

5) ABS sensor
ABS system ensures there is no locking between brake piston and disc brake which are all in critical state of sliding friction and static friction. Mostly it was achieved by inductive transducer to monitor car speed. [16] Gear ring effect of ABS sensor synchronously rotating with wheels can output a set of quasi sinusoidal AC electrical signals whose frequency and amplitude related to the wheel speed. The output signal will be transited to the ABS electronic control unit (ECU) to achieve real time monitoring for wheels.

Figure 6: ABS sensor [16]
6) Air bag sensor

Bag sensor is also called crash sensor. According to different applications, air bag sensors can be divided into trigger collision sensors and protective collision sensors.\(^\text{[17]}\)

Trigger collision sensor is used to detecting the change of acceleration when car is collided. Impact signal will be transmitted into air bag computer system as trigger signal.

Protective collision sensors is in series with trigger collision sensor which can prevent explosion by accident.

![Air bag sensor](image)

Figure 7: Air bag sensor \(^{[17]}\)

7) Gas concentration sensor

This sensor is used to detect gas inside of car and exhaust emission. Especially the main component is oxygen sensor. It can detect the oxygen content in exhaust, then according to the air-fuel ratio, oxygen sensor gives feedback signal to microprocessor device to achieve overall control. \(^\text{[18]}\)

During this process, when the proportion increases, compared with change of oxygen content, output voltage of oxygen sensor goes down. When the proportion decreases, it will influence oxygen content, and output voltage will ascend. All those jump signals will be measured by ECU in time which can correct the fuel-injection quantity and the air-fuel ratio so that ideal condition could be controlled by Gas concentration sensor.
8) Position and speed sensors

The sensor is used to detect crank angle, engine speed, Throttle opening, car speed, accelerated speed, decelerated speed and etc., then it provides the reference signal to the ignition time and injection time. At the same time, engine speed signal is supplied to engine. [19]

Types of on-board position and speed sensors mainly contain alternator, magnetic resistance, Hall Effect type, reed switches, optical type, and magnetic semiconductor transistor.

9) Velocity sensor

Velocity sensor is an important sensor in electric car that is used to measure forthwith speed. According to the different target, it can be mostly divided into revolution speed transducer, vehicle speed sensor and wheel speed sensor. [20]

A. Revolution speed transducer

Revolution speed transducer is used to detect electric motor is rotation speed. There are three kinds of speed sensors commonly used which are electromagnetic induction revolution speed transducer, photoelectric induction revolution speed transducer and Hall Effect tachometric transducer. They all use non-contact measuring principle to enhance security and detection precision of the test.

B. Vehicle speed sensor and wheel speed sensor

Vehicle speed sensor is used to measure the electric car’s drive speeds. The signal is received by speedometer and showed on dash board. At present, most forthwith speed comes from the transformation of the tire speed which is detected by wheel speed sensor. Driver can find it on speedometer. However it is easy to be affected by wheel’s rub, road surface, tire pressure, old and new including braking or slipping which is possible to cause its circumference changed, even stopping work and more serious consequences.

Types of vehicle speed sensors mainly contain electromagnetic induction type, photoelectric type, variable reluctance and Hall type. Electric car widely uses electromagnetic induction and hall type velocity sensor.
3.3 Total automation of electric vehicle

Electric drive control system contains engine control, transmission control, anti-lock braking system, acceleration slip regulation, power steering control, suspension control, cruise control which can keep speed automatically, navigation system, collision avoidance control, airbag control, automatic wiper, automatic window control, air conditioning control, light control, automatic door lock system and etc. most of them consist of feedback control.\[^{21}\]

3.3.1 Fuel engine control system

The hard core is electronic fuel injection (EFI). It can achieve air-fuel ratio control, idle speed control, ignition control, exhaust gas recirculation control and etc. with combined action of other devices.\[^{22}\]

The Core Components is the Electronic Control Unit (ECU), including engine speed sensor, water temperature sensor, the intake manifold pressure sensor, electromagnetic injector, cold start injector and others. According to all kinds of parameters detected, ECU accurately calculates the engine fuel quantity that we need under different working conditions. Then it will control fuel injection and ensure air-fuel ratio of engine mixture in the appropriate range.
3.3.2 Automatic transmission control system

The system consists of electronic control system, gear transmission, shift actuator, torque converter and etc. It can automatically determine the best gear and shift time, which is convenient for operation and makes driving performance reach the best state. \[^{23}\]

According to measured drive speed, engine speed and temperature, hydraulic oil temperature of automatic transmission and etc. the computer control system can detect the car’s running state at any moment and compare the data with shift schedule which has been set. Through calculation, analysis and decision, computer system will send out control signal to shift execution mechanism to complete the automatic shift.

3.3.3 Anti-lock braking system

When car emergency brakes, wheels may completely stop running. Car will dash forward with great inertia effect and it is easy to cause serious traffic accident for example side slip, drift, even rotation. \[^{24}\]

The car installed with ABS system will fully automatically take measures to prevent the locking of wheels through maintaining adhesion force between the tire and ground to improve the stability of drive.
3.3.4 Acceleration slip regulation

When car accelerates or decelerates on rain, snow or wet pavement where surface adhesion coefficient is relatively small, wheels could slip and idle. Then it is possible to lose the direction control ability and cause an accident. Acceleration slip regulation system can avoid slippage, idling and uncontrollable phenomenon, which is used to improve directional stability in driving process. \(^{(25)}\)

In order to avoid drive wheels from slipping, there are two ways to control the whole process which are brake control mode and engine control mode.

A. Brake control mode

When system detects drive wheels in idling or impending idling, electronic control unit will give an order for the wheel to brake. Acceleration slip regulation system usually slowly increases braking torque to ensure that the braking process is smooth.

B. Engine control mode

When system detects drive wheels in idling or impending idling, electronic control unit will give an order in due time to change fuel-injection quantity, duration of ignition, throttle percentage and other solutions to adjust the au-
tomobile engine output torque, which optimizes the stability between drive wheels and road surface adhesion.

![Figure 11: Acceleration slip regulation system](image)

### 3.3.5 Automatic control system for the power steering

When we drive the car at low speed, steering torque is high. Oppositely the steering torque is low when car drivers at high speed. In order to help driver to operate car smoothly and freely, manufacturers research and develop auxiliary torque control devices.[26]

Power steering system based on vehicle driving condition, utilizes control device to adjust power-assisted steering, thereby obtains ideal steering performance.

Generally automatic control system for the power steering consists of vehicle speed sensor, torque transducer, control component, electric or pneumatic or hydraulic device and so on. It has a variety of functions including speed detection, control decisions and power-assisted steering.

System in the process of work constantly tests car’s speed, steering torque and other parameters. Then electronic control unit can receive those collected signals. After calculating the amount of regulating steering, results will be delivered into executive motor, electrical or hydraulic, pneumatic driving devices, pneumatic driving devices and driver is steering device.
According to drive condition, automatic control system for the power steering could automatically adjust the stiffness of automotive suspension and vibration damping. On fluctuant road, power steering system can effectively absorb vibration to avoid the wastage of the body. It also can balance the body when steering, and improve the vibration reduction effect when emergency braking. For some special function vehicles which can automatically adjust the suspension, power steering system can reduce the wind resistance coefficient, energy consumption and increase car’s integral stability.

3.4 Electromotor of electric vehicle

Electromotor of electric vehicle is a kind of electromagnetic device according to the law of electromagnetic induction to achieve energy conversion or transfer. The main function is to produce drive torque, as the power source of the electric car. \[10\]

3.4.1 Types of electromotors

The electric car motor can be divided into alternating-current motor, direct-current motor, ac/dc dual motor, control motor, Switched reluctance motor, the signal motor and so on. Alternating-current motor and direct-current motor are suitable for electric drive. Currently there are some new on-board motors appearance that have promising applications for example induction AC motor or permanent magnetic brushless motor. \[27\]

3.4.2 Performance requirements

The characteristics of vehicle driving are frequent start, acceleration, deceleration and stop. When car climbs or drives with low speed, it needs high torque. Oppositely when car drives with high speed, it just needs low torque. In order to meet the requirements of rotate speed from zero to maximum speed, the electric car motor should have higher specific power and power density. Following 10 aspects are its special characteristics.\[28\]

1) Voltage of electric motor is high. In permissible range, by using high voltage the size of the motor can be reduced, wires and other equip-
ment, especially reducing the cost of the inverter. Under the condition of the same size, working voltage, the highest power and maximum torque are improved from 274V to 500V, 33kW to 50kW and 350N"m to 400N"m respectively. Therefore the application of high voltage system benefits improvement of overall automobile dynamic performance.

2) Rotate speed of on-board induction motor is high, which can reach 8 000—12 000 r/min. It means the high speed motor is smaller and lighter which is conducive to reduce loading equipment quality.

3) Weight is light and volume is small. Weight of electric motor can be reduced by using aluminium alloy shell, and for all kinds of control devices and cooling systems, light materials can be chosen. In order to achieve reduction in vehicle weight and extend driving range, drive motor is required to have higher specific power and efficiency. However compared with it, industrial drive motors usually pay more attention to power, efficiency and cost, and optimize the function near the rated working point.

4) Electric motor should have large pull-in torque and speed control performance to meet the power and torque required when launching, accelerate, driving, decelerating, braking and so on. Also electric motor should have automatic control function to alleviate strength of the driver's manipulation, improve the driving comfort and be able to get the same control response when stepping on the accelerator comparing with Diesel cars.

5) Electric vehicle drive motor needs to have 4 - 5 times overload to meet the requirements of short-term speed up and maximum grade ability. Compared with it industrial drive motor just needs 2 times overload ability.

6) Electric vehicle drive motor should have high controllability, stability precision, dynamic property to achieve coordinated operation for many
motors. Compared with it industrial drive motor just need to meet only one particular performance.

7) Motor should have high efficiency, low loss and achieve braking energy recovery when car slowdown.

8) Safety of the electric system and control system should reach the relevant standards and regulations. Power battery and electric motor’s voltage can reach more than 300V so that it must be equipped with high pressure protection device to ensure safety.

9) It can work reliably in harsh conditions. In order to overcome different environmental problems, motor should have the following features: high reliability, heat resistance and moisture resistance, low noise when running and ability to work long-term under harsh environment.

10) It is suitable for mass production within simple construction, convenient maintenance and cheap price.
4 Environment and applications of electric vehicles

The environmental impact of transport like vehicles is significant because it is a major user of energy, and burns most of the world's petroleum. It causes air pollution, including nitrous oxides and particulates, and it is a significant contributor to global warming through emission of carbon dioxide. By subsector, road transport is the largest contributor to global warming.[29]

4.1 Environmental problems

Our environment is constantly changing. However, as our environment changes, so does the need to become increasingly aware of the problems that surround it. With a massive influx of natural disasters, warming and cooling periods, different types of weather patterns and much more, people need to be aware of what types of environmental problems our planet is facing.[30]

4.1.1 Greenhouse effect

The greenhouse effect is a term that refers to a physical property of the earth's atmosphere. If the earth had no atmosphere, its average surface temperature would be very low of about -18°C rather than the comfortable 15°C found today. The difference in temperature is due to a suite of gases called greenhouse gases which affect the overall energy balance of the earth's system by absorbing infra-red radiation. In its existing state, the earth-atmosphere system balances absorption of solar radiation by emission of infrared radiation to space. Due to greenhouse gases, the atmosphere absorbs more infrared energy than it re-radiates to space, resulting in a net warming of the earth-atmosphere system and of surface temperature. This is the Natural Greenhouse Effect. With more greenhouse gases released to the atmosphere due to human activity, more infrared radiation will be trapped in the earth's surface which contributes to the Enhanced Greenhouse Effect.[31]

4.1.2 Carbon dioxide emission

Main effect of carbon dioxide emission is the greenhouse effect because carbon dioxide has effect of heat preservation which can cause temperature build-up on the earth. Nearly 100 years, global temperature has increased 0.6 °C. According to this rate, when time to the middle of the 21st century, global tem-
Temperatures will rise by 1.5-4.5 °C. However, greenhouse effect will also cause sea-level rise. Ice in North Pole melts. All of these changes for wildlife will be a disaster, which threatens humans’ survival and ecological balance significantly.

Compared with the concentration before industrialization which is 280 parts per million, as of May 2013, concentration of carbon dioxide in earth’s atmosphere has been more than 400 parts per million (four hundred over one million). The growth rate of concentration was 2.0 parts per million per year between 2000 and 2009, and it speeds up year by year.

After consideration and introspection, human factor is the main reason for the sharp rise of carbon dioxide concentrations. 57% carbon dioxide released enters into the atmosphere, the rest will dissolve in the sea and cause ocean acidification. 

![Figure 12: World CO2 emissions by country between 1990 to 2030](source: mongabay.com)

4.1.3 Air pollution

As one of the main sources of air pollution, vehicle exhaust contains a large number of harmful substances. The gas emissions not only smell weird, but cause people dizziness, nausea and affect their health. At the beginning of vehicles’ application, atmosphere can dissolve the toxins by self-purification ability. But with the rapid increase of cars, traffic jams will become common-
place, advantages of vehicle which are convenient, comfortable and efficient. New pollution, the automobile disaster, has been formed.

Scientific analysis shows that the automobile exhaust contains hundreds of different compounds, including solid suspended particles, carbon monoxide, carbon dioxide, hydrocarbons, nitrogen oxides, lead, sulfur oxides and etc. Mass of one car releasing harmful gas in one year is 3 times larger than its own weight.

Recently PM 2.5 has become a social focus which belongs to category of solid suspended particles. For PM 2.5, automobile exhaust is not only one of main sources, but also still has a lot to blame for urban air pollution. Photochemical smog is one of the main effects. Photochemical smog is caused by ozone, aldehydes, ketones, PAN and other secondary pollution which formed by atmosphere under the action of light hydrocarbons and nitrogen oxides. Its influence on the human body is much more than nitrogen oxides and hydrocarbons. \[34\] In history there have been several times serious photochemical smog pollution events with locations without exception were all in large and super large cities. In 1970, in the United States, there was breaking out photochemical smog in Los Angeles. It sickened about three quarters people in the community. \[35\] In 1971, in Japan, there was also photochemical smog in Tokyo which caused coma to students. Visibly, existence of automobile exhaust is a formidable gap between urban large-scale and environment improvement. \[36\] In China, with the rapid development of economy in recent years, there is a large number of large cities and several mega cities which means number of vehicles will increase sharply. It will bring more pressure to environment and atmosphere. At the beginning of 2013 in the Beijing area nightly haze weather is a strong proof.
4.1.4 Water pollution

Oil leaked from cars is among the major contributors to water pollution, according to the Washington State Department of Ecology in its website post "Car Maintenance." Each year, people spill 180 million gallons of used motor oil into lakes and rivers, making it the biggest contributor to oil pollution in those types of waterways. Even if you're not near a stream, rain can wash oil into storm drains, where it travels to waterways. Because motor oil and water do not mix, the oil takes a long time to disappear. As seen in massive tanker spills, oil can harm plants, kill animals and adhere to any substance it touches. Other engine fluids that spill can also contribute to the pollution problem.\textsuperscript{38}

4.2 Applications of electric vehicles

Currently, with the rise of electric cars, there the number of electric vehicle manufacturers is growing up. Compared to traditional gas-online vehicles, the new industry has more potential. Because of their creation, the types and applications of electric vehicles will become more and more colorful.

4.2.1 Examples of electric car’s applications in society

Professional automotive industry consulting company Ihsautomotive in the United States recently published data about world’s market share of pure electric vehicles in the first quarter of 2015. \textsuperscript{39}

The first country on top of the pure electric vehicle market is Norway. In the first three months of 2015, nearly one third of the buyers chose the pure elec-
tric vehicle. The number of registrations reached 8112 which increased by 41% comparing with previous year. Especially Volkswagen e–golf is the most popular model in the Norwegian market.

The second country is in Western Europe, Holland, which is facing the Atlantic Ocean. In the first quarter of this year the Dutch bought 5760 pure electric vehicles. The number of registrations accounted for 6% which increased by 74% compared with 2014.

The third one is Britain. In the first quarter the British bought 8684 pure electric vehicles which accounted for 1.2% of the total number of new cars.

The fourth country is the United States which is the world’s largest pure electric vehicle market. However, because of the great number of new car’s registrations in 2015, the Americans bought 14832 pure electric cars that only occupied 0.8% in its market shares and there was an increase of only 33 cars comparing with the same period in 2014. The main reason which caused this phenomenon is that the USA has very low oil price.

The fifth one is France. In the first quarter the registration of pure electric vehicles accounted for 0.8% and the number of registration was 3626.

The sixth one is Germany. Number of pure electric vehicles registration occupied 0.6% in the first quarter. What is more, Volkswagen e–golf is still the most popular model in Germany.

The seventh country is Japan. In the first quarter it registered 7750 number plates of pure electric cars that accounted for about 0.6% market share (slightly lower than in Germany). Compared with the same period in previous year it decreased by 20%. The reason is the Japanese hybrid technology developed rapidly, hybrid electric vehicles are more practical with an affordable price.

The eighth country is China. In the first quarter it increased 12555 pure electric vehicles. Because China is the world’s largest car market, this huge registration number only accounted for 0.3% in the whole nation. But compared with that in the same period in 2014, the Chinese pure electric vehicle registration amount increase 744%. Basically it illustrated Chinese policy encouraged and succeeded.

In conclusion, high price, short life and technical difficulties for charging are the main problems for further development of pure electric car. In Japan and the United States, traditional automobile manufacturers are not keen on pure
electric car because battery technology is still the biggest bottleneck. Especially in Japan whose hybrid technology occupies the absolute leading position, the price of hybrid car is only higher than that in gasoline about 10000 – 20000 RMB.

According to above-mentioned, Norway occupied 33% market share in leading position which leaves Holland behind whose market share is only 6% far and away. So Norway has become the first country all over the world entering the new age where pure electric vehicles are popularized in society.

4.2.2 Tesla motors

Tesla Motors was established in 2003, headquartered in Silicon Valley region of California in the United States.[40] Tesla is committed to using the most innovative technology, accelerating the development of sustainable transport. It provides new creative technology to achieve sustainable energy supplies, reduces dependence of petroleum in global transportation; vigorously promotes the development of pure electric vehicles in the world through opening patent and cooperation with other auto makers.

At the same time, the Tesla electric cars in terms of quality, safety and performance are reaching the highest standard of automobile industry, and provide the most cutting-edge technology to upgrade services such as complete charging solution, bring people the most extreme driving experience and the most complete consumption experience. Tesla produced several models contain Tesla Roadster, Tesla Model S, double motor all-wheel drive, Tesla Model X.
4.2.3 Self-driving cars

Driverless cars are smart cars also called wheeled mobile robots. Driverless car mainly relies on intelligent pilot operated by on-board computer system.\(^{[42]}\)

Starting in the 1970s, the United States, Britain, Germany and other developed countries already began to study driverless cars. And they all made breakthrough progress in feasibility and practical aspects. However Chinese studies on driverless cars are from the 1980. Then NUDT (National University of Defense Technology) successfully developed the first Chinese driverless car in the true sense in 1992.

Driverless cars are smart cars that can perceive road environment through on-board sensor system, then plan the routes automatically and control the vehicle and reach the destination. These on-board sensors can distinguish vehicle surroundings, control vehicle’s steering and speed on the road by road information, car position and obstacles perceived. So that the vehicle can safely and reliably drive on the road.

Driverless car as an organic whole consists of automatic control, architecture, artificial intelligence, computer vision, and other technology. It is the outcome of computer science, pattern recognition and intelligent control system, and
an important symbol to measure a national scientific research strength and industrial level.
In the field of national defence and national economy driverless car has broad application prospects.
After test Google driverless cars have logged over 200000 miles. Technical personnel said: Google self-driving car can see other cars by cameras, radar sensors and a laser range finder, and can use detailed maps for navigation.
Information collected by manual driving is so huge. Google data center can do it. However now the main difficulty is how to keep driverless car coexist with others on the road and avoid accidents.[43]

Figure 15: Google self-driving [44]
5 Markets of electric vehicle

Many carmakers design electric vehicles intended to satisfy the needs of almost customers. Instead, they should embrace a radical new form of market segmentation.

5.1 Marketing segmentation of electric vehicle

Global carmakers are trying to define a future market for electric vehicles. To reach beyond affluent, environmentally conscious, or technically enamored buyers, these companies will need to develop products that satisfy the consumers’ main concern—good value for money. Given the current cost of energy storage, that is a considerable challenge.\[^{45}\]

A recent study suggests that one way companies can achieve this goal would be to focus on tailoring battery-powered vehicles to the actual driving missions of specific consumers—that is, to the way they use their vehicles. Most existing gasoline-fueled cars, as well as many electric ones now on the drawing boards, are intended for multiple driving missions of differing lengths and speeds. By focusing on specific driving missions of consumers, a company can match a vehicle’s energy storage requirements to a consumer’s particular needs and thus design more economic vehicles. It can also shape its brand and advertising messages and go-to-market strategies for such products more efficiently.

5.2 Definition of beneficiary

A beneficiary in the broadest sense is a natural person or other legal entity who receives money or other benefits from a benefactor. However this concept will also frequently figure in contracts other than insurance policies. For electric vehicles, the concept can be divided into two levels which included customers and countries.\[^{46}\]

For customer who as the first level beneficiary, they do not need to worry about influence of oil price anymore. Compared with gasoline, electricity is much cheaper, which means it can save more expenditure for them. Because car’s construction is different from traditional internal combustion engine vehicles, the maintenance is easy to operate for owners.

Then as the second level beneficiary, government of country can achieve more accomplishments for instance energy saving, environment protection, prevention of atmospheric pollution and greenhouse effect and so on. From aspect of
sustainable development, popularization of electric car is tremendous advance on the way of social evolution.

5.3 How the customer chooses electric vehicle

People who are in the market for a car often turn to gasoline-powered vehicles as the standard choice. While there are many reasons to get an electric car, many consumers do not know about them. People like to stick with what is familiar, and gasoline-powered cars are significantly more affordable. For many people, those two reasons are enough to keep them paying at the pump rather than plugging in. But it is important that any car buyer knows the benefits of going electric in order to make an informed choice. One of the five reasons below may tip the scales in favor of an electric car. [47]

5.3.1 Five advantages

1) Fuel economy

One of the biggest advantages of electric vehicles is fuel economy. Those who drive gasoline-powered vehicles are often concerned by the miles per gallon. With battery-powered vehicles, however, the concept is totally different. Because electric vehicles do not run on gasoline, they have different metrics than gas vehicles. Instead of calculating the miles per gallon, electric vehicles are measured based on the miles they can go on a fully charged battery. When it comes to efficiency, battery-powered vehicles are the clear winner. Generally, electric vehicles can transform about 60 percent of the stored battery power into actual energy. Conventional vehicles that are powered by gas, on the other hand, only convert about 20 percent of their stored potential energy.

Generally, electric vehicle needs to consume 15 KWh when it drives 100 kilometer. According to electric charge in China which is 0.6 RMB per KWh, total price of electric car that drives 100 kilometer is 9 – 10 RMB. Compared with it, relative saved gasoline-powered vehicle needs 7 liters fuel consumption in 100 kilometer. According to price of No. 93 in Beijing gasoline market that is 7.85 RMB per liter, gasoline-powered vehicle need cost nearly 55 RMB at least. So compared with it, cost of electric vehicle is only 1/5 or less.

2) Performance and maintenance
When testing an electric vehicle for the first time, many drivers are often surprised by its smooth performance. There is often a misconception that electric vehicles are slower than gasoline-powered cars. These vehicles often do not come with the conventional internal combustion engine, but they are still capable of the same speeds, horsepower, and acceleration. In fact, electric cars do not require gear shifting, which means that acceleration and braking run more smoothly.

When it comes to maintenance, electric vehicles are also easier to keep in good condition. An electric motor is a lot less messy than an internal combustion engine and typically only has a single moving part. Compared to gasoline cars, it is not necessary to get constant oil changes, tune-ups, filter replacements, and repairs for a myriad of other small parts that are prone to breakage.

3) Reduced carbon footprint
Because electric cars do not run on fossil fuels, it greatly lowers the car owner’s carbon footprint. Those who are conscious about their vehicle’s emissions and its corresponding effect on the environment are happy to note that electric cars do not emit tailpipe pollutants.

4) Tax rebate
In order to increase the number of electric vehicle users, most countries implement new policy to encourage their people. For instance in U.S., the government has offered a tax rebate for all vehicles that have been bought on or before 2010. While the full tax rebate amounts to $7,500, whether or not it is credited to the electric vehicle owner depends on the battery capacity. Some vehicles only qualify for 25 or 50 percent of the tax credit. This means that someone who buys a new electric car equipped with top-tier batteries gets a discount on the vehicle through the rebate.

5) Stylish design
Today’s electric cars are every bit as stylish as their gasoline-powered counterparts. While most people have the misconception that these vehicles are small and boxy golf carts, vehicle designs like the Nissan Leaf and the Tesla Roadster have proven them wrong. Those who are thinking of buying an electric car
should not worry about feeling self-conscious because there are many attractive models that are bound to suit one’s taste. As mentioned, an electric car and a gasoline-powered car look virtually the same until the hood is popped.[47]

5.3.2 Disadvantages

1) Low battery capacity
Although electric cars are much more energy efficient, their batteries do not allow them to go more than 100 to 200 miles on a single charge. However a gasoline car can go upward of 300 miles on one tank of gas. The battery also takes a significant amount of time, four to eight hours, to fully recharge. While an electric car eliminates the need to fill up at the pump, it does require charging, which adds to the owner’s electric bill.

2) Battery lifespan
The vehicle’s battery is the one element that require the most frequent replacing since it has a limited lifespan. Batteries for electric cars are very expensive and run upwards of $1,000. A typical electric car requires one to two battery replacements over the lifetime of the vehicle.

3) Environmental pollution
Unfortunately, electric cars take a toll on the environment when they are being manufactured in factories, leading detractors to say that it does not really help reduce man’s carbon emissions. Studies have found, however, that electric cars do have a lower carbon footprint through the course of their useful lives.

4) Tax rebate limitation
Keep in mind, however, that there is a limit to the number of tax rebates per electric vehicle make and model. For instance, it may be difficult to claim for a Toyota Prius because it is such a popular car. [47]

5.4 Utilization rate of electric vehicles all over the world
As of December 2014, more than 712,000 highway-capable plug-in electric passenger cars and utility vans were sold worldwide. The United States was the leading market with a stock of over 290,000 plug-in electric cars sold since 2008, representing 41% of global sales. Japan ranked second with over
108,000 units sold since 2009 (15%), followed by China with over 83,000 plug-in electric passenger cars sold since 2008 (12%).

However, Norway is the country with the highest market penetration per capita in the world, also the country with the largest plug-in electric segment market share of new car sales, and in March 2014 Norway became the first country where over 1 in every 100 passenger cars on the roads is a plug-in electric vehicle. Estonia, which has the second largest EV market penetration per capita after Norway, is the first country that completed the deployment of an EV charging network with nationwide coverage, with fast chargers available along highways at a minimum distance of between 40 to 60 km.

![Figure 16: Utilization rate of electric car all over the world](image)

<table>
<thead>
<tr>
<th>Country</th>
<th>PEV stock</th>
<th>Growth 2013-14</th>
<th>PEV market share 2014</th>
<th>PEV market share 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>291,332</td>
<td>69.40%</td>
<td>0.72%</td>
<td>0.62%</td>
</tr>
<tr>
<td>Japan</td>
<td>108,248</td>
<td>46.00%</td>
<td>1.06%</td>
<td>0.85%</td>
</tr>
<tr>
<td>China</td>
<td>83,198</td>
<td>190.70%</td>
<td>0.23%</td>
<td>0.08%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>45,020</td>
<td>57.00%</td>
<td>3.87%</td>
<td>5.37%</td>
</tr>
<tr>
<td>France</td>
<td>43,605</td>
<td>52.70%</td>
<td>0.70%</td>
<td>0.65%</td>
</tr>
<tr>
<td>Norway</td>
<td>43,442</td>
<td>113.30%</td>
<td>13.84%</td>
<td>5.60%</td>
</tr>
<tr>
<td>Germany</td>
<td>25,205</td>
<td>107.30%</td>
<td>0.43%</td>
<td>0.25%</td>
</tr>
<tr>
<td>UK</td>
<td>~24,500</td>
<td>145.40%</td>
<td>0.59%</td>
<td>0.16%</td>
</tr>
<tr>
<td>Canada</td>
<td>10,658</td>
<td>90.50%</td>
<td>0.27%</td>
<td>0.18%</td>
</tr>
<tr>
<td>Sweden</td>
<td>8,076</td>
<td>157.40%</td>
<td>1.53%</td>
<td>0.57%</td>
</tr>
<tr>
<td><strong>Global Total</strong></td>
<td><strong>712,000</strong></td>
<td><strong>405,000</strong></td>
<td><strong>75.80%</strong></td>
<td><strong>0.06%</strong></td>
</tr>
<tr>
<td><strong>(since 2003)</strong></td>
<td><strong>405,000</strong></td>
<td><strong>75.80%</strong></td>
<td><strong>0.06%</strong></td>
<td><strong>0.04%</strong></td>
</tr>
</tbody>
</table>

5.5 Geographical area analysis

According to analysis of electric vehicle in aspect pf geographical area, its prospect becomes more and more convincing.

5.5.1 PESTLE analysis

1) Political

A majority of governments encourage to use electric vehicles because they are eco-friendly cars. At the same time the supervision of normal gasoline-
powered vehicles is more and more stringent. For instance, European Union has strict regulations on pollutants from fuel burning cars.

2) Economic
In order to popularize a low carbon life among the public, some governments make concessions on environmentally friendly cars and the main direction is electric vehicle. They support more convenience for general public. For instance, UK is a developed nation with per capita incomes $35,025. It has very strong financial banking system. Now this system will provide easy loans for people to buy and use electric vehicles.

3) Social
With high index of education, people are well aware about the problem of toxic gases produced by cars, which helps the development of eco-car. Nowadays the idea has been deeply rooted in the hearts of the people. Children all know protecting our planet under the influence. For instance people in UK are very particular about protecting their environment as they have learnt the lesson from the Great Smog which killed around 4000 people.

4) Technological
Nowadays power-generation technologies has achieved modernization in many fields. Some countries have electricity in surplus which is a great requirement for electric vehicles to succeed. Scientists and engineers have worked out different kinds of electric cars through different technology. And these cars have been sold in global market. To some extent, some countries are ready and have all the technical knowhow and eligible man power total tackle the service of electric cars

5) Legal
In order to insure safety, comfort, performance and efficiency of electric vehicle, different country has different requests based on their respective national conditions. These requests include its ground speed, duration of flight, quality, manufacturing technique, environmental consequence, energy demand and so on. No matter how electric vehicle and gas-online vehicle have common features in some ways.
6) Environmental

The environmental advantages of electric car should be quite obvious to everybody that increased health for both people and nature. It is long since proved that the use of oil products releases more pollution into the air than the nature can take care of. It also increases risks of both cancer and lung diseases. The pollution produced by cars might also get carried into the atmosphere where it transforms into acidic rain, one of the worst problems for nature and even planted crops. So by using electric vehicles, humanity not only does the nature a favor but also does ourselves a favor.

Table 17: SWOT analysis for popularity of electric vehicles [50]

<table>
<thead>
<tr>
<th>Strength</th>
<th>Weaknesses</th>
<th>Opportunity</th>
<th>Threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Eco friendly</td>
<td>• Needs time to recharge</td>
<td>• Government credits people to own an eco-friendly car</td>
<td>• All electric car manufacturers will be in fierce competition</td>
</tr>
<tr>
<td>• Low cost of Ownership</td>
<td>• Low top speed</td>
<td>• No congestions charges</td>
<td>• Electric automobile market will occupy considerable market share and cause unknown influence for others</td>
</tr>
<tr>
<td>• Cheaper to run</td>
<td>• Batteries change are expensive</td>
<td>• Low taxes for eco-friendly car</td>
<td>• Rise in cost of electricity</td>
</tr>
<tr>
<td>• Good range and crushability</td>
<td>• A lot of new investment for AC or DC charge spots</td>
<td>• Price on Petrol to go up further</td>
<td></td>
</tr>
<tr>
<td>• Simple mechanism</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.5.2 Competition analysis

As use of electric vehicles has been expected to grow, the batteries for the electric vehicles have become critical element because the batteries are a key part of the paradigm shift in the automotive industry. However, the demand for electric vehicles has been growing slowly and the electric vehicle battery industry still has internal and external competitions to become a standardized energy source for electric vehicles. [51]
The electric vehicle batteries need to improve their performance, safety, life cycle, charging time and infrastructure to succeed in the market. Since the electric vehicle battery industry is associated with a variety of stakeholders, it should enhance its performance in complex internal and external competitions by cooperating closely with them. Automobile makers in particular are becoming competitors as well as clients to the electric vehicle battery industry.

As automobile makers aggressively invest in electric vehicle battery manufacturing, the internal competitions to achieve technology, cost, and market leadership are accelerating. In addition, automobile makers have developed fuel cell technologies for fuel cell electric vehicles. Since the fuel cell has the advantages in electric driving ranges, in charging time, and in vehicle design, the fuel cell electric vehicles could well restructure the entire electric vehicle market if they reduce fuel prices and establish charging infrastructures.

The electric vehicle battery industry should seek to speed technology advances for the next generation of battery technologies by identifying key materials, improve battery performance, enhance manufacturing capabilities, and reduce manufacturing costs by expanding the scope of its research and development. If it needs strategic partnerships, the electric vehicle battery industry should look for long-term strategic partners with whom it can grow together. Moreover, the electric vehicle battery industry should enhance its value chain by interacting with suppliers at all tiers from raw material companies to final product makers. Furthermore, the electric vehicle battery industry should seek to attain the economies of scale for the cost and market leadership by diversifying the batteries' applications. Finally, it should compete not on price but on value while strengthening the industry's power.
6 Conclusion and future

Electric vehicles are, slowly but surely, becoming one thing that around a million plug-in vehicles have been sold since 2008. The biggest barrier to public uptake for electric vehicles is charging. \[52\]

At the moment, most countries don’t have a thought, through infrastructure of public plug points where electric car owners can recharge their vehicles, despite the fact that they can travel anywhere between one and seven hours or 40-140 miles on a single charge. This is, at best, anxiety-inducing for car owners; at worst, it could be dangerous and lead to breakdowns during trips. Thankfully, some countries like UK government is looking into ways to improve our electric car infrastructure. Perhaps the most exciting news is the recharging road. This is a stretch of motorway which uses magnetic induction to recharge the cars’ batteries while they’re driving. It looks like the same technology used in wireless phone chargers. \[53\]

![Figure 18: Recharging road in UK](image)

Now, it looks like that hybrid and electric vehicles will be a key to solve all environmental problems for humans, but the reality is far from it. First of all, we have to admit electric car is a great invention for environment and people’s health. But we still can feel it is not so simple when considering how these vehicles get energy from the earth. At present, most energy recharged by electric
vehicles is extra power produced by coal-fired power plants, which may cause more environmental pollution compared to gas-online vehicles.

On the other hand, according to statistical data, most electric vehicles need more energy support than ordinary cars in same circumstances. Although this problem will be solved in the future, all phenomena indicate electric car is a future vehicle rather than current vehicle.

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