

Establishing a Model for Electric Vehicles for Use in Large Cities

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Air pollution in big cities has already become a serious problem and will continue to be so in the future. Individual countries are trying to find possible solutions to this problem and are devoting large budgets to comprehensive air pollution research programs (Wu, 1999; Liao, 1999). Even though motor vehicles cause environmental damage, they also make a major contribution to economic growth (Yang, 1988; Chen, 2000; Yang, 2001). In this study we establish an implementation model for electric cars for use in large cities; we proceed *via* the Delphi Technique and a review of the literature. This model is also arrived at through the utilization of what we call a Scenario Technique (ST). The ST will be able to analyze past situations, predict future ones, and seek to control the present, thus minimizing the future occurrence of the many potential environmental dangers we face on this planet, while maintaining a balance between economic development and the environment.

Keywords: Electric Vehicle Air Pollution Scenario Technique Hybrid Vehicle
Delphi Technique

Introduction

Basically, the impacts of the engine-powered vehicles on the environment may be classified into four categories: noise, air pollution, traffic congestion, and the greenhouse effect (Chen, 2000; Yang, 2001). In fact, these problems are interrelated, because their alleviation in each case revolves around the ownership and use of the vehicle and the fuel it consumes. Motor vehicles produce a great amount of CO, NO_x, and Chlorofluorocarbons that cause the greenhouse effect. Traffic congestion is undirected to influence the economic and environmental damage such as noise, accidents, time delays, air pollution, waste of fuel, etc. In urban areas, noise is mainly caused by motor vehicles (Yang, 1998; Wu, 1999; Wu, 2000). It is also true that motor vehicles cause air pollution by emitting from the tail pipe into the atmosphere gases and emissions such as lead, smoke, sulfur, unburned hydrocarbons (HC),

carbon monoxide (CO), oxides of nitrogen (NO_x), and so on. In addition, the use of organic compounds also causes air pollution during the vehicle manufacture procedures, such as Chlorofluorocarbons, hydrocarbon solvents, and so on.

Some countries have already introduced legislation in an attempt to control air pollution, because motor vehicles are the main source of city air pollution. For example, California in the USA has decided to introduce electric vehicles, and since 1998, manufacturers producing 400,000 vehicles or more must sell a minimum of 2 % of these as zero-emission vehicles (such as electric cars). However, individual countries have different conditions and requirements. This feasibility study of implementing electric vehicles in urban areas is a worthy, valuable topic for every country to examine.

Purposes of the study

During the 1970s, many countries funded the development and research of electric vehicles in order to reduce dependency on Arabian oil. With the passing of time, this situation has gradually diminished due to the longer theoretical life of the total proven oil reserves, which was over 42 years in 1993 compared with 28 years in 1980 (Daniels, 1994). However, many countries are trying to decrease urban air pollution and consider electric vehicles as a possible solution (Paymaster, 1994). Therefore, most developed countries have made rules and encourage the development and introduction of electric vehicles. However, this encouragement has, in most cases, relied upon the view of the problems taken by the government in individual countries. With this difference, individual countries adopt their own methods to encourage the research and development of electric vehicles and the infrastructure needed to support them

(Motor Industry Research Association, [MIRA],

1992).

Marketing research results show that the drivers prefer this preferential treatment to cheaper pricing strategies. It guarantees them less stress, more comfort and saves time. Electric cars are subsidized by the government since they have to compete with conventional cars, especially in the market price, flexibility, economy and long life cycle. Until now, electric cars have not been really competitive. However, the most urgent question is: When is the suitable time to implement electric vehicles in urban areas for every developing and developed country? In other words, how to find a balance point between the economy and the environment is an important research topic at present. Therefore, the purposes of the study are to solve this problem and to develop an implementation model of electric vehicles that can improve the air quality of urban areas.

Literature Review

一、Battle of Electric Cars and Internal-combustion Engine cars

In the early 20th century, the electric car had more advantages than the internal combustion engine car in that the electric car was quieter, easier to drive and start. Then, the electric motor was invented and used in the internal combustion engine in 1921. The internal combustion engine equipped with an electric motor became more operative and convenient than before. In

addition, Henry Ford invented the mass manufacturing method adapted in the manufacturing procedures of the internal combustion engine car. As a result, the electric car lost its competitive advantage over the internal combustion engine car.

二、Energy Crisis

Due to the oil crisis of 1970s, people were interested in again developing electric cars. This was the result of an international political situation. Once

the crisis was over, people had no further interest in the development of electric cars. Lately, however, people have become concerned about the effect of pollution of the environment and recognize the need to keep a clean environment. A lot of alternative sources of energy have been considered for the propulsion of vehicles such as ethanol, methanol, batteries, hydrogen, solar cells, fuel cells, natural gas, and so on. These sources all have the same advantage of creating lower pollution than that produced by vehicles using gasoline. When considering the long-term goal, the only energy source to produce zero emission in urban areas is the electric battery. That fact has spurred renewed interest in the development of electric cars in the 1990s.

三、Mandatory Regulations for Electric Vehicles

In the USA, the Environmental Protection Agency (EPA) estimated that motor vehicles on the highway would account for approximately 38% of NO_x emissions and 22% of anthropogenic VOC (volatile organic compound) emissions and that migration into the Ozone Transport Region (OTR) of non-LEV (Low Emission Vehicles) vehicles would result in a 28 ton/day increase in NO_x and a 16 ton/day increase in VOC emissions in 2005 compared to EPA estimates of highway vehicle emissions in the OTR under the Ozone Transport Commission Low Emission Vehicle program (Federal Register, 1995). Nevertheless, the US legislated the alternative fueled vehicles (including electric vehicles) shall be sold for State government fleets, including agencies thereof but excluding municipal fleets, according to the following percentages for the related model years (Federal Register, 1996):

10% for model year 1997;

15% for model year 1998;

25% for model year 1999;

50% for model year 2000; and

75% for model year 2001 and thereafter. (p. 13)

However, if a covered person or business agency, whose principal job is generating, transmitting, importing, or selling electricity (one of alternative fuels) have notified the Department of Transportation (DOT) its intent to acquire electric motor vehicles, then, the following percentages of new light duty motor vehicles acquired shall be alternative fueled vehicles, according to the follow (Federal Register, 1996):

30% from January 1, 1998 to August 31, 1998;

50% for model year 1999;

70% for model year 2000; and

90% for model year 2001 and thereafter. (p. 20)

In Europe, action is only focused on tax incentives at present; whereas, in Japan the action for using electric vehicles is progressing in the form of cooperation between government and industrial sectors to establish a self-sustaining market (Paymaster, 1994). The Japanese Ministry of International Trade and Industry (JMITI) has set an aim for Japanese auto manufacturers to produce at least 200,000 EVs for use by federal, provincial, and local government agencies, utilities, and the general public, by the year 2000 (Winn, 1994).

四、Electric Vehicles

The electric car has been used on the road since the early days of automobiles. At that time, the electric car had the same position as the internal combustion engine car. The main difference between the electric car and the internal combustion engine car is the driving power (Wu et al., 2000). It is very easy to recognize an electric car or an internal-combustion engine car. From

their names, the electric car equipped the electric motor as the driving power; whereas, the internal combustion engine was equipped with an engine as the driving power. An electric vehicle needs to operate at high voltages to gain from the high efficiency of using an electric motor, but some loads have to operate at low voltages to increase their reliability, e.g., headlights. This means the electric car must have a highly efficient dc/dc converter to transfer a high voltage into a low voltage and to control and/or manage the driving system of the electric car (Chen et al., 2001; Chen, 2000; Yang, 1998).

However, the problem with electric cars is how to obtain a balance between the driving distance per charging and the battery cost. This means how to make electric cars travel far enough to meet the needs and expectations of the customers. Furthermore, one of the outcomes of this situation is to generate an interest in the development of hybrid cars.

五、Hybrid Vehicles

Simply speaking, the hybrid vehicle is a combination of the electric car and the internal combustion engine car (Shien, 2001). It employs both an electric motor and an internal combustion engine system as the driving powers (Yang, 2001). Even though it is not a zero-emission car, it can help in significantly reducing emissions. Accordingly, it can increase driving distances. Generally, it uses the electric propulsion system in urban areas in order to avoid producing emissions, but uses the internal combustion engine system in suburban areas in order to increase driving distances.

There are three different types of hybrid driveline: the series hybrid, the parallel hybrid, and the split hybrid (Schmidt-Bruchen and Adler, 1993; Chang, 2000)(See Figure 1). The torque of the series hybrid to the

wheels is from the electric motor and the engine powers equipped with a generator for recharging the batteries and supplying electrical energy after the batteries are discharged to a specified level. The parallel one with both the electric motor and the engine provides torque to the wheels either separately or together. In addition, the motor can be utilized as a generator to recharge the batteries, thus, the engine can produce more power than is needed to propel the vehicle. The front wheels of the split hybrid are driven by an electric driveline and the other wheels are driven by torque from the engine.

六、Review of Implementing Electric Vehicles in Taiwan

The first experimental electric car (THEV1) was developed by Tsing Hua University in 1973. In addition, Tsing Hua University continued to develop THEV2, THEV3, THEV4, THEV5, THEV6, THEV7, and THEV8. The mass production is from THEV4 to THEV5 between 1979 and 1989. The total production number is 191 electric cars manufactured by Tang Zone company (Hwang, 1999). The number of motorcycles has been increased every year since 1970s in Taiwan, especially in a big city, such as Taipei. According to the statistical report of the Transportation Department in 1998, the number of motorcycles has reached ten million. This means one out of two people owns a motorcycle in Taiwan (Edition Division, 1999). This terrible statistical report prompted the Taiwan government to encourage someone or a research department to develop the electric motorcycle in the 1980s. Until now, electric motorcycles have just begun to be used in Taiwan. For example, Sanyan Motorcycle Company has manufactured one type of the electric motorcycle that is running in some colleges and/or universities and in some of governmental divisions.

Likewise, some private companies have already produced electric bicycles to be used in local towns (Edition Division, 1997). However, at the present time, no central, local, or city governments have decided when, where, and what type of electric cars should be implemented.

There are four regulations to develop electric vehicles in Taiwan (Hwang, 1999). 1)The first one is the development strategy of the automotive industry made by Executive Yuan in 1992. That is the first time electric vehicles were put into the executive policy of Executive Yuan. 2)The second one is the mandatory 2% of the electric motorcycles regulation made by Environmental Protection Bureau on March 1996. The sixth line of the air pollution emission standard of transportation tools aims at 2% of the production number will be electric motorcycles in 2000. 3)The third one is the meeting of the technology council of Executive Yuan. The conclusions of that meeting were

to search other countries to establish the standards related to electric vehicles and establish the infrastructure environment of the electric vehicles. 4)The last one is an action plan of developing electric motorcycles made by Executive Yuan in 1998. The action plan states that the numbers of electric motorcycles will be 10,000 in 1999, 40,000 in 2000, 80,000 in 2001, 150,000 in 2002, 200,000 in 2003, 400,000 in 2006, and 3,000,000 in 2010.

There are two types of electric vehicles incentives: one for producers, the other for users. For producers, the government compensates with a budget to develop electric vehicles or they can apply for a 20% deduction on their income tax. For users, consumers can apply for a NT\$5,000 cash back from the Environmental Protection Bureau after buying a new electric motorcycle and can chose between the following: two times free change of Lead-Acid battery or one-time free change of Ni-MH battery.

Methodology

The research methods used in this study are scenario techniques (ST) and Delphi techniques, which are forecasting methodologies. ST relies on the view of a high point like an eagle hovering in the air. That the eagle knows where it can find its food is based on its past experience. Then, it flies up to a high position and can clearly look down at what happens on the ground. It flies down and easily catches its subject. Delphi techniques rely on the view of a group of experts who have more knowledge in their field, but they cannot meet together to discuss an issue.

— 、Philosophy of Scenario Techniques

If we already knew what would happen in the future, then scenario techniques would not be created any more. In other words, there are a lot of things beyond our control. Let us go back to look at the last century. Almost no one expected the following events and/or products: Airplanes, artificial satellites, computers, intercontinental missiles, oil crisis, the English channel tunnel, transplant surgery, World War I, World War II, etc.

How do human beings minimize the effects of things happening in the future that we cannot control? As we mentioned before, these events and/or products did not suddenly happen. There must have been some hint(s), reason(s), and/or pilot event(s) before they happened. These hint(s), reason(s), and/or pilot event(s) are what we want to understand. Currently, there are still many factors affecting the future world such as: AIDS illness, air pollution, distraction of the ozone shield, knowledge explosion, depletion of crude oil, etc.

Jumping outside of the system is a very useful method to minimize the things beyond human control. This is similar to Laotzi and Chuangtzi philosophy. They were philosophers of China about 3,000 years ago. Chuangtzi said that I am a big fish freely swimming in the southern sea of China. One day I became a big bird and flew into the air. So, I could clearly see what is happening on the earth. Then, I flew down to the earth and could clearly see what I was imagining when flying up in the air. Jumping outside of the system means that I do not think every thing is going the way I saw it earlier. For example, if a person thinks scenario techniques will not work well in this study because he/she knows no one who has used them in the field of the electric vehicles, then we can say that he/she is not able or willing to jump out of the system to think about the scenario techniques.

二、Principle of Scenario Techniques

Scenario refers to the condition of the environment that includes past, present, and future situations. How to analyze, predict and/or control these situations is called scenario techniques.

The theory of scenario techniques is based on analysis of the past. This point is very important for

predicting the future scenarios, because there must be some reason for everything that happens. These things have mostly some specific characteristics that happen gradually, rather than suddenly. Because of these, we can use them to assume the different scenarios of the future and prepare solutions at the moment before they happen. In case of the different scenarios happening, we know how to deal with them with different solutions and are not afraid of facing them. That means we can possibly control future situations or events.

ST is like a telescope and multiple-scope. Please refer to Figure 2 and note the position labeled "resent." It can foresee the rough shape of the future and clearly see the shape of the present based on the analysis of the past and the view from standing on the high point. The analysis of the past can give us a limited range (See the right-side circle of Figure 2) to stand on the high points. The view of standing on the high points can simulate us to think about the future situations and prepare possible solutions to face the different situations that may happen in the future. Usually people assume three to five scenarios to simulate the future situations shown in the right side of Figure 2, such as Scenarios A, B, C, D, and/or E.

三、Procedures of Scenario Techniques

Basically, there are eight steps of scenario techniques to predict the marketing of the electric vehicle in Taiwan. For developing future perspectives that can be used to derive consequences and measurements for the future, the following eight steps must be passed:

1. Problem analysis -- structuring and defining of the investigated area;
2. Area analysis -- identifying and structuring of

the most important influence factors that work on the investigated area;

3. Projections -- finding out the developing tendencies and critical descriptions for the investigated areas;

4. Assumption gathering -- creating and choosing consistent assumptions;

5. Scenario interpretation -- interpretation of the chosen area scenario;

6. Disturbing events analysis -- introducing and analyzing the influences of significant disturbing events;

7. Effect analysis -- developing the scenario (i.e., deriving consequences for the investigated area);

8. Measurement planning -- developing measures and plans.

The diagram shown in Figure 3 explains the abstraction process, which is followed by the scenario techniques. It is very easy to compare this process with a helicopter, which from a starting point (concrete problem) lifts and, finally from a bird \square perspective, sees the connections and interconnections of the problem with its investigated area. From this total view, it is possible to develop different future-oriented solutions for the problem. The helicopter then returns to its landing position, and the problem can be solved (regarding the different alternative solutions).

四、Delphi Techniques

Delphi techniques were mainly used in this study. First of all, a mailed questionnaire was employed to collect the opinions of experts who came from university, industry, and government. The research design was predictive, not descriptive and not experimental, in approach according to the purposes of

the study (Murray & Jarman, 1987; Miller, et al., 1991). In other words, an attempt is not made to describe and manipulate but to collect subjects' opinions based on fair and unbiased conditions. Such a survey approach is highly representative and minimally expensive (Hackman & Oldham, 1975). It also promotes accessibility to frank and accurate information about the objectives of the local politics.

The instrument developed by the researcher based on the literature review was used for conducting the study (Scheibe, et al., 1975; Delbecq, et al., 1975; Miller & Husman, 1991). A questionnaire was sent or faxed to each expert for collecting data related the purposes of the study. Secondary, the researchers made a comparison of all experts' opinions to find out the agreeable and/or disagreeable questions of the questionnaire. Then, they sent out the results of the comparisons to each expert again and asked him/her to write down their reasons for positive or negative responses. We repeated the preceding steps until all experts' responses were consistent with each other (Delbecq, et al., 1975; Eason, 1992).

五、Procedures of Delphi Techniques

The research procedure used in this study is specified below:

1. To identify research problems.
2. To review the related literature on electric vehicles.
3. To prepare a proposal to be discussed with the developmental committee of the experts on the electric vehicles.
4. To identify the population and representatives of the different departments for this study.
5. To decide on the purposes of the study.
6. To list all names and addresses of the developmental committee of the experts.

7. To randomly select the sample of the committee of the experts.

8. To select, develop, and modify an instrument for the study.

9. To mail the instrument (questionnaire) to the experts selected.

10. To follow up the survey by using Delphi techniques.

11. To collect, code, and analyze the data from the

questionnaire.

12. To mail the second questionnaire to get consistent opinions on each question of the questionnaire.

13. To repeat the step 9 to 12 until all experts have the same opinions on each question.

14. To write a final report, summary, and conclusion.

15. To make recommendations based on the findings.

Model Development of Implementing Electric Vehicles

According to the principle of ST, the evaluation model of implementing electric vehicles in urban areas is first to analyze the past scenario of the new policy enforced in the automotive industry in different countries. The environmental pollution related to motor vehicles is reviewed in American, Asian, and European continents. If the pollutants were emitted by motor vehicles and resulted in the damages of human beings, animals, and/or plants, the zero-emission vehicles must be implemented to replace the existing vehicles. So, this point is a priority to determine when the government should start enforcing the use of electric vehicles in urban areas (Lai et al., 1998).

Secondly, an estimate of the reserve quantity of crude oil in the world is needed to predict how many years are still available for use in motor vehicles. In addition, individual countries have different oil production and consumption levels. Therefore, the energy consumption and distribution of each country is individually analyzed. If a country reaches a stage of an oil crisis, such as, when there is not enough oil for national defense, then, that is the time to implement the use of electric vehicles.

Third, transportation analysis is used to evaluate the saturation point of the city fast-transit system. This point can be used as a reference parameter. That means this city cannot reduce the growth rate of motor vehicles. In other words, when the air pollution of the city will get continuously worse in the near future, that is the best time to implement zero-emission vehicles (like electric vehicles) in the urban areas.

Fourth, geographic analysis is used to evaluate the structure of the road. There are two different analyzing directions in the geographic analysis: how many kilometers per day per car in average and how much energy is needed per day on average. For example, if a car needs 400 km per day, this city is not ready to implement electric vehicles according to the present technology. Namely, a small or medium and flat city such as Taichung is better than a big and hilly city such as San Francisco to implement electric vehicles. Currently, the best driving distance is below 150 km per day per car.

Fifth, judgment analysis is used to clearly determine whether or not to implement specific types of electric vehicles in the specific areas. Generally, the

judgment value (JV) is equal to or smaller than one (1) that means this type of motor vehicle is a suitable car to be substituted for electric vehicles equipped with a fast on-board charger. The formula of judgment value is as follows:

$$\text{Price of EV} + (\text{Tax} + \text{MF}) * 10 \text{ years} + (\text{Price/km}) * 100,000 \text{ km} + \text{RP}$$

$$\text{JV} = \frac{\text{Price of EV} + (\text{Tax} + \text{MF}) * 10 \text{ years} + (\text{Price/km}) * 100,000 \text{ km} + \text{RP}}{\text{Price of PV} + (\text{Tax} + \text{MF}) * 10 \text{ years} + (\text{Price/km}) * 100,000 \text{ km} + \text{RP}}$$

$$\text{Price of PV} + (\text{Tax} + \text{MF}) * 10 \text{ years} + (\text{Price/km}) * 100,000 \text{ km} + \text{RP}$$

Where:

JV: judgment value

EV: electric vehicles

PV: petrol vehicles

MF: maintenance fee of the engine or the motor

RP: residual price

Finally, the government can adjust the judgment value according to the steps one through four. Then, reduce the tax or price/km of electric vehicle or give more incentives and policies, such as: electric vehicles can use a specific lane during rush hours or the public parking lots provide a special parking places only for electric vehicles.

The evaluation model of implementing electric vehicles in the urban areas is shown in the following diagram (Figure 4):

Conclusions

This model is a draft for a feasibility study of implementing electric vehicles in the flat urban areas. It is based on the principle of Scenario Techniques that were discussed in the literature review. It is recommended to do further studies in order to correct or modify this model. In addition, it is recommended to select a big city of a country to do the feasibility study

of implementing electric vehicles, and then to make some suggestions to the local government, based on the judgment analysis. An additional purpose for my presentation of this paper is to stimulate everyone to brainstorm about the strengths and shortcomings of this model and to give me some concrete suggestions for improvement

Definitions

Alternative fuel means methanol, denatured ethanol, and other alcohol; mixtures containing 85 % or more (or such other percentage, but not less than 70%, as determined by the Secretary, by rule, to provide for cold start, safety, or vehicle functions) by volume of methanol, denatured ethanol, and other alcohol with gasoline, or other fuels; natural gas; liquefied petroleum gas, hydrogen; coal-derived liquid fuels; fuels (other

than alcohol) derived from biological materials; electricity (including electricity from solar energy); and any other fuel the Secretary determines, by rule, is substantially not petroleum and would yield substantial energy security benefits and substantial environmental benefits (Federal Register, 1995).

Zero-emission vehicle (ZEV) means any vehicle that is certified to produce zero emissions of any criteria

pollutants under any and all possible operational modes and conditions. Incorporation of a fuel fired heater shall not preclude a vehicle from being certified as a ZEV provided the fuel fired heater cannot be operated at ambient temperatures above 40 degrees Fahrenheit and the heater is demonstrated to have zero evaporative emissions under any and all possible operational modes and conditions (F.R. Vol. 60 No. 195-10.10.1995. p 38).

Model year means the manufacturer has an annual production period (as determined by the Administrator of the Environmental Protection Agency) that includes January 1 of any particular calendar year. If the manufacturer has no annual production year, the model year is the calendar year (USA-PART 501, 08/1995, p 4).

Model type means a particular class of an automobile (USA-PART 501, 08/1995, p 4).

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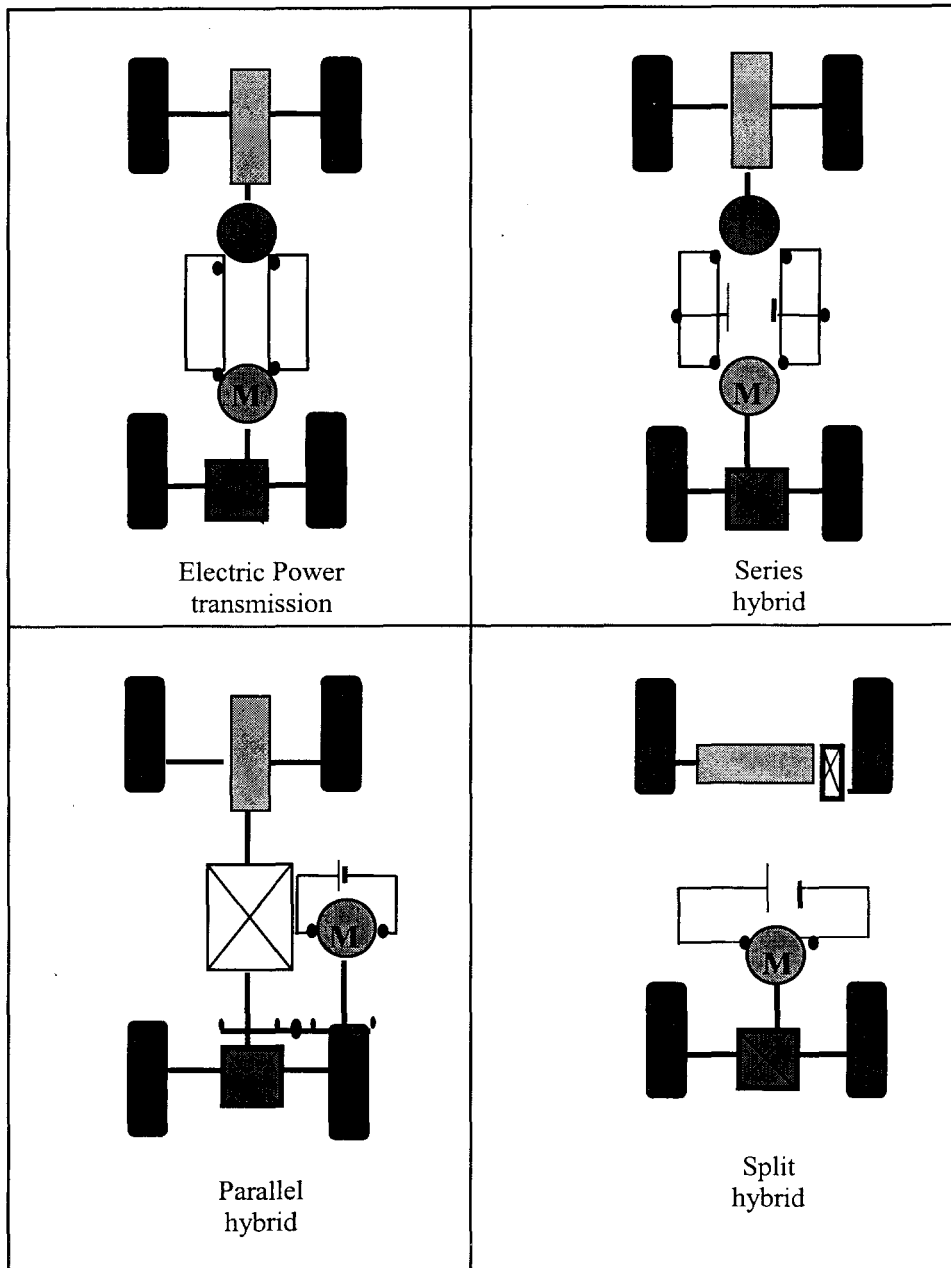


Figure 1. Alternative Drive Concepts With Electrical Components
(Source: Schmidt-Brucken and Adler, 1993)

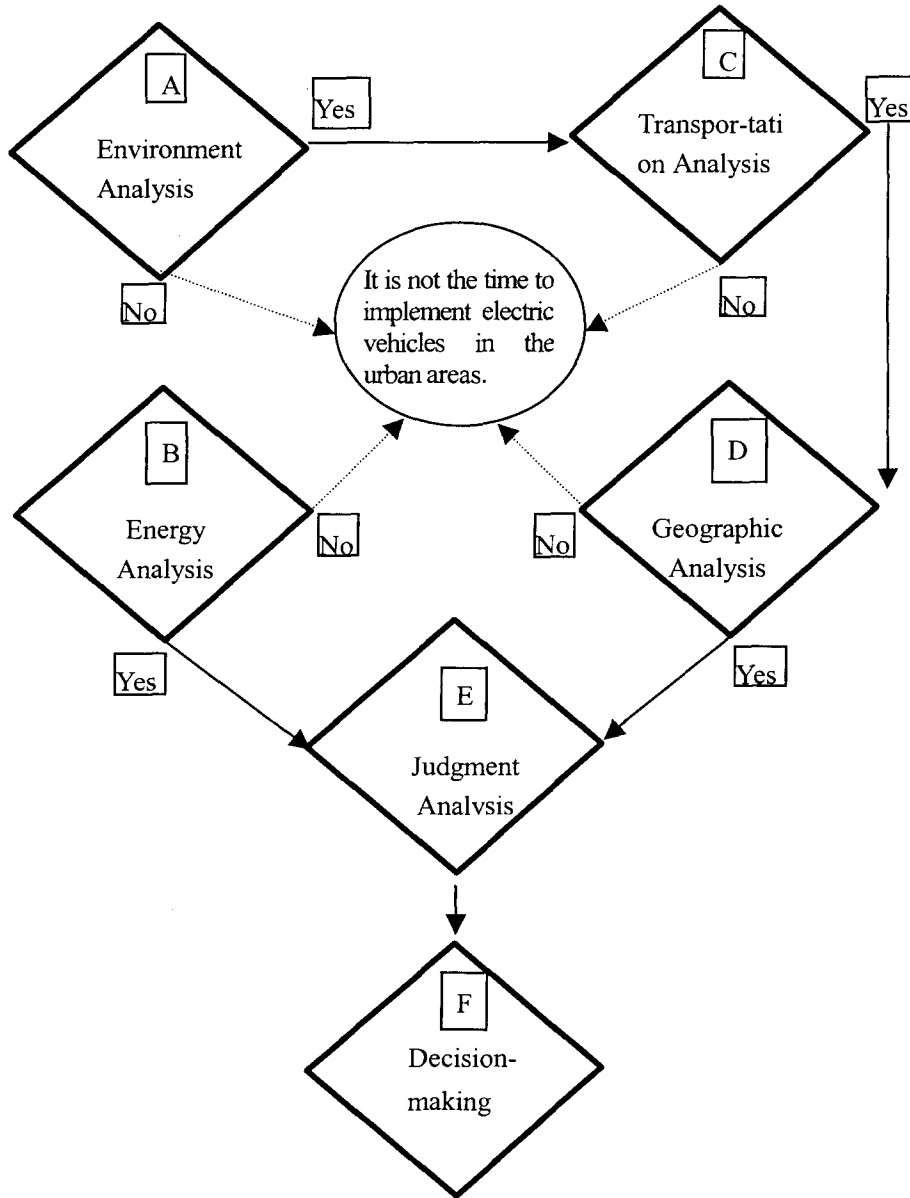


Figure 4 Evaluation Model of Implementing Electric Vehicles

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電動車輛執行模式之建構研究

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大都會之空氣污染一直持續惡化中，世界各國皆投資大筆經費，盡其所能的尋找解決之道(吳浴沂，民 88；廖峻慶，民 88)。雖然車輛的使用對各國的經濟成長貢獻頗大，但是，相對的也造成了大都會的空氣污染(楊模華，民 87；陳志信，民 89；楊燕枝，民 90)，然而如何在經濟與環保之間尋找其平衡點，是每個研究科技單位(Research and Technology Organization)的主要任務。本研究的主要目的乃祈求透過情境科技(Scenario Techniques)方法來達成經濟與環保間的平衡。不過，正如我們所知，世間仍舊存有許多事物是超乎人類所能的，但是，我們還是要盡可能的去將傷害減至最低的程度。情境科技就是在這種情況下所產生的一種研究法，簡言之，情境科技是依其過去的情況，分析與預測未來的情境，然後再回到現在來控制當前的情境；其中再輔以文獻探討與德懷術(Delphi Techniques)來建構出電動車輛的執行模式。

關鍵詞：電動車 空氣污染 情境科技 複合車 德懷術。