PERGAMON

Transportation Research Part D 4 (1999) 127–146

TRANSPORTATION RESEARCH PART D

The market acceptance of electric motorcycles in Taiwan experience through a stated preference analysis

Yi-Chang Chiu [a,1], Gwo-Hshiung Tzeng [b,*,2]

[a] *Transportation Engineering Program, Department of Civil Engineering, The University of Texas at Austin, Austin, TX 78712, USA*

[b] *Energy and Environmental Research Group, Institute of Traffic and Transportation, College of Management, National Chiao-Tung University, 114, 4F, Sec. 1, Chung Hsiao W. Road, Taipei, Taiwan*

Received for publication 9 January 1999

Abstract

The environmental and energy concerns of using motorcycles in urban areas have fostered the rapid development development of electric motorcycles (EMs) in Taiwan in recent years. EMs' zero-emission, low noise level and high energy efficiency features provide the promising potential to alleviate the severe environmental pollution problem caused by the existing gasoline motorcycles. This study summarizes the recent development of the EM. More specifically, this study aims to analyze the potential demand for EMs based on an interview survey using stated preference modeling approaches. Study results show that female motorists are the potential target market for EMs. Developmental and energy-use issues of EMs are also discussed in this study.

Keywords: Electric motorcycle; Air pollution; Energy use efficiency; Discrete choice model; Stated preference

1. Introduction

Urban areas in and around tropic–subtropic regions have long suffered from the air pollution problem due to the condensed population and high motor vehicle density as in Taiwan, Thailand, Indonesia, Malaysia, Hong Kong, Southern China, etc. Although Taiwan continues to demonstrate considerable improvement in air quality in recent years, the current level of air pollution is still far above that in other developed countries. Based on the monitoring records from the Environmental Protection Agency (EPA), the annual ratio of days with PSI (Pollutant Standards Index) greater than 100 dropped down to 6% in 1997. However, compared to the 2% of other

* Corresponding author. Tel.: +886-2-2314-6515 ext. 505; tel./fax: +886-2-23120519; fax: +886-2-2312-0082; e-mail: ghtzeng@ccsun5.cc.nctu.edu.tw

[1] Yi-Chang Chiu is currently a Ph.D candidate in Department of Civil Engineering, The University of Texas at Austin.

PII: S1361-9209(99)00001-2

developed countries (EPA, 1997), it is clear that Taiwan still needs continuing efforts to reduce the air pollution level.

There are over 21 million residents and 13 million motor vehicles in Taiwan. Motorcycles account for 64% of the total motor vehicles on the island (ITR/MTC, 1995). In the Taipei Metropolitan area, the total number of motor vehicles reaches up to 1.4 million, 54.8% of them are motorcycles. On average, one in every two residents own a motor vehicle and one in every three residents own a motorcycle. Nearly 30% of travellers choose motorcycles as their primary or secondary means of transportation for daily activities. Within the motorcyclist population, 30% are females (ITR/MTC, 1992; Chang, 1995). In this geographical area, mobile pollution sources contribute 99% of carbon monoxide (CO), 66.3% of hydrocarbon (HC) and 95% of nitrogen dioxide (NO_x). Motorcycles contribute 5% of CO, 60% of HC and 3% of NO_x. The pollutants that a four-stroke-engined 50 cc motorcycle (let alone the more emissive two-stroke-engined motorcycle) emits per km are usually much higher than a 2-litre passenger car; 2.7 times higher for CO and 6.7 times higher for HC and NO_x (EPA, 1997). These statistics indicate the excessive air pollution generated by the use of motorcycles. In other words, controlling motorcycles' emission levels is the key to improving the air quality in Taipei.

Motorcycles/scooters are popular in many countries. In Japan, scooters are the popular light duty vehicles for short trips. Cities in South Asian countries such as Bangkok rely heavily on motorcycles. Motorcycles are also popular in European countries (e.g. France, Italy) for leisure or sport purposes. In Taiwan, a large number of urban residents depend on motorcycles for all types of journeys (working, going to school or shopping) despite attempts to increase use of the public transport systems.

Several factors lead to the extensive use of motorcycle in urban areas in Taiwan: high population, mixed land-use, short daily trip distance, deficiency of parking spaces and the easy operation and maintenance of motorcycles. High population and mixed land-use are the typical characteristics of cities in Taiwan. Table 1 shows that Taiwan's population density is much higher than other major countries in the world. In the Taipei Metropolitan area, the population density even reaches up to 9700 persons per km^2.[2] The extremely high population density and the highly mixed land-use intensify the use of lands and lead to severe traffic congestion and deficiency of parking spaces (Amsden, 1991). In such a situation, the commuters' transportation solution is to use motorcycles because of their ease of riding, ease of parking[3] and low operating costs. The mixed land-use

Table 1
Population and motor vehicles densities in several countries (Environmental Protection Agency, 1997)

Items	Taiwan	USA	Japan	Germany	UK	The Netherlands	France
Population density (person/km^2)	589	27	332	228	238	414	105
Motor vehicle density (number/km^2)	367	20	211	99	102	185	59

[2]Taipei's latest demographic figures are population, 2,633,363 and city area, 271.8 km^2, according to the Taipei City Government.

[3]Certain portions of sidewalks along the major streets in Taipei have been designated as parking spaces for motorcycles in order to accommodate the demand for motorcycle parking.

usually results in short trip distance and contributes to the use of motorcycles. On average, commuters in Taipei travel 13.6 km daily, but only 12.2 km for motorcycle commuters (ITR/MTC, 1992; Tzeng and Chiu, 1995). These figures are significantly lower than the 15.8 km for cities with more distinct land-use regulation (Ferguson, 1995). The characteristic of daily trip distance aggravates the dependence on the motorcycle because the short trip distance usually magnifies disutilities of waiting time, walking time and parking costs that are generally incurred by automobiles or other public transportation modes. Motorcycles, particularly small-displacement-engined scooters,[4] have been welcomed by the public since the 1980s.

In order to reduce the environmental impact of motorcycles in urban areas, the EPA progressively restricts the emission levels of motorcycles. The third-stage emission standard for motorcycles, adopted from 1 January 1998, imposes stricter requirements in reducing pollutants for new model motorcycles. Table 2 shows the updated emission requirements for prototype, production and routine operation of new motorcycle models. The emission of CO is required to be reduced from 3.75 to 3.25 g/km for prototype motorcycles and from 4.5 to 3.5 g/km for newly manufactured models; $HC+NO_x$ reduced from 2.4 to 1.75 g/km for prototype and 3.0 to 2.0 g/km for newly manufactured models; and HC reduced from 7000 to 6000 ppm for both prototype and newly manufactured models. The standard for motorcycles emission in routine operation remains unchanged.

In addition to the new emission standards, industry and government are seeking more effective measures to reduce the air pollution caused by motorcycles. The zero-emission, low noise level and high-energy efficiency features make electric motorcycles (EMs) a very appealing solution. Developing EMs comes with many other advantages. It not only helps reduce the dependence on gasoline, but also stimulates the technological innovation of automobile industries in Taiwan (Chiang, 1992). These visualised advantages identified EMs as one of the most important industries and as one of five major pollution prevention approaches in the coming decades by the government (National Science Council, 1997).

Although EMs are environmentally friendly, they underperform compared with gasoline motorcycles in many respects, particularly in speed and cruise distance between refueling/recharging. The inferior operating performance of EMs gives broad concern for their market acceptance,

Table 2
The second-stage and third-stage emission standard for motorcycle models (Environmental Protecton Agency, 1997)

Stage	Items	Emission standards			
		Motion mode		Idling mode	
		CO (g/km)	$HC+NO_x$ (g/km)	CO (%)	HC (ppm)
	Prototype (new)	3.75	2.4	4.5	7000
2nd	Production (new)	4.5	3.0	4.5	7000
	Operation (routine)	–	–	4.5	9000
	Prototype (new)	3.25	1.75	3.75	6000
3rd	Production (new)	3.5	2.0	4.0	6000
	Operation (routine)	–	–	4.5	9000

[4]The official definition of small-engine-volume model is motorcycles with displacement volume of less than 90 cc.

particularly from EM developers and government agencies. EM developers attempt to draw a clear picture of consumers' response to EMs' attributes in order to better allocate their research resources and initialize a viable market size. The government agencies are seeking public opinion in order to establish policies which take into account various aspects in developing the emerging vehicular technologies. Although several studies discussed the purchase behavior in relation to motorcycles in Taiwan (Chang, 1979; Chin, 1986), very few studies have been conducted on EMs. This is because it is a new technology with new attributes that previous research has not covered or explored. A new study with pertinent modeling approaches is, therefore, desirable.

This study aims to understand the market response and the potential demand for EMs. This study is the extension of the research project that addressed the issues of potential demand for the EMs (Tzeng and Chiu, 1995). Because EMs are still in the prototype testing stage, there are little significant market data available for analysis. This situation warrants the use of the stated preference (SP) approach in model development. Two stages of surveys were conducted. The first-stage survey focused on the determination of pertinent attributes to be used in SP choice models. Hundreds of respondents were presented with questions on the critical factors affecting their decisions to purchase motorcycles.

Statistical analyses were applied in order to determine the market segmentation of motorcycles. Gender was found to be the most significant factor in market segmentation; namely, males and females had significantly different preferences in choosing motorcycles. In the second-stage survey, hundreds of households were interviewed with SP questions relating to motorcycle choice. Respondents were asked to express their preferences for hypothetical alternatives in terms of their attributes. In the model calibration, multinomial logit models (MNL model) were found to be pertinent in describing choice behavior.

The rest of this paper is organized as follows. A synthesis of EM development and a brief introduction of the SP approach are presented in Section 2. Section 3 describes the contents of the two-stage surveys. The motorcycle choice model results are discussed in Section 4. Section 5 addresses other considerations of market penetration, social and economic impacts. The final section concludes this paper.

2. Characteristics of EMs and SP approach review

This section contains two sub-sections: Section 2.1 discusses the unique features of the EM and its current development status; Section 2.2 reviews previous electric-vehicle related studies and the SP modeling framework.

2.1. Characteristics of EMs and current development progress

Research into EMs in Taiwan originated in the early 1980s due to the petroleum crisis. At that time, hundreds of EMs were manufactured and sold to domestic and foreign markets. EMs, similar to other electric vehicles, use batteries to power the motor and move the vehicle. Transmission and electronic control systems are designed to control the speed and operation of the vehicle. The operational characteristics of the EM significantly differs from the gasoline motorcycle in two ways. First, the EM is powered by electricity. There is no tailpipe emission produced during vehicle operation, whereas the gasoline motorcycle combusts gasoline and emits significant pollutants. Second, the EM propulsion motor entirely stops when the vehicle stops and the accelerator is released, whereas the gasoline motorcycle engine maintains an idling speed. These features supposedly make EM a more efficient motorcycle model in energy consumption and reducing emission than the conventional gasoline motorcycle.

Several prototype models have been announced by research groups or industries in different countries in recent years. As Table 3 presents, several newly announced EM models, City-Bike, SWAP and ZES2000, were released by companies or research institutes in Taiwan (Chiang, 1992; Shang Wei, 1997). Most of these models are currently at pilot field-test stage (Tzeng, 1993; Tzeng and Chiu, 1995). Japanese auto-makers announced their prototype in 1994 and have been conducting testing with government agencies (Tokyo R&D, 1994; CALSTART, 1998). Other European auto-makers (Borde, 1997; CALSTART, 1998) presented different models of EMs, including a hybrid electric scooter (Piaggio, 1998) which is equipped with an inter-switchable combustion engine and electric motor. These models, in general, have a cruise range between 50 and 80 km. The maximum speed ranges from 30 to 80 km/h.

In general, EMs underperform compared with gasoline motorcycles in speed and cruise range due to the limited battery capability and energy density. The undesirable cruise range was found the main obstacle for market acceptance (Calfee, 1985; Bunch et al., 1993). To synergize research efforts and facilitate development progress, government agencies and industrial entities have jointly initiated several integrated development programs to improve the EM's performance and to design the infrastructure system for future deployment.

A formal strategic alliance, which was sponsored and supervised by the Energy Commission, Ministry of Economic Affairs, was founded in 1992. The strategic alliance, led by the Industrial Technology Research Institute, incorporated academia and industry to tackle four critical issues

Table 3
Specifications of new released electric motorcycle models and comparison with the generic gasoline motorcycle

Make	Generic gasoline motorcycle	Kang-Yang	Shang Wei	ITRI	Peugeot	Tokyo R&D	Piaggio
Country	Taiwan	Taiwan	Taiwan	Taiwan	France	Japan	Italy
Model	–	City-Bike	SWAP	ZES2000	–	ES600	Zip & Zip[a]
Year	–	1991	1997	1994	1996	1994	1997
Body style	–	Scooter	Scooter	Scooter	Scooter	Scooter	Scooter
Max. speed (km/h)	80–100	40	80	50	45	55	30/60
Distance between recharge (km)[b]	80–120	50	80	65	70	80	45/80
Climbability (degree)	30	12	30	12	12	21	–
Weight (kg)	85–110	110	130	100	115	117	–
Battery type	–	Pb–acid	Pb–acid	Pb–acid	Ni–Cd	Pb–acid	Pb–acid
Number of batteries	–	4	4	4	3	8	2
Charging time (h)	–	4–8[c]	3–8	4–8	4–8	4–8	4–8
Acceleration noise (dB)	72	–	58	58	–	–	–

[a] This model of scooter is the first gasoline-electric hybrid motorcycle.
[b] This is measured under constant speed (30 km/h) driving condition.
[c] Regular mode takes 8 h, quick mode charge to 60% of the capacity in 4 h.

in EM development: power supply, electrical control and transmission, system design, and planning and integration. The alliance is also responsible for establishing specification standards, facilitating technological and informational exchanges, and conducting promotional activities.

The government's determination to facilitate EM production is also demonstrated in legislation and public education. The third-stage emission standard for motorcycles requires that all motorcycles sold by major manufacturers must be electric, with at least 2% by the year 2000. The targeted market share of EM is set to be 40,000 by the year 2000 and 400,000 (about 40% of the motorcycle market) by the year 2006 (Executive Yuan, 1997). The National Science Council announced EM as one of five major directions for pollution prevention. All EM purchasers will receive a subsidy[5] of NT$5000 and two battery replacements. EMs qualify for goods tax exemption and are recognized as environmentally friendly products. Several pilot studies are in progress to capture motorists' actual use experiences and more than 300 vehicles have been deployed and tested in the field.

The EM uses electricity as its propelling power, thus the tailpipe emission is nearly zero. However, to accurately estimate the air pollution indirectly incurred by the use of EMs, the emissions generated by power plants should be considered. EPA estimates EMs generate approximately 0.013 g/km of particulate matters (PM10), 0.105 g/km of SO_x, 0.043 g/km of $HC + NO_x$ and 4.31 g/km of CO_2 (EPA, 1993). Compared with the third-stage emission standard for gasoline motorcycles, EMs certainly generate less CO, $HC + NO_x$ and CO_2. The EPA calculates the estimated pollution reduction in CO as 2.8%, $HC + NO_x$ as 2% by the year 2010 when about 9 million EMs are sold, replacing one third of the gasoline motorcycles. From the viewpoint of monitoring and regulating air pollution sources, it is easier to control the pollution from power plants than that from millions of mobile motorcycles, which makes the objective of reducing the air pollution easier to achieve.

EMs are more efficient than gasoline motorcycles in energy utilization. An EM outputs 41% of its input energy, which outperforms the 15% of a gasoline motorcycle. As Table 4 shows, EMs mainly lose energy in charging/discharging. They save energy because of efficient motor and better transmission design, and no idle spinning when the vehicle stops. If the energy loss during the electricity generation is also considered, the EM's energy efficiency is about 15%, which is similar to the gasoline motorcycle. It suggests that EMs are advantageous in energy utilization if they are charged during evening off-peak period of electricity consumption. According to the current power provision structure in Taiwan, the estimated energy saving by replacing one third (3 million) of the total number of motorcycles in the year 2010 is about 245 kilolitres of gasoline, equivalent to 3% of the annual gasoline consumption. If 80% of EMs are charged during the evening off-peak period, the energy utilization efficiency will be increased by 4.2% (EPA, 1997).

The competitiveness of EM in terms of operating costs depends on the government's subsidiary policies. The battery cost contributes one third of the production cost and is the major barrier for lowering the production cost. The battery cost is expected to be reduced once the EMs reach mass production, but the reduction may be limited. The operating cost of EMs is also affected by the battery cost considerably. Under normal use conditions, a battery should be replaced after 300 times charging/discharging cycles, equivalent to a 5-year operation. The estimated traveling distance of a motorcycle is about 15,000 km in such a period of time. The operating cost of an EM,

[5]The maximum number of purchases which will qualify for a subsidy is 40,000 by the year 2000.

Table 4
The estimated energy efficiency of electric motorcycles (IDB, 1993)

Energy conversion process			Efficiency (%)	
Power generation	*Profile (%)*			
Hydraulic		6.6	85.0	
Fossil fuel		59.3	35.0	
Petroleum	(16.2)			
Coal	(35.4)			
Natural gas	(2.1)			
Others	(5.6)			
Nuclear		32.8	32.1	
Cogeneration		1.3	80.0	
Output		100.0		37.9
Power distribution loss				
Transmission			3.36	
Distribution			2.98	
Output				93.7
Battery				
Charger			80	
Charge/Discharge			80	
Output				64.0
Vehicular propulsion				
Transmission			90	
Motor			80	
Propeller			90	
Output				64.8
Overall efficiency				41.5 (14.7)

including the electricity, battery depreciation and regular maintenance, is approximately NT$1.16/km, as Table 5 shows. It is lower than that of a gasoline motorcycle by only a slim margin. The operating cost of the EM that excludes the battery cost is merely NT$0.16/km. The current subsidy provided by the government agency covers part of purchase cost and the battery replacement and will be discontinued once the number of recipients of the subsidy reaches 40,000. The expiration of the subsidy may also have an impact on the operating costs of EMs.

The EM is also renowned for other ergonomic features. The EM outperforms the gasoline motorcycle in noise level and vibration. Based on testing results (Chiang, 1992), EM's acceleration noise is 58 dB. Compared with 72 dB of a gasoline motorcycle, EM is more acoustically friendly. About 67% of motorists have had their legs burnt by the tailpipe of motorcycles (Chang, 1995). Most current designs of motorcycles could not protect motorists, especially the backseat passenger, from leg injuries caused by touching the tailpipe. However, the EM's high-temperature component is not exposed outside of the vehicle body, thus causing less harm and threat to motorists.

Table 5
The operating cost of electric motorcycle versus gasoline motorcycles[a]

Cost	Electric motorcycle	Gasoline motorcycle
Purchase cost (NT$/purchase)		
Battery (Pb–acid)	10,500	400
Production cost	31,000	20,000
Production retail price	56,000	35,000
Operating cost (NT$/km)		
Battery depreciation included	1.16	1.23
Battery depreciation excluded	0.16	1.20

[a] The exchange rate of US$ to NT$ was US$1 = NT$33 in 1998.

2.2. Previous studies of EMs using stated preference (SP) approaches

SP approaches involve presenting respondents with a series of hypothetical products that have been characterized in terms of their attributes, and collecting responses that provide preference information about the relative importance of the attributes. SP methods are the most feasible means of approximating laboratory conditions on a large scale and have a number of advantages over the conventional revealed preference methods (Kroes and Sheldon, 1988) which, in contrast, are based on actual travel choices.

SP methods are common in marketing and applied decision research literature (Louviere, 1988). They have been applied in many consumer behavior and market forecasting studies; including, forecasting the demand for new local rail services (Preston, 1991) and telephone subscription demand (Madden et al., 1993) and valuing environmental amenities (Adamowicz, 1994). There were many studies forecasting the demand for electric vehicles using various types of econometric modeling approaches (Kurani et al., 1996). Although there is some skepticism, SP approaches mostly inspire confidence in analyzing and forecasting new technology, products and services. Several SP studies of electric or alternative-fuel vehicles have been conducted in the past decade (Beggs and Cardell, 1980; Train, 1980; Beggs et al., 1981; Calfee, 1985). Some recent studies are particularly motivated by the pressing need for clean-fuel vehicles due to the deteriorating environmental qualities in the California Basin area (Bunch et al., 1993).

Studies of EMs have not been recognized because EMs were not ready for commercialization until recent years. This study is a pioneering exploration of the demand for EMs. A careful and complete interview-survey was conducted to collect responses in order to ensure model quality. In addition, the implicit impact of EMs on environmental and energy management are discussed.

3. The SP survey

This section describes the procedure, results and preliminary findings of the survey. The survey in this study was composed of two stages. The first-stage survey mainly focused on identifying pertinent attributes and tolerance limits of attributes, both of which would be used for describing the hypothetical choice alternatives. Literature review and consultation with experts were involved in the final determination of attributes. The second-stage survey is the extensive SP survey.

3.1. The first-stage survey

In the first-stage survey, respondents were randomly selected and interviewed at gas stations in Taipei City. The questionnaire contained three parts: socio-economic data, important factors in choosing motorcycles and corresponding tolerance limits. The first part included motorcycle ownership, use frequencies, use purpose, weekly driving range and need to buy a motorcycle in the coming 3 years. The second part contained 15 pre-specified potential attributes. Respondents were asked to freely specify up to 7 attributes. For each attribute that the respondent selected, the tolerance limit was also requested. The tolerance limit of an attribute was defined as an upper or lower bound beyond which the associated alternative was definitely rejected from consideration. For those attributes contributing negative utilities, the upper limits were requested, otherwise, the lower limits were requested. For example, for the attribute "purchase price", the respondent was asked how much beyond the purchase price the alternative was definitely unacceptable. The tolerance limits of attributes help to better define attribute levels in the second-stage questionnaire design.

The data collected during the first-stage survey were further placed into statistical analyses. All the potential attributes were ranked based on the frequencies of being chosen by respondents. Table 6 shows the top 10 attributes that respondents considered essential in choosing a motorcycle. Purchase price is ranked in first place, which means being out-of-pocket raised the most concern. Emission level is ranked in fourth place, indicating that the public is concerned about environmental problems. It also implied that motorists would appreciate the EM's no-emission feature.

For the purpose of the SP approach, in order to alleviate the cognitive burden of a choice task that would already be complex, it was necessary to select a reasonable number of attributes, as well as to avoid intangible, abstract attributes. Therefore, this study only used important and quantifiable attributes as model variables. Reliability, agility and safety were difficult to measure

Table 6
Ranks of potential attributes

Attributes[a]	Rank
Purchase price[a]	1
Reliability	2
Maximum speed[a]	3
Emission level[a]	4
Operating cost[a]	5
Style (scooter or traditional)[a]	6
Agility	7
Safety	8
Cruise distance between refueling/recharging[a]	9
Acceleration	10

[a] Selected attribute.

and were excluded in this research. Table 6 indicates the attributes that were selected as variables in the model.

In addition to the selection of attributes, the corresponding tolerance limits were also calculated and summarized in Table 7. The tolerance limits were divided into two categories, male and female. From the discriminatory analysis that is explained in the following paragraphs, it is shown that gender is a pertinent criterion for market segmentation in motorcycle choice. The results in Table 7 show that males and females expressed considerably different tolerance limits. Males tolerate a higher purchase price, whereas females not only seek a lower purchase price, but also tolerate lower speed down to 20 km/h. Males also tolerate higher operating cost and cruise range than females.

Previous studies (Chang, 1979; Chin, 1986) concluded that gender was one of the appropriate market segmentation criteria for the motorcycle market. In order to verify if the motorcycle-purchasing behavior remains similar over time, this study conducted discriminatory analysis and again verified the conclusion. In establishing the discriminatory function, tolerance limits of all the selected attributes were treated as explanatory variables. Several different dependent variables were examined and the results are displayed in Table 8. From the percentage of prediction error and the Mahalanobis Distance that indicated the average distance between groups, gender certainly distinguished most of the attributes. Personal income was also an appropriate criterion. The discriminatory analysis results concluded the need for different designs of the second-stage questionnaire for male and female. Apparently, females' tolerance limits of attributes were lower than males. The attribute levels in the questionnaire for males were adjusted accordingly to ensure attribute levels remained in a reasonable range for the respective gender group.

3.2. The second-stage survey

A total of 256 random households in Taipei were recruited and interviewed by several researchers. One male and one female over 18 years old[6] were interviewed in each household. Contributing households were selected and supplementary interviews were conducted for those households that did not generate two respondents. The questionnaire contained two parts: (a) household and personal socio-economic information and (b) motorcycle choice questions. The socio-economic information included variables such as gender, age, highest education, household size, and personal and household income.

Table 7
Tolerance limits of attributes

Attributes	Male	Female
Purchase price (NT$) (upper bound)	48,900	34,500
Maximum speed (km/h) (lower bound)	43.0	20.0
Operating cost (NT$/100 km) (upper bound)	71.6	43.5
Cruise range (lower bound)	46.7	30.7

[6] In Taiwan, the minimum age requirement for a motorcycle driving license is 18 years.

Table 8
Discriminatory analysis results

	Gender		Household income		Personal income	
	Male	Female	< 40,000	> 40,000	< 40,000	> 40,000
Purchase price (NT$)	48,900	34,500	36,800	49.600	39,100	48,210
Maximum speed (km/h)	43.00	20.00	32.25	35.63	32.03	47.89
Emission (Y/N)	0.37	0.59	0.40	0.48	0.5	0.26
Operating cost (NT$/100 km)	286.44	174.14	210.00	282.29	231.20	295.81
Cruise range (km)	46.70	30.76	40.75	42.02	35.32	63.68
Mahalanobis distance	2.801		1.464		1.662	
Prediction error (%)	19.7		24.5		23.8	

The second and third parts contained two motorcycle questions. Comparing a higher number of questions presented to the same respondent in other studies (Bunch et al., 1993), the lower number of questions hopefully reduced response errors and endogenous biases caused by fatigue and repetitive responses. In motorcycle choice questions, three motorcycles—one EM, one low-engine-volume[7] motorcycle and one high-engine-volume gasoline motorcycle—were presented in a choice set. For all the attributes, four levels were used to cover most of the ranges. The attribute ranges for the three alternatives are also specified differently in order to reflect the different actual ranges of the three types of motorcycles. The question design used to produce the variation in attribute levels was an orthogonal main effect plan for a 2^{127} factorial in 128 runs. The orthogonal design, as a common exercise in SP approach studies, assured that attributes are virtually independent. Based on the conclusion of the first-stage survey, questions for females and males were designed with different attribute levels. The tolerance limits of attributes were taken into account to create the questionnaire for two market segments. The attribute ranges of the three motorcycles are presented in Table 9 and an example of motorcycle questions is presented in Table 10.

4. Calibration results of the motorcycle choice model

In coding and analyzing the data, we obtained valid entries from all male respondents and from 244 out of the 256 female respondents. Several possible models were calibrated with the data. Multinomial logit model (MNL), nested multinomial logit model (NMNL) and multinomial probit model (MNP) are the three major model specifications that were calibrated. In the choice set, two out of the three alternatives are traditional gas motorcycles; it is natural to assume the hierarchical choice behavior. The calibration results show this assumption is not supported, namely; the assumption of independence of irrelative alternative is sustained and the MNL model is adequate. The following sections present the MNL model results.

[7]A low-engine-volume motorcycle is defined as one with engine displacement of less than 90 cc.

Table 9
Attribute ranges of the three motorcycles

Motorcycle types	Attributes	Male		Female	
Electric motorcycle	Purchase price (1000 NT$)	30	55	30	45
	Maximum speed (km/h)	50	80	40	60
	Emission level[a]	0	0	0	0
	Operating cost (NT$/100 km)	6	18	6	18
	Cruise range (km/refueling)	80	110	55	85
Low-engine-volume motorcycle	Purchase price (1000 NT$)	30	50	30	50
	Maximum speed (km/h)	45	75	45	75
	Emission level	0.3	1	0.3	1
	Operating cost (NT$/100 km)	45	50	45	50
	Cruise range (km/refueling)	70	110	70	85
High-engine-volume motorcycle	Purchase price (1000 NT$)	47	70	47	70
	Maximum speed (km/h)	60	90	60	90
	Emission level	0.3	1	0.3	1
	Operating cost (NT$/100 km)	55	70	55	70
	Cruise range (km/refueling)	80	120	55	120

[a] The emission level is set as 0 for the electric motorcycle and 1 for the second-stage emission standard. The other attribute levels are set between 0 and 1.

Table 11 presents female, male and pooled MNL model results. These results show that the asymptotic t statistics of most of the generic variables are significant. The signs of these variables are intuitively reasonable as well. The assumption of segmented model against pooled model can be verified by examining the log-likelihood ratio test $-2(L(M)+L(F)-L(A))$, where $L(M)$ is the log-likelihood value of male model, $L(F)$ is the log-likelihood value of female model and $L(A)$ is the log-likelihood value of the pooled model. If $-2(L(M)+L(F)-L(A))$ is greater than the critical value, then the segmented model assumption is supported. In our model, $-2(L(M)+L(F)-L(A))=36.9>\chi^2(0.95;11)=19.68$ means the segmented models better explain the motorcycle choice behaviors than the pooled model. The log-likelihood index ρ^2 for female and male models are 0.30 and 0.28, respectively, which indicate motorcycle choice is well captured by the proposed models.

The results show that both females and males are, as expected, sensitive to purchase price. As discussed earlier, the purchase price of the EM is less competitive compared with the gasoline motorcycle. Besides subsidiary actions currently implemented by government agencies, other strategies, such as offering a leasing program, may also increase the incentive to own an EM.

Speed is found to be a significant attribute in this study but not in previous studies about electric vehicles (Calfee, 1985; Bunch et al., 1993). Two possible reasons explain why speed is an important feature affecting intention of choice. First, as discussed previously, a motorcycle's agility and high acceleration are appealing characteristics to most of the motorists. Because of the heavy traffic congestion in urban areas, motorists usually prefer moving as fast as possible in order to save time, as long as the traffic conditions and safety permit. Less worried about being caught by the law enforcers due to the heavy traffic condition, most aggressive motorists tend to

Table 10
Examples of motorcycle choice questions

	Electric motor(EM)[d]	LV motor[d]	HV motor[d]
Situation 1			
Purchase price ($)	1300	1100	2500
Maximum speed (km/h)	70	60	85
Operating cost ($/100 km)	0.8	1.3	2.2
Emission level	0	0.8	1
Cruise distance (km/refueling)	110	100	150
Style	SC	SC	ST
Environment friendliness	Yes	No	No
Preference score (1–7)[a]	( )	( )	( )
Situation 2			
Purchase price ($)	1000	1000	2200
Maximum speed (km/h)	50	55	75
Operating cost ($/100 km)	0.6	1.5	2.5
Emission level	0	0.7	0.5
Cruise distance (km/refueling)	90	120	130
Style	ST	SC	ST
Environment friendliness	Yes	No	No
Preference score (1–7)[a]	( )	( )	( )
Understanding about motorcycle and EM (1–7)[b]	( )	( )	( )
Questionnaire design (1–7)[c]	( )	( )	( )

[a] Please score from 1 to 7; 1, the most preferred; 7, the least. You can provide the same score to two or more alternatives if you feel they are similar in performance.
[b] For understanding about the motorcycle and the electric motorcycle; 7, very bare understanding; 4, medium understanding; 1, full understanding; 2, 3, 5 and 6, intermediate levels.
[c] For questionnaire design: 1, very poor design, distinct choice cannot be made upon it; 4, fairly good design, information provided is sufficient; 7, excellent design, distinct choice can be made upon it; 2, 3, 5 and 6, intermediate levels.
[d] LV, low-engine-volume; HV, high-engine-volume; SC, scooter; ST, traditional; EM, electric motorcycle.

frequently cruise at high speed, and sometimes violate the speed limit. Second, the performance gap in speed between existing EMs and gasoline motorcycles is wide enough to trigger the respondents' concerns and this is revealed in the model.

Operating cost is significant for the male model when associated with age. The negative sign of the coefficient indicates that older males are more concerned about the cost incurred by routine operation of motorcycles. Other the other hand, females or younger motorists might not be sensitive in this regard. As discussed earlier, operating cost is compounded by the high depreciation cost of the battery. The subsidy on battery replacement that is offered by the EPA might be helpful, particularly for males. Cruise range is another significant variable in the male model. Cruise range affects the frequency of recharging. Higher frequency of recharging incurs more inconvenience. The more improvement in this regard, the more attractive the EM is to male motorists. Females are not as sensitive in the driving range; in other words, females might be more likely to accept the EM's current level of cruise range.

Table 11
Motorcycle choice MNL model for male and female

Items	Female		Male		Pooled	
	Coefficient	*t*	Coefficient	*t*	Coefficient	*t*
Constant (1)	−0.511	−0.536	−0.192	−0.237	−0.501	−0.854
Constant (2)	0.089	0.199	0.164	0.448	−0.198	−0.754
Purchase price (1,000 NT$)	−0.012	−2.903	−0.017	−2.171	−0.020	−2.427
Maximum speed	0.023	2.182	0.039	4.811	0.024	4.000
Age×operating cost (NT$/100 km)	−0.001	−0.665	−0.001	−3.196	−0.006	−2.743
Cruise range $^{1/2}$ (km)$^{1/2}$	0.061	1.026	0.137	2.011	0.034	1.505
Emission level	0.125	1.533	1.295	2.351	1.004	1.894
Style (0, scooter; 1, traditional)	−1.029	−4.903	0.007	0.388	−0.455	−3.432
HV motorcycle (constant)× future purchase preference (1, LV; 0, HV)[a]	−1.357	−3.019	−1.136	−1.983	−1.347	−2.998
EM (constant)×college education (dummy)[a]	0.871	2.819	0.824	2.692	0.718	3.452
EM (constant)×number of motorcycles per household member[a]	1.090	1.850	1.346	2.038	1.206	2.854
EM (constant)×quality of questionnaire[a]	0.466	3.116	0.069	0.514	0.255	2.655
Respondents	–	128	–	128	–	256
Sample size	–	244	–	256	–	500
$LL(O)$	–	268.06		281.24	–	549.31
$LL(C)$	–	215.63	–	235.71	–	452.60
$LL(B)$	–	188.89	–	202.54	–	409.88
ρ^2	–	0.30	–	0.28	–	0.25
$-2(L(M)+L(F)-L(A))$	–	–	–	–	–	36.9

[a] HV, high-engine volume; LV, low-engine-volume; EM, electric motorcycle.

Emission level does not appear to be a significant attribute for male motorists. While examining the ranking of emission level in the first-stage survey for male respondents, we found the emission levels ranks the third highest. Comparing the model estimation results with the ranking of emission levels, the inconsistency suggests that the direct-format survey might be more affected by the social-norm bias. Female motorists significantly favor this attribute of the EM and suggest the potential in accepting EMs. Scooter-style motorcycles are, in general, lighter, easier to sit upon and step down from, and equipped with automatic transmission. These features are found to be preferred by females, possibly because scooters are more compatible with the physical characteristics of females. Males do not reveal distinct preference in this regard. EMs are currently heavier than scooters because of the weighty batteries. The reduction and distribution of battery weight are important design considerations to improve the ridability of EMs.

Education is a significantly favorable demographic attribute to EMs for both males and females. The positive sign indicates those who receive higher education are more supportive to EMs. Well-educated respondents are probably more informed about the latest development of EMs and, perhaps, more concerned about the environmental impacts caused by transportation activities. Another significant variable associated with EMs is the number of motorcycles per household member.

The positive sign of this variable shows that the greater the number of motorcycles that a household member owns the more likely he/she is to purchase an EM. This implies that people perceive the potential risk of shifting to an entire new transportation mode. EMs are new alternative motorcycles to the market, and most people do not have prior experience. For a first time buyer, he/she probably tends to avoid the risk of being bogged down by an unfamiliar product. On the other hand, a household which owns several motorcycles may be willing to try an EM because owning more motorcycles could be less impacted if the EM turns out to be unreliable.

The variable "quality of the questionnaire" addresses possible affirmation or informational biases introduced by the survey instrument. These types of errors are regarded as a serious form of error specific to SP models (Bonsall et al., 1990; Wardman, 1991). The informational biases suggest that if respondents have better knowledge, prior information or descriptions provided by the survey of the presented situation (alternative), they could possibly perceive less uncertainty and risk of the novel alternative in the choice set, and have more positive attitudes toward the alternative. We asked respondents if the questionnaire clearly described the background, presented the situation or properly displayed alternatives so that they could comfortably make choices. The result of this variable in the female model suggests that the more confident they feel about the questionnaire, the more likely they are to choose EMs. This situation could be a spurious statistical correlation, but is more likely an extraction of the errors associated with SP models. These biases usually cause scale factor problems and need specific treatments to correct them (Wardman, 1991).

Examining the trade-offs for the generic attributes eliminates the issue of scale factor and provides insight. Fig. 1 shows the trade-offs between speed and purchase price. The relationship indicates that an increase in maximum speed by 1 km/h is equivalent to an increase in vehicle purchase price of approximately NT$2300 for males and NT$1900 for females. A reference point from which to measure change in purchase price is set to NT$30,000 for a speed of 40 km/h. Both settings are the minimum levels in the SP questionnaires. Fig. 1 shows males are willing to pay more than females in exchange for maximum speed, which is consistent with the general observation that they are more used to cruising at higher speed than females. These high trade-offs show that motorists are considerably concerned about the performance of speed. They are willing pay nearly one tenth more of the purchase price for a 1 km/h increase in speed. Recognizing the implication, manufacturers should continue improving the performance of speed in order to meet motorists' riding habits and expectations.

The relationship between purchase price and cruise range is shown in Fig. 2. The reference point from which to measure change in purchase price is set to NT$30,000 for a cruise range of 50 km. The nonlinear relationship shows the decreasing marginal utility as the distance between refueling/recharging increases. Approximate purchase price equivalents for equal-interval increases are NT$350 for an increase of 50–70 km, NT$210 for 70–90 km and NT$170 for 90–110 km. Comparing the relationship between purchase price and speed, the improvement in speed is seemingly more critical than range. This finding is not particularly seen in previous studies.

Based on the calibration results of both male and female choice models, we clearly capture major factors that impact male and female motorcycle choice behaviors. The characteristics of the EM, as discussed previously, are higher purchase price, lower speed, shorter cruise distance and, perhaps, lower operating cost. Most of these attributes receive significant attention from both male and female respondents. The subsidiary actions will hopefully improve the acceptance of EMs, however, the battery cost should be eventually lowered. The significance of speed and cruise distance suggests that the improvement of the performance will result in a substantial gain in interest. The importance of education indicates that continuing public education, social awareness of environmental protection and marketing efforts are necessary strategies for maintaining the growth of the EM industry. The body design for EMs should be in scooter style in order to be more attractive to female motorists. Female motorists, who constitute nearly one third of the 'motorist population' are identified as the potential target market for EMs. They ride motorcycles at lower speed, prefer scooters and favor environmentally friendly products. These features reduce the barrier for EMs to be accepted by the female motorists. Overall,

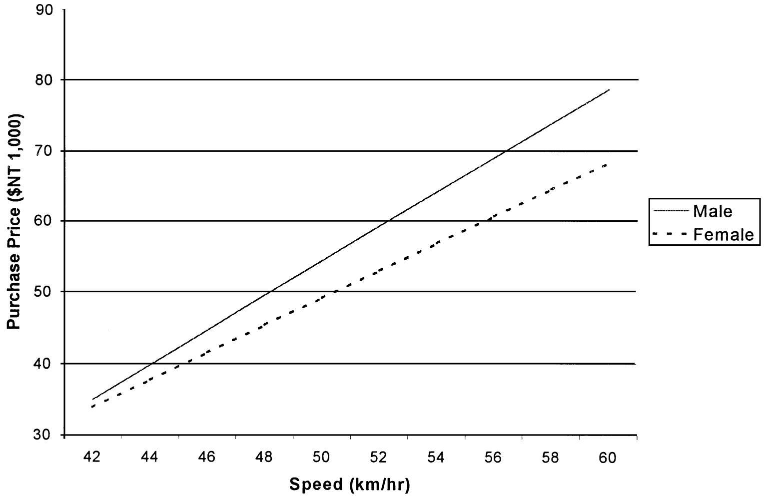

Fig. 1. Relationship between purchase price and maximum speed.

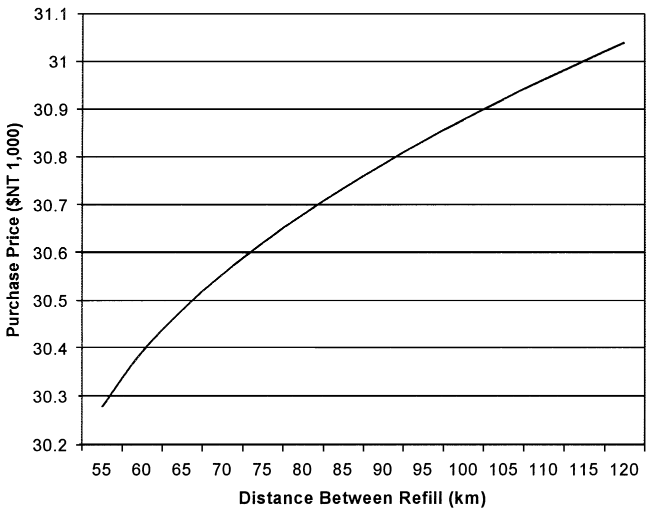

Fig. 2. Relationship between purchase price and distance between refueling/recharging.

manufacturing high quality and reliable EMs at an affordable price is an essential determinant for the lasting success of the EM.

5. Discussion

The results of SP choice models present preference information under a controlled laboratory situation. These results provide essential insights into consumer preference structure. However, the successful launch of EMs depends on many other influential factors as well.

Performance, as found in the model, is a vital factor in persuading people to buy an EM. To increase the maximum speed and the driving range, the performance of the prevailing lead–acid batteries needs to be improved. In addition, the innovation of higher efficiency batteries, such as nickel–cadmium, nickel–hydrogen, lithium or other high-performance batteries, should also be continued. These battery technologies have been applied to electric vehicles by major electric-vehicle research institutions (Anon. 1996; Mendler, 1997), but the overwhelming costs still make the wide acceptance of these batteries a long way off. A good short-term alternative in manufacturing acceptable EMs is hybrid EMs. Electric-vehicle development communities expect hybrid electric vehicles to be more widely accepted by the market (Mendler, 1997), because the similar energy or environmental benefits can be obtained without compromising the performance much. Piaggio (1998) has shown the concept of hybridization is implementable in the motorcycle. In their application, the gasoline engine and the electric motor can be switched interchangeably depending on the driving conditions. When motorists enter congested traffic areas, they can switch the power to the electric mode to save energy and reduce emissions. The gasoline engine can be turned on to cruise at high speed and recharge the battery when the power level runs low.

Promotional strategies and continuing education of the public are important for initial and long-term success. Developers should pursue the scooter-style body design. The EM should carry an image of being a hassle-free and emission-free product. Various design considerations should be more sensitive to female motorists. As a previous study suggested (Kurani et al., 1996), a successful market launch depends on designing electric vehicles that do respond to consumer preference for the novel attributes of electric vehicles, and do not necessarily attempt to duplicate all the performance attributes of gasoline vehicles. The same philosophy also applies to EMs.

Government agencies could be of help in terms of soliciting the participation of public service agencies and providing more incentives. Participation of public service entities such as the postal service or the utility service[8] will definitely help to achieve the short-term market penetration objective. The large fleets of these public services provide significant demand for EMs. With proper coordination and identification of functional requirements, EMs are hopefully going to replace a certain portion of the fleets that will be replaced in the future.

Similar to other alternative vehicles, the infrastructure system is a critical component for the EM development program. The EM infrastructure, including charging stations, maintenance and service shops, and a battery recycling service network, is the linchpin in achieving the commercialization and

[8]Taipower Inc. the sole legitimate company was licenced to provide and distribute electricity in Taiwan until the recent deregulation. Taipower provided over 25,000 MW electricity in 1997 and accounts for over 99% of the total power generation in Taiwan.

wide acceptance of the EM. Particularly when in-home charging is not feasible for most motorists[9] in urban areas, a carefully designed and implemented charging network is needed. Flexible battery charging or exchanging schemes such as on-road/off-road charging stations, on-site/door-to-door battery exchange services have been considered and evaluated (Tzeng, 1993). Battery recycle service networks need to be established so as to properly recycle or dispose of the batteries and minimize the possible contamination. Certified mechanical service providers are also needed to ensure the services for routine maintenance and repairs are sufficient. Additional incentives, such as designated parking lots, discounted parking rate and convenient charging facilities, will increase the confidence of the public and ensure a smooth transition of mode shift.

A large-scale pilot study program incorporating more than 20 research institutes and companies is being conducted (EPA, 1996) to obtain direct assessment of the performance and infrastructure system of EMs. Due to the changing nature of technologies, the features and specifications of EMs are expected to be evolving in the coming years. Continuing studies should be conducted in order to keep track of the longitudinal market responses to EMs and the peripheral operating systems.

It is a consensus that motorcycles will not cure the urban congestion problems in Taiwan. Policy makers should cautiously avoid negative impacts or competition on the mass transport systems by promoting EMs. Namely, there perhaps exists an optimal market scale for EMs under the consideration of future energy demand/supply forecast, energy utilization efficiency and transportation system integration. The continuing studies in this respect will help to understand the impacts of EMs from social and economic viewpoints.

6. Conclusions

EMs are an entire new transportation mode in Taiwan. The rapid developments in recent years are mainly driven by environmental and energy efficiency issues.

This paper summarizes the recent significant progress of EMs from legislative and technological perspectives. The aim of this paper is to shed light on opportunities for EMs from consumer behavior standpoints. The SP modeling framework is adopted in this study because EMs are still new to the market and the Revealed Preference information is not available for analysis. The statistical significance and the ease of interpretation of SP methods help to build the model for analyzing the potential demand of EMs. The statistical analysis results suggest the segmentation of the market based on gender. The MNL models show the significant difference between female and male respondents in evaluating motorcycle attributes. Results indicate that speed is a particularly important attribute in choosing motorcycles. Respondents are also sensitive to a vehicle's cruise range when it reaches a lower level. Female motorists particularly welcome scooter-type body design, due to the physical compatibility. Age, education and number of motorcycles per household member are the significant socio-economic attributes that affect the choice. The study found that female motorists are more likely to accept EMs than males at current levels of performance. Performance is a vital factor for achieving market penetration. In order to increase the

[9]The prevailing residential building type in urban areas in Taiwan is multi-storey complex apartments, which prohibits residents from in-home charging, unless the safety regulation codes and building design are modified accordingly.

maximum speed and driving distance, higher energy-efficiency batteries should be considered. Other types of EMs, such as hybrid gasoline–EMs, could be a good alternative. The basic infrastructure systems for EMs, such as charging facilities and mechanical services, are also essential for establishing wide acceptance.

Acknowledgements

This research was sponsored by the Industrial Technology Research Institute and the Bureau of Industrial Development, Ministry of Economics, Taiwan, ROC. The authors thank their colleagues who participated in the various stages of this project, especially in data collection. Special thanks to the two anonymous referees for their helpful comments. Certainly, the authors are solely responsible for the viewpoints, conclusions and errors in this paper.

References

Adamowicz, W., 1994. Combining revealed and stated preference methods for valuing environmental amenities. Journal of Environmental Economics and Management 26(3), 271–293.

Amsden, A.H., 1991. Big business and urban congestion in Taiwan: the origins of small enterprise and regionally decentralized industry. World Development 19, 1121–1135.

Anonymous, 1996. Impacts in producing and recycling EV batteries. Automotive Engineering 104, 83–86.

Beggs, S.D., Cardell, N.S., 1980. Choice of smallest car by multi-vehicle households and demand for electric vehicles. Transportation Research 14A, 380–404.

Beggs, S.D., Cardell, N.S., Housman, J., 1981. Assessing the potential demand for electric cars. Journal of Econometrics 16, 1–19.

Bonsall, P.W., Wardman, M., Nash, C.A., Hopkinson, P., 1990. Development of a survey instrument to measure subjective valuations: approaches to the estimation of non-use benefits of local public transport services. In: Ampt, E.S., Meyburg, A., Richardson, A. (Eds.), Selected Readings in Transport Survey Methodology. Eucalyptus Press, Sydney.

Borde, D., 1997. The development and production of the electric motorcycles by Peugeot. Proceedings of the 1997 Symposium on Electric Motorcycles, Taipei, Taiwan, ROC.

Bunch, D.S., Bradley, M., Golob, T.F., Kitamura, R., 1993. Demand for clean-fuel vehicles in California: a discrete-choice stated preference pilot project. Transportation Research 3A, 237–253.

Calfee, J.E., 1985. Estimating the demand for electric automobiles using fully disaggregated probabilistic choice analysis. Transportation Research 19B, 281–301.

CALSTART, 1998. 13th International Electric Vehicle Symposium (EVS13), Osaka, 1996 [online]. (http://www.calstart.org/news/evs13).

Chang, H.L., 1995. The study on the helmet use behavior of college students. Technical report prepared for Yamaha Education Foundation, National Chiao-Tung University, Hsin-Chu, Taiwan.

Chang, T.L., 1979. Purchase Behaviors and Market Segmentation Analysis for Motorcycles in Taiwan. Master thesis, Department of International Business, National Chengchi University, Taipei, Taiwan.

Chiang, W.M., 1992. The Technical Evaluation and Planning of Electric Motorcycle. Technical Report prepared for The Energy Commission, Ministry of Economic Affairs, Taipei, Taiwan, ROC.

Chin, T.I., 1986. The purchase behavior for motorcycles. Master thesis, Department of Business Administration, Soochow University, Taipei, Taiwan.

Environmental Protection Agency, 1993. The emission levels of motor vehicles. Taipei, Taiwan.

Environmental Protection Agency, 1996. The Pilot Study in Understanding the Post-use Experience of Electric Motorcycle Users. Taipei, Taiwan.

Environmental Protection Agency, 1997. Air pollution control approaches in Taiwan. Taipei, Taiwan.
Executive Yuan, 1997. The strategic plan for electric motorcycle development. Taipei, Taiwan.
Ferguson, E., 1995. Demographics of carpooling. Proceedings, Transportation Research Record 1496, Washington DC.
IDB, 1993.
ITR/MTC (Institute of Transportation Research, Ministry of Transportation and Communication), 1992. The large-scale household activities and transportation use survey in Taipei metropolitan area. Technical report, Taipei, Taiwan.
Institute of Transportation Research, Ministry of Transportation and Communication, 1995. Transportation System Status and Capacity in Taiwan Area. Technical Report, Taipei, Taiwan, ROC.
Kroes, E.P., Sheldon, R.J., 1988. Stated preference methods. Journal of Transport Economics and Policy 22, 11–25.
Kurani, K.S., Turrentine, T., Sperling, D., 1996. Testing electric vehicle demand in 'hybrid households' using a reflexive survey. Transportation Research 1D(2), 131–150.
Louviere, J.J., 1988. Analyzing Decision Making: Metric Conjoint Analysis. Sage University Papers Series no. 67. Sage Publications, Newbury Park, CA.
Madden, G., Bloch, H., Hensher, H., 1993. Australian telephone network subscription and calling demands: evidence from a stated-preference experiment. Information Economics & Policy 5(3), 207–230.
Mendler, C., 1997. Taking a new look at hybrid electric vehicle efficiency. Automotive Engineering 105, 67–70.
National Science Council, 1997. White Paper on Science and Technology. National Science Council, Taipei, Taiwan.
Piaggio, 1998. Piaggio Zip & Zip: twin engines with a single philosophy [online]. (http://www.piaggio.com/showroom/).
Preston, J., 1991. Demand forecasting for new rail station and service. Journal of Transport Economics and Policy 22, 11–25.
Shang Wei, 1997. The specifications of SWAP. Exhibition materials, The 1997 Symposium on Electric Motorcycles, Taipei, Taiwan.
Tokyo R&D, 1994. The specifications of ES600. Exhibition materials, The 1997 Symposium on Electric Motorcycles, Taipei, Taiwan.
Train, K., 1980. The potential market for nongasoline-powered vehicles. Transportation Research 14A, 405–414.
Tzeng, G.H., 1993. The design and planning of infrastructure systems for electric motorcycles, Technical report prepared for the Industrial Technology Research Institute, Institute of Traffic and Transportation, National Chiao-Tung University, Taipei, Taiwan.
Tzeng, G.H., Chiu, Y.C., 1995. Exploring the potential demand of electric motorcycle in urban area. Technical report prepared for the Industrial Technology Research Institute, Institute of Traffic and Transportation, National Chiao-Tung University, Taipei, Taiwan.
Wardman, M., 1991. Stated preference methods and travel demand forecasting: an examination of the scale factor problem. Transportation Research 25A(2/3), 79–89.