Stated Responses to Policy Interventions and Technological Innovation of Electric Motorcycles in Laos

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Abstract: Recently, the heavy pollution from motorcycles prompts the trend to promote electric motorcycles (EMs) with no emission and higher efficiency. This research represents people's stated responses to different policy interventions and technological innovations of EMs, from the perspective of human choice behavior, in Vientiane, Laos. Based on a stated preference (SP) survey, a dogit model with parameterized captivity functions was adopted to examine the important influential factors to the choice of EMs by accommodating people's heterogeneous captivity to different alternatives in a choice set. Simulations under different policy-related and technology-related scenarios were conducted, as well. Based on the analysis results, it is found that the preferred distance to charge station is 0.8 km - 1.0 km and people are more likely to choose EMs when the cruising range is longer, operation cost is lower, and the diffusion rate is lower.

Keywords: Electric Motorcycle, Stated Preference, Income, Policy Interventions, Laos

1. INTRODUCTION

Motorcycles/scooters are popular in many Asian countries. In Taiwan, a large number of urban residents depend on motorcycles for all types of journeys (working, going to school and shopping, etc.) despite efforts to increase use of the public transport systems (Chiu & Tzeng, 1999). In Japan, scooters are popular for short trips, especially for students. Cities in South Asian countries, such as Hanoi and Bangkok, rely heavily on motorcycles.

In Asian cities, motorcycles are more popular than cars for several reasons. Firstly, since the income level is relatively low, motorcycle are more affordable than cars. Secondly, motorcycles are popular because urban population densities are too high and the number of roads is too few to support large numbers of cars. Not only are roads too few, so are parking spaces. Thirdly, since traffic congestion is a widespread problem in several cities, such as Bangkok, Shanghai, and Taipei, motorcycles are popular because they can be more easily handled around the traffic (Colella, 2000).

Urban areas in Asia have suffered from the air pollution problem for a long time due to the high population and motor vehicle density. Despite their popularity, motorcycles have bad effects on local air quality and human health. They produce a disproportionate amount of vehicle pollution for their size due to the two-stroke engine, which exhaust more emissions than conventional ones. Considering the irreplaceable position of motorcycle, the heavy pollution from motorcycle prompts the trend to promote electric motorcycles (EMs) with no emission and high efficiency.

Recent years, many studies have focused on EMs, most of which are from the design or technology perspectives, such as battery, refuel system, and motor (Liu *et al.*, 1994; Lai, 2003;

Sheu, 2008; Hsu, 2010). Some others investigated the impact of EM from environment to economic perspectives (Cherry, 2009; Bishop, 2011). Another big group of EM studies focused on the market acceptance of or people's attitude to EMs from different angles. Tso and Chang (2003) thought that full-cell scooters are a viable niche market in Taiwan under the analysis of commercial aspects, such as economics, consumer demand, and government intervention. Chiu and Tzeng (1999) analyzed the potential demand for EMs based on an interview survey using stated preference modeling approaches and found out that the female motorists are the potential target market for EMs. Chen *et al* (2012) applied a structure equation modeling approach to find out the relationships among green consumption attitude, perceived risk, and perceived value toward hydrogen-electric motorcycle purchase intention. It analyzed the key factors of consumer behaviors and further discussed improvement solutions.

Most of the existing studies have focused on the market in developed cities, such as Taiwan, Shanghai, at least the mid-income cities like Bangkok. So what is the situation in least developed countries (LDCs)? What is people's attitude to the EMs, which is still a not-yet-existing product in their market? We have reasons to believe that, in LDCs, market acceptance of EMs may be different from that in developed countries because of the low income level. Hence, it is important to know the people's attitude to EMs under the consideration of deployed incentive policies and innovative technologies and to find out the vital factors influencing on the choice between conventional motorcycles (CMs) and EMs.

Laos is chosen as a study country. The environment problem caused by transportation section in Laos is also very serious. CO_2 emission has been increasing rapidly from 643,410 t CO_2/year in 2001 to 2,179,297 t CO_2/year in 2011. It is estimated that it will continue to increase more rapidly and reach at 3,832,668 t CO_2/year in 2020 and 6,286,348 t CO_2/year in 2030 (Low-emission Transport Study, 2013). Motorcycle plays a dominant role in whole transport system. Laos is one of the least developed countries, in which the urbanization and motorization are at the start-up period. There is no local motorcycle producer, which means customers need to pay a high import tax for motorcycle. Fortunately, Laos is rich in clean energy resources. As the self-declared "Battery of Asia", it has a huge amount of affordable electricity. In fact, electricity from hydroelectric power generation can supply more than 30 times the domestic demand[1]. Under all these circumstances, Lao is a suitable country to launch the promotion of EMs in the near future.

This study chooses Vientiane, capital city of Laos, as study area. Since EMs are currently not available in the market of Laos, it is difficult to adopt the preference for current existing gasoline-powered vehicles to describe people's choice behavior of EMs. Therefore, a stated preference (SP) survey method was applied to collect data in this study.

In the rest of this paper, Section 2 describes the SP experiment design and gives a preliminary statistic analysis of survey data. In Section 3, a dogit model is built to describe the motorcycle choice behavior and its estimation results are discussed afterward. Finally, conclusions are summarized along with policy implications in the last section.

2. SP EXPERIMENT DESIGN

The SP approach, originating in mathematical psychology, has been widely used in transportation (Hensher, 1994; Kroes and Sheldon, 1988; Louviere *et al.*, 2000; Polak and Jones, 1997), since it can measure how people choose not-yet-existing travel modes, or how people take actions under new policies (e.g., road pricing and intelligent transport systems).

[1] http://www.dotlao.gov.la/ (Accessed February 1, 2013)

The deployment of EMs in Laos is another example that requires the application of SP approach.

This approach examines individual responses to a series of experimentally designed choice alternatives, which are typically described in terms of combinations of attributes with several pre-defined levels. Besides the ability to directly measure the demand/response under not-yet-existing conditions, the SP approach has other advantages over the conventional revealed preference (RP) approach, which is based on observed choice in real situations. These advantages include the ability to control statistical problems such as multi-collinearity and lack of variance in explanatory variables, the increased possibility of including subjective or qualitative factors as explanatory variables and cost-efficiency to develop models from a relatively small size of samples. In the SP survey, each respondent is usually asked to answer two or more SP questions; however, the RP survey can only obtain one answer from each respondent. In this sense, as a survey method, the SP survey is more efficient than the RP survey in order to obtain enough samples.

The purpose of implementing an SP survey in this research is to examine factors influencing the deployment of EMs in Vientiane, Laos, from the perspective of human choice behavior. To effectively examine influential factors, a pilot survey was first conducted before implementing the SP survey in a full scale.

2.1 Pilot Survey

The pilot survey aimed to identify the pertinent attributes and their tolerance levels, both of which would be used to describe the hypothetical choice alternatives in the SP survey. In this step, the questionnaire contained three parts: the overall recognition of EMs, important factors in choosing EMs and corresponding tolerance levels. The respondents were asked to give an overall impression of EMs. After that, they were asked to freely choose up to five attributes which they thought were important attributes to consider. For each attribute that the respondent selected, the tolerance level was also reported.

In the pilot survey, 500 respondents were randomly selected. People's recognition results are shown in Table 1. We can see that only 18% of the respondents were familiar with EMs and knew how it works, 45% only knew the name, and 37% knew nothing about EMs.

Table 1. People's Recognition of Electric Motorcycles (EMs)

Recognition items	Sample size (Share)
1) Know how it works	91 (18%)
2) Know the name	225 (45%)
3) Know nothing	184 (37%)

Important attributes in choosing EMs are shown in Figure 1, which shows the frequency of each attribute being chosen, i.e., how many people think it important of each attribute for choosing an EM. The top eight attributes were chosen to be used for the SP design.

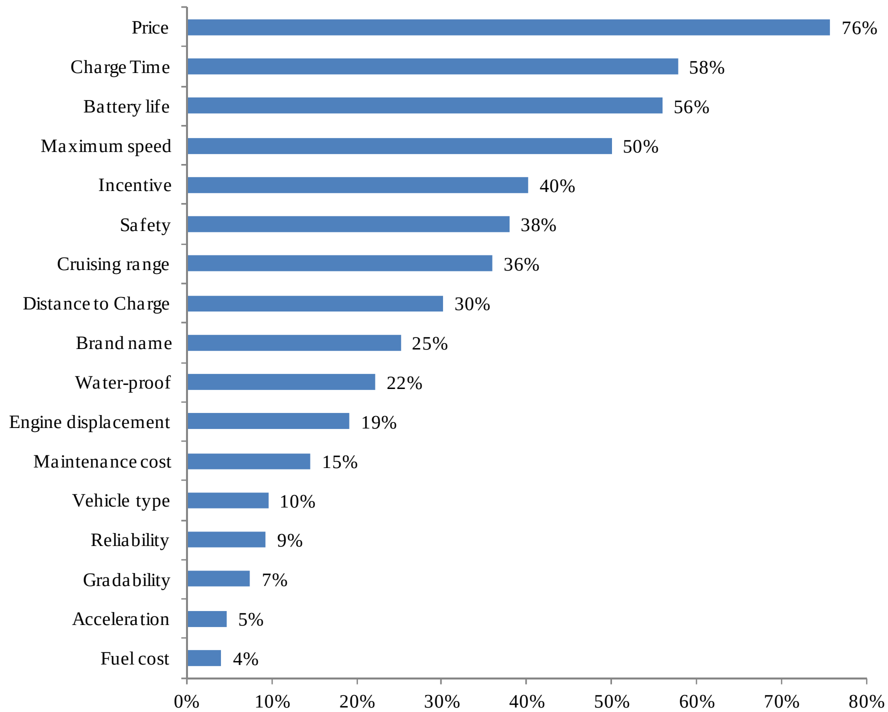

Figure 1. Important Attributes for EMs Ownership

2.2 SP Survey

This SP experiment was designed to investigate how respondents would choose different types of vehicles under different hypothetical attributes of EMs, considering the influence of future income level, technology innovation and policy interventions. The future income level is especially important in this SP experiment because under the current income level in Laos, the price of EM is too high as a two-wheelers automobile. Hence the deployment of EMs requires the reflection of the increase of income in Laos in future. For policy interventions, infrastructures and subsidies and so on for supporting the deployment of EMs were incorporated in the survey.

The challenge was how to set the future income level which allows respondents to make a realistic and reliable choice of EMs. Setting a too low income level would result in that nobody would choose an EMs and a too high income level would lead to an unrealistic choice of EMs. With such consideration, here, two levels of future monthly income were assumed, i.e., US$2,000, 1,000. These values mean that each respondent can buy a conventional motorcycle (CM) almost one month income, more or less.

The purchasing price of EM is much higher than that of CM. For better comparison, three levels of purchasing cost were assumed for EM and one fixed value for CM. The fixed price for motorcycle is US$1,300, so the three levels for EM are almost 2 times, 2.5 times, and 3 times of CM, whose absolute values are US$2,500, 3,200, and 4,000, respectively.

Another important factor influencing purchasing behavior is the subsidy. Here the subsidy means the percentage of body price subsidized by government. Considering the tolerance level obtained from the pilot survey, three hypothetical levels of subsidy for EM were given, i.e., 0%, 10%, and 20%.

The operation cost of EM is much lower than that of CM. This is an advantage which could cover the weakness of high purchasing price. To confirm this advantage, the lifecycle cost was included as an attribute in the SP design. It was assumed that annual trip distance is 10,000 km. Lifecycle cost for CM includes vehicle body price, operation cost, maintenance cost and insurance for 10 years, and for EM, battery replacement cost for one time was added and subsidy was subtracted.

Here, three choice alternatives – 1) CM, 2) EM, and 3) no buying – are presented as a choice set. Each choice set is shown with a combination of the attributes with different values which are specified by reflecting the tolerance levels answered by the respondents in the pilot survey and the future technological progress of EMs based on literature review. All the attributes chosen in the SP experiment are listed as follows:

(1) Engine displacement for CM(fixed): 125 cc
(2) Efficiency of CM: 30 km/l, 55 km/l
(3) Efficiency of EM (fixed): 20 km/kwh
(4) Maximum speed: CM: 100 km/h, 120 km/h EM: 60 km/h, 100 km/h
(5) Cruising range: 60 km. 100 km, 150 km
(6) Charge time: 2 h, 4 h
(7) Battery life: 5 yrs, 8 yrs
(8) Diffusion rate: 5%, 20%
(9) Distance to charge station: charge at original/destination, 1 km, 2 km
(10) Warning sound: with, without
(11) Future monthly income level (US$): 1,000, 2,000
(12) Vehicle body price for CM (fixed): US$1,300
(13) Vehicles body price for EM (US$): about 2 times of CM body price, 2.5 times of CM, 3 times of CM, i.e., US$2,500, US$3,200, US$4,000
(14) Subsidy for EM (of body price): 0, 10%, 20%
(15) Lifecycle cost for 10 years includes vehicle body price, operation cost, maintenance cost and insurance, and battery replacement cost for one time by subtracting the subsidy under the assumption 10,000 km per year.

The orthogonal design, a common exercise in SP approach studies, is used to generate SP cards assuring that attributes are virtually independent of each other. As a result, 27 SP cards are obtained. To reduce response errors and biases caused by fatigue and repetitive responses, the 27 cards were randomly grouped into nine blocks, each of which include three SP cards. Each respondent was asked to answer only one block. In other words, each respondent only answered three SP questions for the motorcycle choice experiment. Appendix I is an example SP question card and Appendix II shows all the SP cards from the orthogonal design.

2.3 Basic Data Description

The survey was conducted in Vientiane in June, 2012. A simple introduction of electric motorcycle appeared at the beginning of questionnaire, after which are the explanation of attributes which will shown in the following SP cards. Respondents were firstly required to read these carefully and then to finish the SP cards.

Totally there were 1,008 respondents taking part in the survey, among which 577 are male. As shown in Figure 2, respondents between 20 and 50 years old are the main source of respondents, accounting for 85%. Only 109 households do not own motorcycles, and near 60% own more than one. The monthly income level distribution of respondents' households is also shown in this figure. Most of the respondents are distributed in the categories between $75 and $750, and the densest category is US$250-500. The distribution trend is in line with reality.

Each respondent was requested to answer three SP cards. In total, we got 3,024 samples (SP cards). Table 2 shows the choice results. The share of EM is quite high, accounting for 51%, which indicates that under the hypothesis in the SP question, half of the respondents would like to buy an EM.

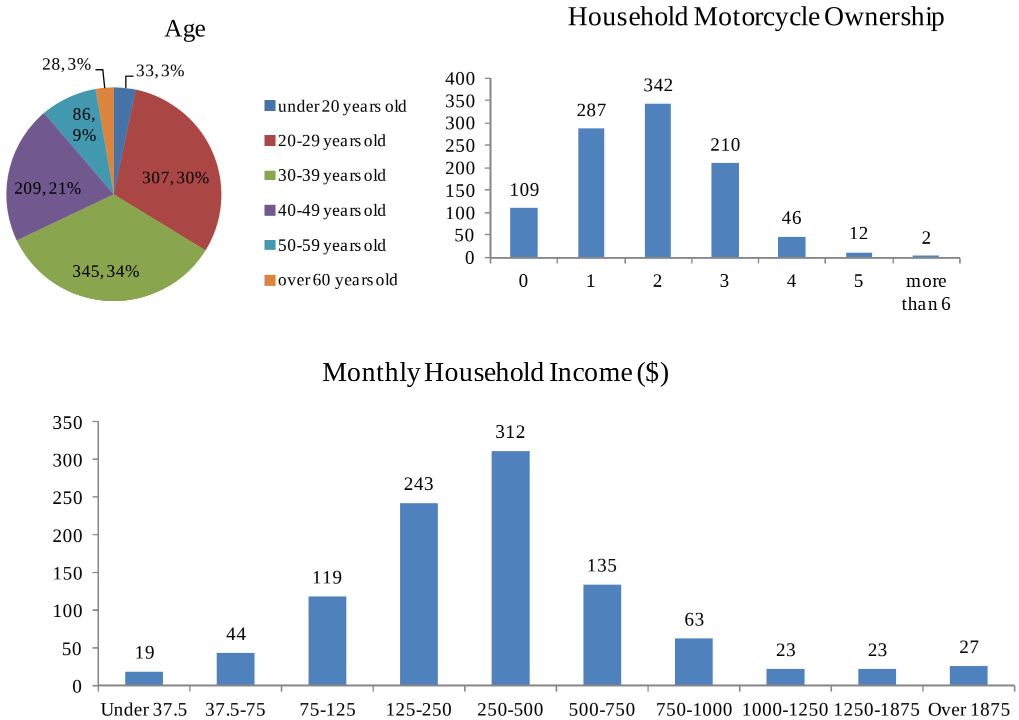

Figure 2. Respondents' Distributions by Age, Motorcycle Ownership and Income

Table 2. SP Survey Choice Results

Choice alternatives	Sample size (Share)
1) Electric motorcycle (EM)	1,528 (51%)
2) Conventional motorcycle (CM)	1,005 (33%)
3) No buying	491 (16%)

3. ANALYSIS OF ELECTRIC MOTORCYCLE CHOICE BEHAVIOR

3.1 Model

In order to explore influential factors of motorcycle ownership behavior, this study uses a discrete choice model to represent the behavior. In this study, the choice set in the SP survey contains three alternatives: no buying, EM, and CM. Considering that people may be captive to a certain alternative, especially in the developing countries, meaning that people may hardly change their choice despite of policy incentive or technology improvement, a dogit model is applied to present the motorcycle ownership behavior.

Dogit model was introduced by Gaudry and Dagenais (1979). They presented a specification in which the individual is either captive to an alternative or is free to choose from the full choice set according to a Multinomial Logit (MNL) model; they called this the "dogit" model. It can relax the independence of irrelevant alternatives (IIA) issue without losing the intuitive and practical appeal of the logit format which allows for some pairs of alternatives to be held but without simultaneously destroying itself as a distinct model for the rest of the alternatives considered. The advantage of this model is that some pairs of choice alternatives may exhibit the IIA property while other pairs may not. The structure of dogit model is shown as follow:

$$P_i = \frac{exp(V_i) + \theta_i \sum_j exp(V_j)}{(1 + \sum_j \theta_j) \sum_j exp(V_j)}, \; i, j = 1, 2, \ldots, \text{N}, \tag{1}$$

where,

P_i : probability of choosing the ith of N alternatives,

V_i : a linear function of K independent attributes (x_{ik}) of the ith alternative, and

θ_i : degree of captivity (a non-negative parameter) of the ith alternative, $\theta_i \geq 0$.

Joffre and Moshe (1987) denominated the Parameterized Logit Captivity (PLC) model as the generalization of Gaudry and Dagenais' "dogit" model, which suggested the degree of captivity parameter be parameterized as functions of independent variables. Specifically, since θ_i is restricted to be non-negative, they suggested that

$$\theta_i = exp(\sum_s \gamma_s Z_{is}), \; i = 1,2,\ldots,\text{N}, \tag{2}$$

where,

Z_{is} : the sth variable that explain the captivity degree parameter θ_i of the ith alternative, and

γ_s : unknown parameter of Z_{is} .

This study argues that the individuals with different characteristics may have different degrees of captivity. Therefore, the PLC model is used to represent the choice behavior by explaining the captivity parameter with the individual attributes, such as age, gender, the income level, and current motorcycle ownership.

3.2 Explanatory Variables

As for the explanatory variables, some modifications are done to the attributes in the SP experiment. It is expected that people with different income levels might have different attitudes toward monetary attributes of different types of motorcycles. Reflecting the actual attributes included in the SP experiment, here, the body price and subsidy divided by income are treated as two composite explanatory variables. This is because that people with higher income have a higher affordability than those with lower income. Additionally, since lifecycle cost is composed of body price, subsidy and some other cost, it cannot be used in model directly. The operation cost ratio of the lifecycle cost is chosen as a variable. Moreover, since cross-aggregation analyses show that the choice of EM has a quadratic relation with the station distance, a linear term and a squared term for the distance are introduced as two additional explanatory variables. Of course, the vehicle-specific attributes and individual attributes as well as constant terms are also introduced to explain the motorcycle ownership choice behavior. The chosen explanatory variables are listed in Table 3.

Table 3. Explanatory Variables

Explanatory variables for captivity functions	
Age (years old)	1: 0-19, 2: 20-29, 3: 30-39, 4: 40-49, 5: 50-59, 6: more than 60.
Gender	Male, 0; Female, 1.
Current monthly household income (US$)	1: under 37.5, 2: 37.5-75, 3: 75-125, 4: 125-250, 5: 250-500, 6: 500-750, 7: 750-1,000, 8: 1,000-1,250, 9: 1,250-1,875, 10: over 1,875
Motorcycle ownership (dummy variable)	Own a motorcycle: 1; otherwise: 0.
Explanatory variables for utility functions	
Cruising range (km)	Cruising range with a full charge of battery
Station distance (km)	The distance to charge station
Station distance^2	Squared term for the distance to charge station
Diffusion rate (%)	Percentages of EMs owned in the market
Body price/income	Ratio of purchasing price divided by future monthly income
Subsidy/income	Ratio of government subsidy divided by future monthly income
Operation cost/lifecycle cost	Ratio of operation cost in lifecycle cost
Maximum speed (km/h)	Maximum speed for two types motorcycles
Efficiency (km/*l*)	Fuel efficiency of CMs

3.3 Estimation Results and Discussion

3.3.1 Estimation results

Using the 3,024 samples collected, the dogit model is estimated, as shown in Table 4. McFadden's Rho-squared is 0.101, which is not sufficiently high, but acceptable to identify influential factors of motorcycle ownership in the future Vientiane. Looking at the introduced explanatory variables, one can see that parameters of most of the explanatory variables are statistically significant at 99%, 95% or 90% level. These results directly support the use of dogit model and SP survey.

Looking at the alternative-specific attributes, one can notice that cruising range, charge distance, operation cost, and diffusion rate are vital influencing factors. Firstly, the positive parameter of cruising range indicates that people are more likely to choose motorcycle if the cruising range with a full charge of battery is longer. Secondly, the parameter of the first-order distance variable is positive and that of the second-order distance is negative. This means that the distance to charge station has a quadratic effect on EM choice and the most preferred distance is around 1 km. Thirdly, the negative diffusion rate parameter indicates that people prefer to choose EM when the ownership rate is low. This shows a psychological phenomenon that people in Vientiane would like to be the innovator not the imitator. Owning an EM could be a symbol of higher social status. This finding is useful for the deployment marketing of EM. Finally, the operation cost significantly influence people's choice. The lower percentage of operation cost in total lifecycle cost will increase the probability of choosing the corresponding vehicle. This implies that EM will have a promising potential market in Vientiane due to its low operation cost. Looking at the parameters of body price and subsidy, they are not significant. The insignificance usually comes from two reasons: 1) this attribute really has no influence on the choice, and 2) the variance of this attribute is too small to generate influence. In this case, since respondents gave higher priorities to the body price and subsidy, such insignificant is probably because that the variance of body price and income ratio is too small.

Table 4. Model Estimation Results

Independent Variables	Parameter	p_value
Captivity functions		
No buying alternative		
age	-1.509**	0.000
gender	-0.015	0.969
current household income	-0.122	0.296
motorcycle ownership	3.192**	0.000
Electric motorcycle (EM) alternative		
age	-0.926**	0.000
gender	0.437+	0.072
current household income	-0.074	0.318
motorcycle ownership	2.574**	0.000
Conventional motorcycle (CM) alternative		
age	-0.505**	0.000
gender	0.443**	0.008
current household income	0.049	0.253
motorcycle ownership	0.713*	0.033
Utility functions		
No buying alternative (as a reference)	0	
Electric motorcycle (EM) alternative		
constant term	2.684*	0.019
range	0.005*	0.031
station distance	0.764*	0.043
station distance^2	-0.451*	0.015
diffusion rate	-2.768*	0.020
body price/income	-0.197	0.119
subsidy/income	-0.495	0.229
operation cost/lifecycle cost	-4.468*	0.040
maximum speed	0.003	0.497
Conventional motorcycle (CM) alternative		
constant term	1.303	0.644
body price/income	-0.197	0.119
operation cost/lifecycle cost	-4.468*	0.040
efficiency	0.019	0.551
maximum speed	0.003	0.497
Initial Log-likelihood	-3,322	
Converged Log-likelihood	-2,988	
McFadden's Rho-squared	0.101	
Adjusted McFadden's Rho-squared	0.094	
Sample size (SP cards)	3,024	

+significant at 90% level, *significant at 95% level, and **significant at 99% level

As for captivity function, most parameters of variables are significant, which means the dogit structure with parameterized captivity is suitable and consistent with the real choice behavior. For the no buying alternative, age and motorcycle ownership are significant, which means that when people decide whether to buy a motorcycle or not, their age and current motorcycle ownership in the household will significantly influence their choice. When they choose between CM and EM, gender will become important to describe the captivity.

3.3.2 Relative influences of independent variables

To further understand the relative influence of each variable on the utility of each alternative, the proportion of variance is calculated as shown in equation (3), where the influence of unobserved factors (i.e., the error term) is ignored. The bigger the proportion is, the larger the influence of the variable on choice behavior is. The results are shown in Table 5.

$$\text{Proportion of variance (\%)} = \frac{\mathrm{var}(\beta_k x_{ik})}{\mathrm{var}(\sum_k \beta_k x_{ik})} = \frac{\beta_k^{\,2}\,\mathrm{var}(x_{ik})}{\sum_k \beta_k^{\,2}\,\mathrm{var}(x_{ik})} \tag{3}$$

Table 5. Relative Influences of Variables based on Variance Proportion (VP)

Electric motorcycle alternative		Conventional motorcycle alternative	
Explanatory variables	VP	Explanatory variables	VP
range	3.2%	body price/income	9.5%
station distance	34.4%	operation cost/lifecycle cost	0.0%
station distance^2	50.2%	efficiency	88.7%
diffusion rate	3.4%	maximum speed	1.9%
body price/income	2.8%		
subsidy/income	1.4%		
operation cost/lifecycle cost	4.4%		
maximum speed	0.3%		

Note: The "No buying" alternative serves as a reference.

It is revealed that the most dominating factors for EM are the two terms of charge distance accounting for 84.6% of the total variance of EM utility, while efficiency is the most influential factor in CM, accounting for 88.7% of the total variance of CM. Contrary to expectations, as for the EMs, the body price relative to household income accounts for only 2.8% and the subsidy for only 1.4%. Comparing with these two monetary factors, the influence of diffusion rate (3.4%) is higher and people attach more importance to "operation cost/lifecycle cost" (4.4%).

3.3.3 Simulation

Here, after examining the important influential factors, simulations of the motorcycle choice behavior with respect to the changes in factors related to some policy interventions and technology innovation are conducted based on the above-estimated dogit model. Concretely speaking, choice probabilities of different choices are calculated with respect to different sets of explanatory variables that are introduced to explain choice behavior.

Since the simulations are carried out based on the collected SP data, the choice probability of an alternative under study due to the change of an explanatory variable is calculated by fixing the other explanatory variables to their average values of the whole SP samples. Note that if future values of relevant explanatory variables can be properly given, demand forecasting can be done using the estimated model. Here three related attributes, which are confirmed to significantly affect the choice behavior, are separately simulated: future annual income, cruising range, and distance to charge station.

Future income

Choice result is based on the assumption of future income level which could afford to purchase EM. Under different income levels in the future, it is expected that the ownership of motorcycle will change. Different values of annual income levels (namely GDP per capita) in a wide range by reflecting the potential levels of future income are assumed including the GDP predictions of the years 2020 ($1,495) and 2030 ($2,304) in Laos (predicted by Laos government). For better understanding, the corresponding monthly incomes are shown in parentheses. The results are shown in Figure 3.

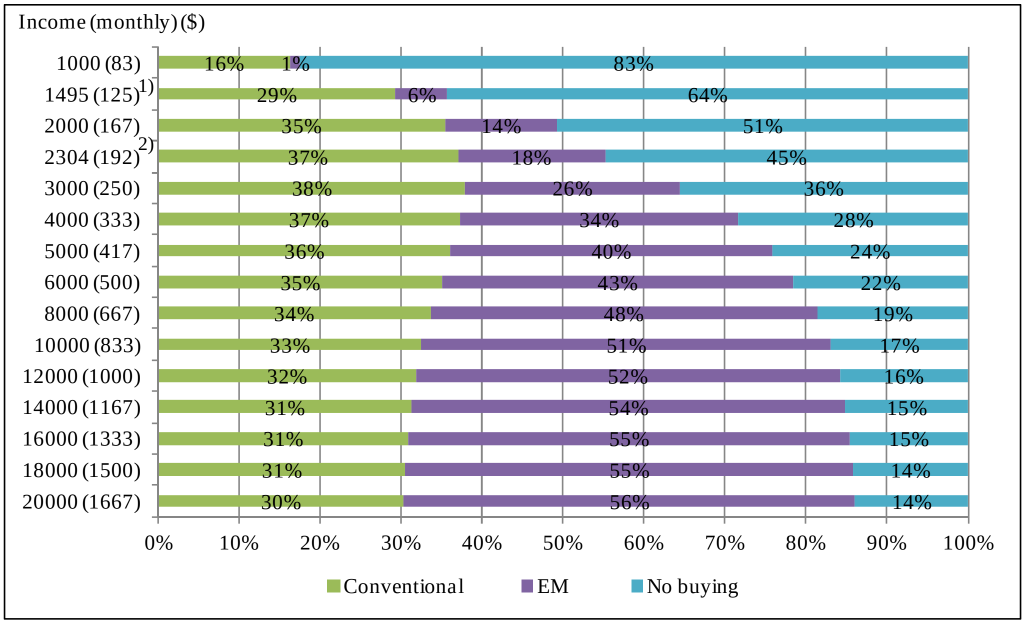

Figure 3. Simulation Results under Different Income Levels

Note: 1) Income level predicted in 2020; 2) Income level predicted in 2030

We can see that the increase of income will surely increase the ownership of EM. For CM, the ownership will increase before the income reaches at $4,000-$5,000 and after that it will decrease slowly. In contrast, EM will continuously increase. By calculating the rate of increase of EM, one can find out that it will reach the peak at 12.79% when the income level is at $4,000 and then goes down to less than 5% after income reaches at $10,000. In other words, the ownership of EM will increase rapidly before $4,000 and after that the increasing speed will slow down to a stable level at $10,000.

Cruising range

Since people care about the cruising range of electric vehicles, the simulation under different levels of cruising range of EMs is also conducted (see Figure 4). Values of cruising range are specified based on the development of existing and future technologies, identified from literature review. One can see that the percentage of EM will directly increase as the cruising range increases.

Examining the trade-off for the attributes eliminates the issue of scale factor and provides insight. The trade-off between cruising range and the price-to-income ratio is shown in Figure 5. The relationship indicates that an increasing in cruising range by 50 km is equivalent to an increase in Price-to-income ratio by 1.27, which means people would like to pay additional 1.27 times of his monthly income for an increase of 50 km. This high trade-offs show that motorists are considerably concerned about the performance of cruising range. Recognizing the implication, manufacturers should continue improving the performance of cruising range in order to meet motorists' r expectations.

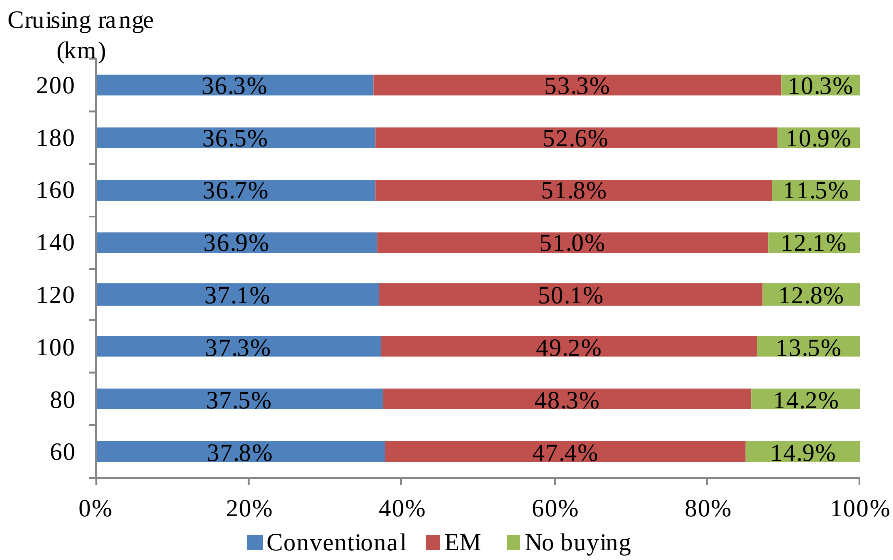

Figure 4. Simulation Results under Different Cruising Ranges

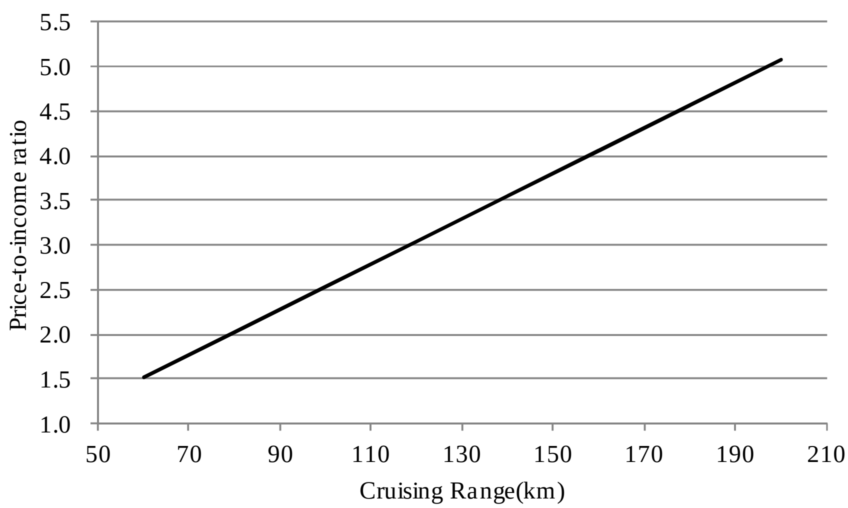

Figure 5. Relationship between Cruising Range and Price-to-income Ratio

Distance to charge station

As introduced in model estimation result, the choosing probability of EM has a quadratic relationship with distance to charge station. After calculating the probability under different levels of distance to charge station (from 0 km to 2 km, reflecting the results of the pilot survey), it can be found that when the distance is 0.8 km ~ 1.0 km, the share of EM can reach the highest value, about 51.6-51.7%. And the distance being shorter or longer than 0.8 km ~ 1.0 km will cause the decrease of the EM share. This result will help when planners work on the layout of the charge stations in the deployment of EM.

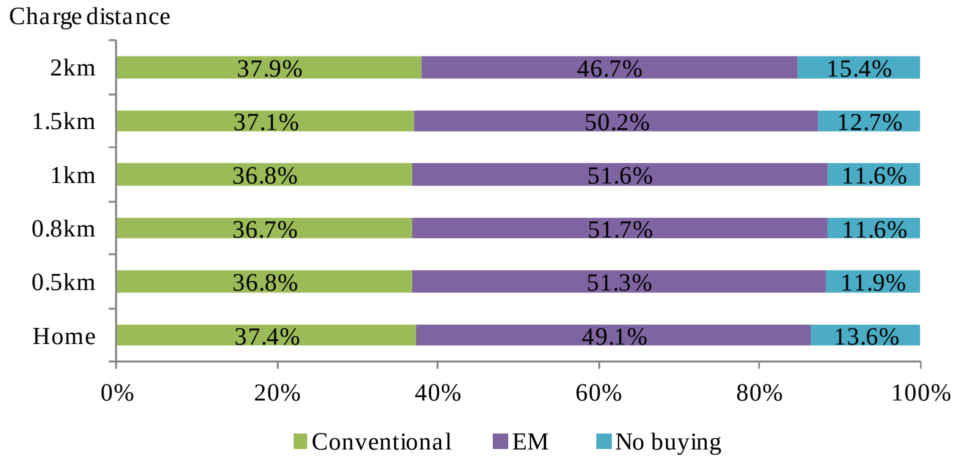

Figure 6. Simulation Results under Different Charge Distances

4. CONCLUSION

In Laos, one of the least developed countries, its transport systems (which dominating modes are motorcycles) have been mainly run on petroleum, which completely depend on imported fuel. This has significant implications of the country's environment and energy security. On the other hand, "Laos, Simply Beautiful" is the country's tourism slogan. Damages to tourism industry due to environmental pollution should be highly concerned. Fortunately, Laos is rich in clean energy resources. Motivated by the above matters, this study looked at how people in Vientiane would choose electric motorcycles (an environmentally friendly mode) in future, considering incentive policies, improvement of EM technology, and future income, and found out the important influencing factors. Even though EM has already been in the market in developed cities for years, it is still not familiar to people in Vientiane (our survey revealed that less than 20% of people know how EM works). To quantitatively capture the features of ownership choice behavior of EM, we conducted an SP survey supported by a pilot survey. In the pilot survey, the pertinent attributes and their tolerance levels were investigated at the individual level to describe the hypothetical choice alternatives in the SP survey. In the SP survey, respondents were asked to choose different types of vehicles under different hypothetical attributes of EMs, considering the influence of future income level and policy interventions. To reflect the feature of captivity in people' choice behavior, we adopted a dogit model with parameterized captivity functions, which accommodate people's heterogeneous captivity to different alternatives in a choice set.

Our analysis based on the SP data and the dogit model confirms that cruising range, charge distance, operation cost, and diffusion rate are major influential factors. People are more likely to choose EM when the cruising range is longer, charge distance is 0.8 km - 1.0 km, the operation cost is lower, and the diffusion rate is lower. These findings can give some suggestions to policy making and technology innovating. First of all, trade-off between cruising range and the price-to-income ratio is quite high, and people would like to pay additional 1.27 times of his monthly income for an increase in cruising range by 50 km. The manufacturers should continue improving the performance of cruising range in order to meet motorists' expectations. Moreover, the preferred distance to charge station is 0.8 km - 1.0 km, which could provide scientific evidence when setting up the charge facilities. Furthermore, the lower percentage of operation cost in total lifecycle cost will increase the probability of choosing the corresponding vehicle. This implies that EM will have a promising potential market in Vientiane due to its low operation cost. Additionally, the negative diffusion rate parameter indicates that people prefer to choose EM when the ownership rate is low. This shows a psychological phenomenon that people in Vientiane would like to be the innovator not the imitator. This phenomenon implies that the government should have some measures and policies to stimulate people when the diffusion rate is high. Last but not least, as discussed in simulation result, before annual income comes to $4,000, it is the high-speed growing period of EM in Vientiane, and producers and government should grasp the opportunity to promote EM. When the income reaches a certain level, the major competitor of EM may not be CM but cars. So buying other vehicles could be included in the “no buying choice”, it is not possible to distinguish from our survey. That could be our future studies. Aspects mentioned above are essential for establishing a stable EM market in Laos.

APPENDICES

Appendix I：An Example of SP Question Card

Attributes (***Bold & italic type: values change across SP card***)		Alternative 1	Alternative 2	Alternative 3
		Conventional motorcycle	**Electric motorcycle**	**Do not buy any motorcycle**
Attributes of conventional motorcycle	Engine displacement	125 CC	Battery: 2-5 kwh	
	Fuel efficiency	***35 km/l***	20 km/kwh	
	Fuel type	Gasoline	Electricity	
Attributes of Electric motorcycle	Cruising range		***150 km***	
	Charge time of battery		***4 h***	
	Battery life		***5 yrs***	
	Distance of charge station from origin/destination		***Charge at origin/destination***	
	Engine sound for traffic warning		***with***	
	Diffusion rate in market		***5%***	
Common attributes	**Your monthly income level in future (US$)**	***1,000***		
	Vehicle body price (US$)	1,300	***3,200***	
	Subsidy level by government (US$)	No subsidy	***640***	
	Total cost for 10 years (US$)	5,400	***4,460***	
	Emission	with tailpipe emission	without tailpipe emission	
	Maximum speed (km/h)	***120***	***100***	
CHOICE: Check only one box		❐	❐	❐

[1] Total cost includes vehicle body price, operation cost, maintenance cost and insurance, and battery replacement cost for one time by substracting the subsidy (only for EV/PHEV).

Appendix II：Orthogonal table of SP survey (italic number is calculated according to other attributes)

Block No.	Card No.	Efficiency (km/*l*)	Cruising range (km)	Charge time	Battery life	Distance to charge station	Sound	Diffusion rate	Future income (US$)	EM price (US$)	Subsidy (% of EM price)	*Subsidy (US$)*	*Total price for EM (US$)*	Maximum speed for EM (km/h)	Maximum speed for CM (km/h)
1	1	35	150	4h	5yrs	home	yes	5%	1000	3200	20%	*640*	*4460*	120	100
1	10	35	100	2h	8yrs	1km	yes	20%	2000	3200	10%	*320*	*4780*	100	100
1	19	35	100	4h	5yrs	2km	yes	20%	1000	2500	20%	*500*	*3900*	100	60
2	2	35	150	2h	8yrs	2km	yes	20%	1000	2500	0	*0*	*4400*	100	60
2	11	55	100	2h	8yrs	home	yes	5%	1000	3200	10%	*320*	*4780*	100	60
2	20	55	100	4h	5yrs	2km	yes	5%	2000	4000	0	*0*	*5900*	100	60
3	3	55	150	2h	5yrs	2km	yes	5%	2000	3200	0.2	*640*	*4460*	100	60
3	12	35	150	2h	5yrs	2km	no	5%	1000	4000	10%	*400*	*5500*	120	60
3	21	35	150	2h	5yrs	1km	no	20%	1000	3200	0.2	*640*	*4460*	100	60
4	4	35	150	2h	8yrs	1km	yes	5%	2000	2500	0	*0*	*4400*	120	60
4	13	55	150	2h	5yrs	1km	yes	5%	1000	4000	10%	*400*	*5500*	100	60
4	22	55	150	4h	8yrs	home	no	5%	1000	2500	0	*0*	*4400*	100	100
5	5	35	150	4h	5yrs	home	yes	20%	2000	4000	0.1	*400*	*5500*	100	100
5	14	35	60	2h	5yrs	home	no	5%	2000	3200	0%	*0*	*5100*	100	60
5	23	35	100	2h	5yrs	home	yes	5%	2000	2500	0.2	*500*	*3900*	120	60
6	6	35	100	4h	8yrs	2km	no	5%	1000	3200	0.1	*320*	*4780*	120	60
6	15	55	60	2h	8yrs	home	yes	20%	1000	4000	20%	*800*	*5100*	120	60
6	24	35	60	4h	5yrs	1km	yes	5%	1000	2500	0.1	*250*	*4150*	100	60
7	7	35	100	2h	5yrs	1km	yes	5%	1000	4000	0	*0*	*5900*	120	100
7	16	35	60	2h	5yrs	home	yes	5%	1000	2500	10%	*250*	*4150*	100	60
7	25	35	60	2h	8yrs	2km	yes	5%	1000	4000	0.2	*800*	*5100*	100	100
8	8	35	100	2h	5yrs	home	no	20%	1000	4000	0	*0*	*5900*	100	60
8	17	55	100	2h	5yrs	1km	no	5%	1000	2500	20%	*500*	*3900*	100	100
8	26	55	60	2h	5yrs	2km	no	20%	2000	2500	0.1	*250*	*4150*	120	100
9	9	35	60	4h	8yrs	1km	no	5%	2000	4000	20%	*800*	*5100*	100	60
9	18	35	60	2h	5yrs	2km	yes	5%	1000	3200	0	*0*	*5100*	100	100
9	27	55	60	4h	5yrs	1km	yes	20%	1000	3200	0	*0*	*5100*	120	60

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