Estimating Willingness to Pay for the Use of Biodiesel Fuel from Paired Comparison Approach: The case of Bangkok, Thailand

P. Duangchinda
Southern Economy Research Unit, Faculty of Economics and Business Administration, (*Thailand*)

Abstract

Biodiesel fuel is one alternative fuel which can be substituted for petroleum diesel in condition the limited capacity of fossil energy reserves. The purpose of this study is to quantify consumer's willingness to pay (WTP) for biodiesel fuel by paired comparison (PC) approach. The PC approach suggested that Bangkok residents were willing to pay £0.0068 per litre more for biodiesel per 1% reduction in other vehicle operating costs (OC) and £0.0052 per litre per unit (%) reduction in pollution emissions (PE), but £0.0067 per litre per unit (%) increase in cetane number (CN), Of course, the results application of all study finding will apply to use for decisions on the efficient management of the biodiesel fuel.

***Index Terms*--Bangkok, Biodiesel fuel, Paired Comparison, Willingness to Pay**

INTRODUCTION

Energy consumption has increased extraordinarily. On the other hand, nowadays the total reserves of fossil sources are limited which are global environmental awareness [1]. Sustainable development is, therefore, a potential way of increasing alternative and renewable energy supply. To be sustainable, development must satisfy human needs and improve quality of life [2, 3].

This is due to the constant increasing price of petroleum, uncertainties concerning petroleum availability and the environmental concerns about pollution coming from vehicle emissions. Among the proposed alternative fuels, biodiesel fuel has received much attention in recent years for diesel engines [4].

This paper presents an available range of economic value of the biodiesel fuel characteristics: fuel cost, operation costs, cetane number and pollution emissions that are needed for the effective biodiesel fuel in order for them to be sustainable energy developments in Thailand. Using paired comparison (PC) model use the value of environmental goods to assess the willingness to pay (WTP) for non-market goods.

MATERIAL AND METHOD

Choice modeling (CM) one of stated preference can reveal individual preferences by asking respondents to choose their most preferred, to rate them and to rank that the options presented to them [5]. The paired comparison model uses the value of environmental goods to assess the economic efficiency of the use of biodiesel fuel. This design has comparative qualities, as each relies on a different cognitive process for eliciting preferences. Huber et al. [6] cite that the PC approach is better predictor of longer-market adaptations to new products with relatively unfamiliar attributes. Moreover, the PC technique has not been used in environmental economics to measure in the context of alternative fuels characteristics for sustainable development in the case of Thailand according to the current literature.

The main part of this study into measurement of biodiesel fuel in economic terms uses the PC model. In PC approach using the 6,340 choices elicited from 634 respondents, the conditional backward method of binary logistic regression was estimated the procedure utilizing a maximum likelihood paradigm. In part of attitudes to biodiesel fuel was analysed using Friedman's test. All parts of this study were explored using the SPSS version 14.0.

The choice modeling questionnaire design was to choose a set of attributes from all the possible sets expected to affect the preference for the biodiesel fuel in the question. To accomplish this, not only were focus groups and one-on-one interviews used but also extensive literature reviews were conducted to select attributes. The determination of attribute levels needs to considered with CM design. This is to avoid imposing linearity on respondent preferences [7]. Furthermore, it is necessary to use unequal increments between attribute levels [8]. Five types of attributes were used in the CM survey: fuel type (FT), fuel cost (FC), operating costs (OC), cetane number (CN) and pollution emissions (PE). Table I shows fuel attributes and levels used in the choice modeling, in the PC exercises. It also provides brief definitions and expected signs of using the CM method to estimate willingness to pay for biodiesel fuel.

As 49 choice sets of alternative biodiesel fuel scenarios were crease, 5 were drawn randomly. Two alternatives in each choice set were asked to rate by each respondent for the PC survey as a set of biodiesel fuel characteristics (alternative fuel) and diesel fuel characteristics (status quo). It would seem that there is a tendency to value what one knows and is familiar with using a different value hypothetical scenarios (Fig. 1).

TABLE I
VEHICLE FUEL ATTRIBUTES AND LEVELS USED IN THE CHOICE EXPERIMENT

Attribute (UNIT)	Definition	Levels	Expected sign
Fuel Type (DUMMY)	The number of different kinds of fuel; fossil fuel (diesel) and alternative fuel (biodiesel)	diesel, biodiesel	-,+
Fuel Cost (BAHT)	Price for using fuel	20,23,25,30,36,40	-
Operation Costs (%)	Cost increase with vehicle use, except fuel costs such as maintenance and repair costs	-10,-5,-2,0	-
Cetane Number (%)	Expression of diesel fuel quality, such as quick starting engines, longer engine durability, reduced noise and vibration	0,7,12,15	+
Pollution Emissions (%)	Emissions from fuel of adverse health effects including CO, NO_2, SO_2,PM_{10} and O_3	-64, -50, -37,-22,-10,0	-

Suppose that you were considering purchasing a new vehicle fuel, which fuel would you prefer (choose a preferred one).

Category	Fuel A	Fuel B
Fuel Type:	Diesel	Biodiesel
Fuel Cost (Baht/litre) :	20.00	40.00
Operation Costs:	Like present	10% less
Cetane Number:	Like present	15% better
Pollution Emissions:	Like present	64% less

I would buy:

❒	❒	❒	❒	❒
Strongly prefer A	Slightly prefer A	A and B are about equal	Slightly prefer B	Strongly prefer B

Fig. 1. Example of paired comparison question

The survey was carried out in Bangkok after the initial design and pre-test stages. The final questionnaire comprised three parts. A general attitudinal question about biodiesel fuel in Bangkok, Thailand was introduced in the first part. The second part contained the PC exercise. The final part was to provide information on a variety of socio-economic characteristics such as age, gender, education and income levels. The survey was based on face-to-face interviews, for a sample of 650 sample populations included both Bangkok residents and people who worked in Bangkok by multi-stage sampling consists of stratified and cluster sampling. Around 98% of all interviews were completed providing sufficiently complete responses to permit empirical analysis.

RESULT AND DISCUSSION

The Bangkok's residents were asked to rate the level of their concerns towards air pollution, their views on the relative seriousness of health impacts and to reveal their attitudes towards regulations controlling air pollution. The main finding from the questionnaire showed that the Bangkok survey residents were very concerned about air pollution problems (A) and they thought that very high air pollution would have serious adverse impacts on health (B). Moreover, then most people also slightly agreed with the control policy of air pollution produced by vehicles (C) (Fig. 2). All three opinions (A, B and C) showed significant differences between these features by testing with the goodness of fit test at a level of significance 0.05.

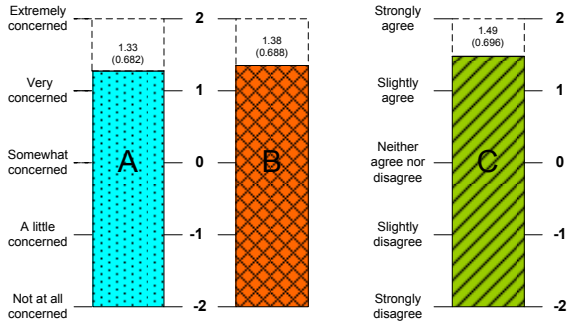

Fig. 2. Opinions on air pollution in Bangkok

Note: 1.33 (0.682) } Mean (Std. Deviation)
Significant at 5% level

A = Air pollution concern
B = Health impacts of air pollution concern
C = Regulation for controlling air pollution from vehicle

Figure 2 on a scale ranging from -2= not at all concerned to 2 = extremely concerned.

Somewhat surprisingly, air problem was the highest concern (4.68) in all environmental problems by the sample ranking in the Bangkok area. Next was solid waste (3.33) and water problems (3.05), which came second and third, respectively. The least concern was the problem about soil (1.24) (Fig.3).

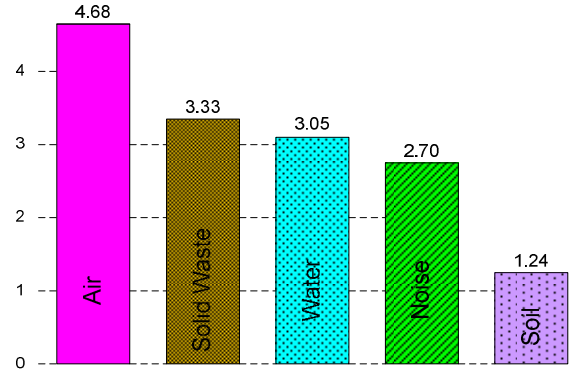

Fig. 3. The ranking of environmental problems in Bangkok

Note: 4.68, 3.33, 3.05, 2.70 and 1.24 were the mean rankings in the Friedman's test. This was significant at the 5% level.

After giving some factual regarding biodiesel fuel, the main finding from the questionnaire showed that the Bangkok survey residents, it was clear that the high price of biodiesel fuel (4.22) was the greatest barrier to the purchase of biodiesel fuel for the Bangkok residents. The engine start factor (2.52) was the lowest ranked obstruction in causing people to purchase biodiesel fuel (Fig. 4). Furthermore, suppose the Bangkok residents would have to buy biodiesel fuel at £0.5470 (40 Baht) per litre as a possible biodiesel fuel price to completion with diesel fuel at present, they would firstly be concerned about the vehicle's engine (3.55) such as high lubricates, smoother operation, complete combustion and top speed. On the other hand, economic reasons (1.75) such as creating jobs and distributing income to farmers, was the lowest ranked reason concerned by using the Friedman test at a level of significance 0.05 (Fig. 5).

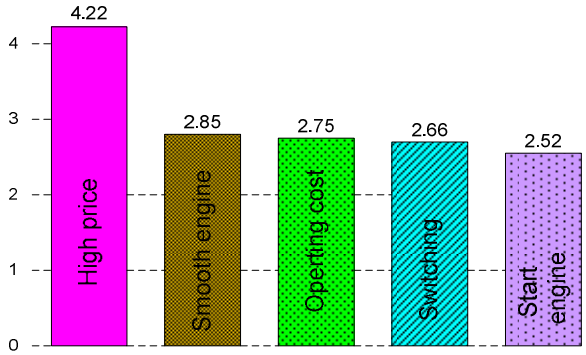

Fig. 4. The factors that affected biodiesel fuel concern

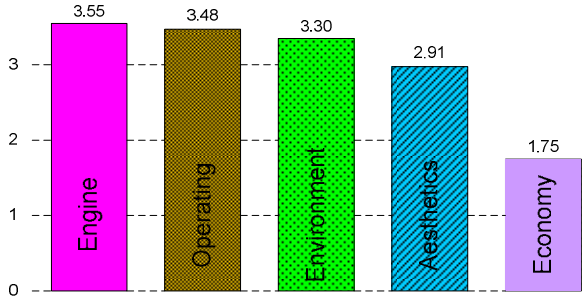

Fig. 5. Factors behind willingness to pay for biodiesel fuel at £ 0.5470 per litre

Note: Figure from 3 to 5 on a scale ranging from 1= the lowest concerned to 5 = the highest concerned. The numbers above diagrams were the mean rankings by the Friedman's test.

The conditional backward method of binary logistic regression was the procedure utilizing a maximum likelihood paradigm. The model is able to account for most of the variance and therefore best suited to predicting preferences for biodiesel fuel (H-L test Sig . = 0.000[1], Pseudo R square = 0.115[2]). The model specification found to have the best fit of explanatory variables with the most statistically significant coefficients (Table II).

The overall fit of the model was acceptable by the conventional standards used to describe probabilistic choice models [9]. All of the fuel characteristic attributes are significant factors in the choice of biodiesel fuel characteristics scenario. All main attribute factors were the coefficient signs with a priori expectations: FC, OC, CN and PE. The sign of all attribute coefficients were highly statistically significant at the 95% confidence level (at the coefficient value each of the main attributes in Table II, the values were 0.000). This indicated that most attribute levels were negative on FC, OC and PE. For example, as the price of biodiesel increases, the utility of biodiesel decreases, and as pollution emission decreases, the utility of biodiesel increases. On the other hand, the cetane number was a positive coefficient estimate implying that, with an increase in the cetane number, the utility of biodiesel increases. In addition, it might be implied that the respondents had the most concern with fuel cost (FC), operating cost (OC), cetane number (CN) and pollution emissions (PE), respectively (see the coefficient value of each attribute in Table II).

To account for heterogeneity of preferences across respondents, the effects of the social, economic and attitudinal characteristics of the respondents on their choice of fuel characteristic scenario must be investigated. On account of possible multicollinearity problems, it is not possible to include all the interactions between the social, economic and attitudinal characteristics of the respondents collected in the survey (Table II) and the four fuel characteristic attributes when estimating a basic conditional logit (CL) model with interactions [10]. The CL model with interactions model has a higher overall fit compared to the basic CL model because of Pseudo R Square of 0.123 and log-likelihood values of -7105.02. The coefficients of the main attributes were all highly significant (the coefficient value of each main attribute can be seen in Table II; the values were 0.000). Moreover, all main attributes using the interaction model have larger coefficients than the basic CL model. The coefficient signs of the CL model with interactions were similar to the basic CL model. Of course, the socio-economic variables and interaction of respondent-specific characteristics with choice specific attributes were influenced by the explanatory variable.

When considering the socio-economic variables, only one variable was statistically significant. Gender was positively related to choosing biodiesel at 95% confidence level. Female residents preferred to choose biodiesel fuel rather than male residents. Socio-economic variables such as family size, family income, hours per trip, number of cars in family and expenditure on fuel

[1] The model adequately fits the data. Hosmer-Lomeshow (H-L) test is a test of goodness of fit.

[2] The R^2 value in the logit model is similar to R^2 in conventional analysis except that significance occurs at lower levels.

were not found to have a significant effect at 95% confidence level. The positive interactions between the two characteristics and socio-economics (PE*Number car and CN*Num family) were at 95% confidence interval. There was a higher level of pollution emissions interaction with number of cars in the family which showed that the respondent would choose a biodiesel fuel. Also, the higher the level of cetane number interaction with the number of families, the more likely it was that the respondent would select a biodiesel fuel scenario (Table II).

TABLE II
RESULTS FOR BINARY LOGIT MODEL FOR BIODIESEL FUEL

Attribute	Basic Conditional Logit Model			Conditional Logit Model With Interaction		
	Coefficient	Std. error	Sig.	Coefficient	Std. error	Sig.
ASC	13.421	.845	.000**	13.307	1.693	.000**
Fuel cost (FC)	-.745	.043	.000**	-.756	.086	.000**
Operation cost (OC)	-.371	.035	.000**	-.375	.036	.000**
Cetane number (CN)	.265	.022	.000**	.367	.045	.000**
Pollution emissions (PE)	-.256	.017	.000**	-.284	.029	.000**
Socio-economic variables				.184	.059	.002**
Gender[3]				.307	.163	.059
Number in family				-.058	.033	.079
Income of family				.045	.024	.063
Hour trip				-1.819	.951	.056
Number of cars				.002	.001	.068
Expenditure on fuel				-.015	.008	.064
FC*Num family				.022	.009	.011*
CN*Num family				.091	.048	.060
FC* Number car				.031	.015	.040*
PE*Number car				.000	.000	.082
FC* Expenditure fuel				.000	.000	.079
PE* Expenditure fuel						
-2 Log likelihood	7145.97			7105.02		
Significant	.000**			.000**		
Pseudo R- Square	.115			.123		
Number of observation	634			634		
Sample size	6340			6340		

** Significant at 1% level, *Significant at 5% level

Table III shows the implicit prices or marginal willingness to pay (MWTP) values for each of the biodiesel fuel attributes with the respective 95% confidence intervals. These were all positive, implying that respondents had a positive WTP for increases in the quality or quantity of each attribute. It was also indicated that the Bangkok residents had the most WTP for OC, CN and PE respectively by using both analysis methods. It was slightly different at about £0.0002 between CN and PE with the basic CL method, and around £0.0001 difference between OC and CN with the interaction method. In general, respondents' average WTP level with the CL model interactions was higher than respondents' average WTP with the basic CL model (see Table III).

TABLE III
ESTIMATES OF WTP FOR BIODIESEL FUEL IN BAHT (B) AND £[4] PER RESPONDENT USING PAIRED COMPARISON

Attribute	Mean WTP Baht(B) and £ Basic CL model & CL model with interactions	Order
Operation Costs (OC)	0.50B (£0.0068) &0.50B (£0.0068)	1
Cetane Number (CN)	0.36B (£0.0049) &0.49B (£0.0067)	2
Pollution Emissions (PE)	0.34B (£0.0047) &0.38B (£0.0052)	3

The implicit prices are shown in Table III above; there was no evidence of estimates of compensating surplus. To estimate overall WTP for biodiesel fuel, it is necessary to include the ASC, which captures the systematic but unobserved information about respondents' choices. In order to estimate the respondents' WTP for alternative biodiesel fuel scenarios, the study concentrated on possible pollution emission options.

The estimates of WTP for the pollution emission scenarios are described in Table IV. These are marginal estimates showing WTP for a change from the current situation[5]. These estimated consumer surplus using the CL model with interactions, both social and economic. The variables were all set to the sample averages.

From Table IV, the decrease in percentage of pollution emission generated higher benefits in both models. Recall that the CL model with interactions had a better fit than the basic model, and hence the former was the preferred model as a result of preferences which varied across individuals in accordance with their socio-economic background.

The model parameters can also be used to estimate value differences between profiles. For instance, it is able to evaluate the overall fuel characteristics between an alternative scenario and the current situation. Estimates of willingness to pay were calculated for five alternative scenarios in choice sets in terms of the PC survey.

The compensating surplus (CS) welfare value using the interaction logit model indicates that the value attached to scenario 5 was £0.2477 (18.1155 Baht). That is, the average willingness to pay found in the Bangkok survey residents for biodiesel fuel characteristics (scenario 5) compared to diesel fuel (current situation) was £0.2477 (Table V) . In the paper, the CS value is used with the logit model with interaction because it has a better fit than the basic model.

[3] Male code is 1 and Female code is 2.

[4] Average exchange rate 73.1304 Baht was £1 in 2005 (source: www.bot.or.th).

[5] No changed for pollution emission.

TABLE IV
ESTIMATES OF COMPENSATION SURPLUS OF BIODIESEL FOR EACH SCENARIO USING PAIRED COMPARISON APPROACH

Scenario of percentage pollution emissions decreasing	Basic conditional logit model Baht (B) and (£)	Conditional logit model with interactions Baht (B) and (£)
2%	0. 69 B (£0.009)	0.75 B (£0.010)
5%	1.72 B (£0.023)	1.88 B (£0.026)
10%	3.44 B (£0.047)	3.76 B (£0.051)
20%	6.87 B (£0.094)	7.51 B (£0.103)
30%	10.31 B (£0.141)	11.27 B (£0.154)
40%	13.74 B (£0.188)	15.03 B (£0.205)
50%	17.18 B (£0.235)	18.78 B (£0.257)
60%	20.62 B (£0.282)	22.54 B (£0.308)
70%	24.05 B (£0.329)	26.30 B (£0.360)
80%	27.49 B (£0.376)	30.05 B (£0.411)
90%	30.93 B (£0.423)	33.81 B (£0.462)
100%	34.36 B (£0.470)	37.57 B (£0.514)

Significant at 5% level

TABLE V
ESTIMATES OF WILLINGNESS TO PAY FOR VARIOUS SCENARIOS BY USING PAIRED COMPARISON METHOD

Scenario	Fuel type	Operation cost	Cetane number	Pollution emissions	WTP Baht and £	
					Basic CL model	CL with interaction model
Current situation	Diesel	Like present	Like present	Like present		
Scenario 1	Biodiesel	2% less	Like present	10% less	18.0591 B (£0.2469)	17.8001 B (£0.2434)
Scenario 2	Biodiesel	5% less	7% better	22% less	18.1402 B (£0.2481)	17.8941 B (£0.2447)
Scenario 3	Biodiesel	5% less	12 % better	37% less	18.2095 B (£0.2490)	17.9747 B (£0.2458)
Scenario 4	Biodiesel	10% less	15% better	50% less	18.2897 B (£0.2501)	18.0629 B (£0.2470)
Scenario 5	Biodiesel	10% less	15% better	64% less	18.3378 B (£0.2508)	18.1155 B (£0.2477)

The modeling results can also be used to estimate values associated with a range of scenarios resulting from different fuel characteristics. Thai government managers can use these value estimates and approximate the value of any change in operating cost, cetane number and pollution emissions to determine which scenarios are likely to have the greatest net benefit for the community. From the empirical analysis, scenario 5 produced the highest willingness to pay £0.2477 (18.1155 Baht) by using the interaction model. Aggregate willingness to pay can be compared to aggregate costs in a cost-benefit analysis framework to assess whether the Bangkok residents are likely to experience a net benefit from proposed change to management.

CONCLUSIONS

Certainly, it is essential that the Thai authorities consider health impacts of emission pollution and primarily focus on a solution to the air pollution issue and encourage the use of alternative fuel with low emissions. This is because the results of the Bangkok survey inhabitants' opinions on environmental problems in Bangkok illustrate that air pollution is the biggest concern of the citizens surveyed. The sampled residents in Bangkok are also very worried about air pollution problems and believe that the air crisis will have serious adverse impacts on human health. Moreover, the majority of the surveyed citizens are able to follow regulations relating to air pollution produced by vehicles.

The main factors influencing the households' willingness to pay for using biodiesel fuel are pollution emissions and operation costs, £0.0052 and £0.0068 per litre of fuel, respectively by using PC approach. It implies that policy-makers and researchers have to develop biodiesel fuel and other alternative fuels for reducing pollution emissions because the WTP for biodiesel fuel is rising when biodiesel fuel is seen to diminish air pollution. In addition, another factor has to consider for biodiesel fuel quality is reducing maintenance, repair and engine-rebuild costs as second priority of individual preference.

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REFERENCES

[1] Müller-Steinhagen, H. and Nitsch, J. : *The contribution of renewable energies to a sustainable energy economy*, Process Safety and Environmental Protection, (2005) 83, (B4), pp. 285-297.

[2] Huisingh, D.: *New challenges in education for sustainable developmen'*, Clean Techn Environ Policy, (2006) 8, pp. 3-8.

[3] Lindley, S. J.: *Virtual tools for complex problems: an overview of the Atlas^{NW} regional interactive sustainability atlas for planning for sustainable development*, Impact Assessment and Project Appraisal, (2001) 19, (2), pp. 141-151.

[4] Zhou, P. L., Fet, A. M., Michelsen, O. and Fet, K.: *A feasibility study of the use of biodiesel in recreational boats in the United Kingdom*, Journal of Engineering for the Maritime Environment, (2003) 217, pp. 149-158.

[5] Hanley, N., Mourato, S. and Wright, R. E.: *Choice modelling approaches: A superior alternative for environmental valuation?* Journal of Economic surveys, (2001) 15, (3), pp. 435-462.

[6] Johnson, F. R., Banzhaf, M. R. and Desvousges, W. H.: *Willingness to pay for improved respiratory and cardiovascular health: A multiple-format, stated-preference approach*, Health Economics, (2000) 9, pp. 295-317.

[7] Bateman, I. J., Carson, R. T., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G. and Mourato, S.: *Economic Valuation with Stated Preference Techniques: A Manual.* Chelteham, UK: Edward Elgar. (2002)

[8] Foster, V. and Mourato, S.: *Behavioural Consistency, Statistical Specification and Validity in the Contingent Ranking method: Evidence from a Survey on the Impacts of Pesticide Use in the U.K.* CSERGE. (1997)

[9] Ben-Akiva, M. and Lerman, S.: *Discrete Choice Analysis: Theory and Application to Travel Demand.* Cambridge MA: MIT Press. (1985)

[10] Breffle, W. and Morey, E.: *Investigating Preference Heterogeneity in a Repeated Discrete-Choice Recreation Demand Model of Atlantic Salmon Fishing*, Marine Resource Economics, (2000) 15, pp. 1-20.