Public Preferences and Random Utility Model for Pollution Impact Mitigation Measures in a Lignite-fired Power Plant at Mae Moh, Thailand

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Abstract

A coal-fired steam power plant located in Mae Moh, Lampang, a province in the north of Thailand has been in operation since 1978 with a generating capacity of 2,400 magawatts, and estimated SO2 emission of 150 tons/hour. In order to mitigate the impacts of the emission, flue gas desulphurization (FGD) units were installed and a community development fund was set up. Fifty five residents living in the vicinity of the power plant were asked to compare attributes of the two measures and stopping the operation under four different concerns, which are health, agriculture, income and job opportunity, and public acceptance.

Utility functions are determined by an application of random utility model (RUM) with substitution units, which are the inverses of the attributes, of the three measures as parameters. Plots of the utility functions at different levels of preferences are given to elaborate the significance of the community development fund and FGD units over the shutting off the power plant.

Key words: Public preference/ Mae Moh coal-fired power plant/ Random utility model/ Emission impact mitigation/ Flue gas desulphurization

1. Introduction

Mae Moh power plant belonging to the Electricity Generating Authority of Thailand (EGAT) is a coal-fired steam power plant located in Lampang, a province in the north of Thailand. There exist thirteen power generating units in

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the power plant, of which the first unit was commissioned in 1978, and the rest were developed consecutively. The power plant, which is fueled with lignite mined from a nearby open pit mine of 135 square kilometers, and has been assigned as the base load generators, as lignite is the cheapest fuel in electricity generation and is available in the country. After the first three units were decommissioned in 2000, the plant continues delivering electricity by the remaining ten units with a total generating capacity of 2,400 magawatts, and 40,000 tons/day of lignite consumption.

1.1 Lignite quality and emission from the power plant

The low heating value (LHV) of the lignite supplied by the mine varies from 1,300 to 3,600 kcal/kg, and the average sulphur content is 2.88%. SO_2, which could have an impact on human health, crops and livestock, was found to be 3,418 μg/m^3 by measurement in 1992 while the standard level was at 1,300 μg/m^3(Wangwongwatana et.al., 2003). The maximum hourly concentration of SO_2 from the power plant was estimated to be 150 tons/hour.

1.2 Impact mitigation measures

There have been several measures implemented to mitigate the impacts of the emissions on the residents living in the nearby area, such as installation of flue gas desulphurization (FGD) units and remote monitoring stations, corporate social responsibility programs, and community development fund. Two major measures considered in this study are the installation of FGD units and the set-up of a community development fund.

A. Community development fund

Contributions are required from power plants to set up a community development fund, which is used to rehabilitate and to increase the knowledge, the awareness and the participation of the residents in the surrounding area who are affected by the plant's operation. The contribution is at a rate of 50,000 Baht/MW/year during the construction, while during the plant's operation the rates are different depending on the fuel type used for power generation, ranging from 1.00 Satang/kWh for electricity generating from renewable energy and municipal solid waste (MSW) to 2.00 Satang/kWh for coal-fired power plants (100 Satangs = 1 Thai Baht = approx. 0.032 USD). Mae Moh power plant is operated as a base load power

generator and delivers 1,300 to 1,400 GWh/month of electricity, and is required to contribute to the community development fund about 27 million Baht/month or 17% of the whole country (EPPO, 2010).

B. Flue Gas Desulphurization

Flue gas desulphurization systems (FGD) were installed for units 4-13 during 1995 to 2000 to reduce the concentration of emitted SO2 at the allowable level. There were not any FGD units installed for power generator units 1-3 as they were kept as cold stand-by units. The systems are capable of removing as much as 95% of SO_2 by the scrubbing units with wet limestone process. SO_2 emissions from the power plant were reduced from 150 tons/hour to less than 7 tons/hour, and the maximum hourly concentration of SO_2 was reduced from more than 3,000 $\mu g/m^3$ in 1992 to less than 500 $\mu g/m^3$ (Wangwongwatana et. al, 2003).

C. Stop the operation

Stopping the operation of the power plant is included as an alternative for the interviewees to choose. Although there has not been any plan to shut off the power, it is meant to provide a closed end answer for the interviewees.

1.3 Random Utility Model (RUM) and Applications

Random utility model is normally used to determine utility by a set of explanatory variables and information of the choice situation (Train, 2009). If u_{ij} represents utility of an individual i gaining from the product j, the utility u_{ij} is composed of a deterministic component v_{ij}, and a stochastic error component e_{ij} as follows:

$$u_{ij} = v_{ij} + e_{ij} \quad (1)$$

The probability of u_{ij}, which is denoted by P_i, can be determined with Logit model where each e_{ij} is independent and identically distributed:

$$P_i = \exp(v_i) / \Sigma_j \exp(v_j) \quad (2)$$

The coefficients of the utility function can be found by maximizing the log-likelihood term:

$$\beta = \Sigma_i n_i \log (P_i) \quad (3)$$

Random Utility Model (RUM) has been applied with cases relevant to the study of social preferences. Cole and Brannlund (2009) measure public preferences for climate policy measures by employing the choice experiment (CE) approach, which asks survey respondents to choose a climate policy measure from a list of

alternatives that are described by general characteristics and various levels of interest (attributes) through a random utility model (RUM). The random utility model is employed by Lupi (2005) in the estimation of the demand for fishing, which involves determining where and how often people go fishing under different price regimes. The travel cost method is used to estimate the demand for non-market goods like the demand for recreational areas. The traditional travel cost model and the random utility model provide a prediction of current demand for a particular site. Recreation demand accounting for choice set familiarity and favorite sites are estimated by Parsons et.al. (1999) using the random utility model. Familiar and unfamiliar sites are specified with different utility functions, of which favored sites are assumed to have higher utility than non-favored sites. It is found that travel and time cost are a less important determinant of site choice, while the unfamiliar sites tend to have a lower site utility. Berman (2007) argues in the paper that the prior RUM applications to commercial ocean fisheries have been based on an unrealistic aggregation of potential fishing sites, and outlines a new approach based on poisson approximation that is theoretically consistent with the Random Utility Model. He demonstrates that the new approach provide nearly identical results to what would be achieved by estimating a standard RUM model, and suggests future researches address how to carry out detailed site-choice applications within a more complex and complete discrete choice framework. Consumer preferences for airline service attributes between Ponta Delgada and Lisbon: the most important air corridor between the Azores and Mainland Portugal is analyzed by de Menezes and Vieira (2008). The results imply high willingness to pay measures with statistically significance for punctuality warranties and comfort. On the opposite, the willingness to pay for additional daily flights is quite low.

2. Methodology

Even with the mitigation measures, there were complaints about the emission from the power plant and resistance to the operation of the plant. It is therefore worth finding out whether the people who are directly exposed to the adverse effects of the pollution really want the power plant to stop its operation or if they prefer other mitigation measures. The findings will be useful for

future planning for the mitigation of the emission impacts. There are four (4) concerns included in the study.

1. Health
2. Agriculture
3. Income and job opportunity
4. Public acceptance

The following mitigation measures are considered as alternatives for the relief of the concerns.

1. Community development fund
2. Flue gas desulfurization
3. Stopping the plant operation

2.1 Survey Sampling

A total of 55 samples were randomly selected from the two sub-districts, Ban Dong and Som Pad, which have been impacted by the pollution. Both villages are located within a radius of five (5) kilometers from the power plant. One of them is in the north, while the other is in the south of the power plant.

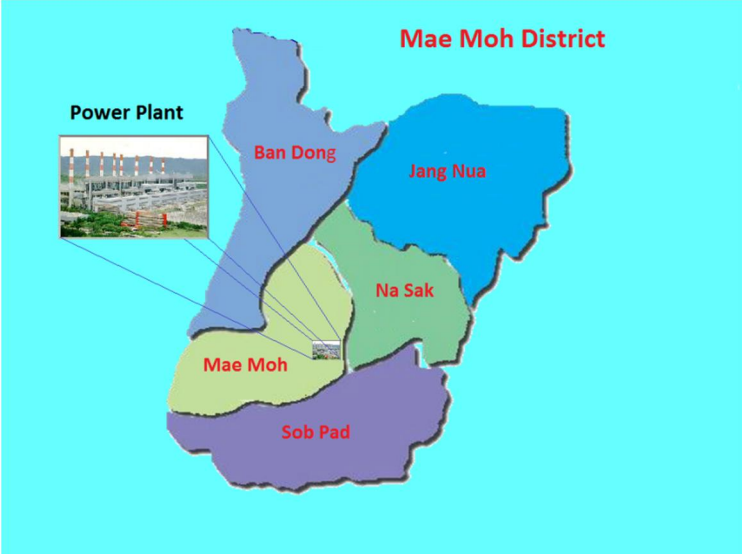

Figure 1: Locations of villages in Mae Moh

There are 2,151 households and 1,404 households in Ban Dong and Som Pad sub-districts respectively (NSO, 2010). The total households in both sub-districts are 3,555 households. According to Yamane's formula (Yamane, 1973).

$$n = N/(1+Ne^2) \quad (4)$$

where n = sample size,

N = population size, and

e = level of precision.

The confidence level, 1-e, can be determined by substituting n = 55,

N = 3,555, and found to be 86.6%.

2.2 Interview

The interview was carried out in two parts, comparing concerns and the mitigation measures. First, each sample was asked to compare the severity of the four (4) concerns; health, agriculture, income, and public acceptance. Secondly, the interviewees are requested to compare all possible pairs and give attributes for the mitigation measures for each concern. Attributes are given based on the preferences that the interviewee is certain for the relief of the environmental impacts. On the scale of 1 to 9, an attribute of 1 is for the measure with the least preference while an attribute of 9 is for the measure with the most preference.

3. Results and Discussion

3.1 Public preferences for various concerns

The interviewees ranked their preferences for different measures (community development fund, flue gas desulphurization, and stop plant operation) by giving different attributes with respect to each criterion are illustrated in Figure 2, 3, 4, and 5

The interviewees were asked to compare and score the concerns pair-wisely. The concern with the most scores was considered as his selection. Income and health seemed to be of greater concern for the interviewees than the other two, which were public acceptance and agriculture. Twenty four (24) interviewees and twenty three (23) interviewees voted for the concerns for health and income respectively, while five (5) interviewees and three (3) interviewees chose agriculture and public acceptance, as shown in Table 1

Table 1: Weights given for different concerns

Concerns	No. of samples	%
-Health	24	43.6
-Agriculture	5	9.1
-Income	23	41.8
-Public Awareness	3	5.5
Total	55	100.0

3.1.1 Concern 1: Income and job opportunity

Figure 2 shows that the community development fund is preferred as the best measure to relieve the concern of income and job opportunity with a weight of 53.9% of attributes. Flue gas desulfurization units, is the second choice

with a weight of 33.7%, while stopping the plant operation is the last option with a weight of 12.4%.

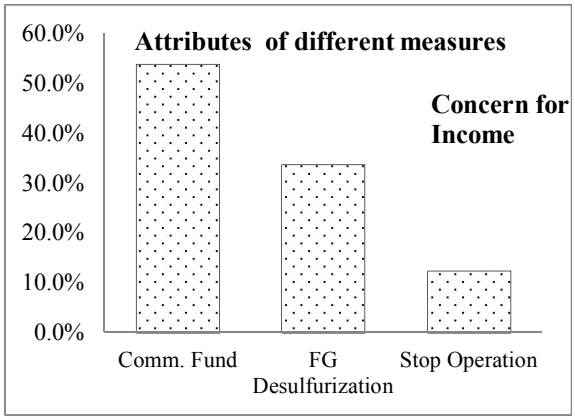

Figure 2: Percentages of attributes given for different measures for the concern for income and job opportunity

3.1.2 Concern 2: Agriculture

When agriculture was in focus, the interviewees viewed that the community development fund and flue gas desulfurization units were the measures that could be effective remedies. They were weighted of 44.7% and 41.0% respectively, while the ceasing of plant operation was 14.3%, as shown in Figure 3

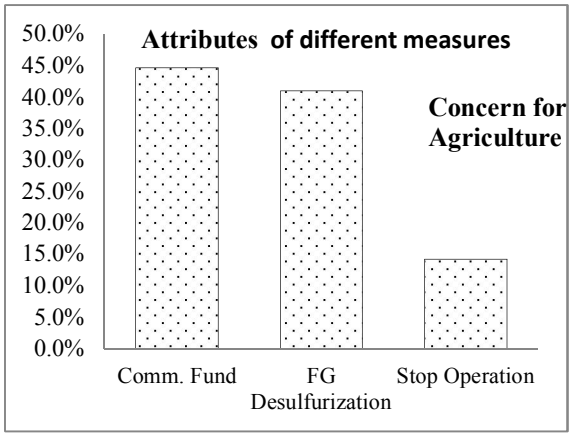

Figure 3: Percentages of attributes given for different measures for agricultural concerns.

3.1.3 Concern 3: Health

The interviewees agreed that for the concern for health flue gas desulfurization was the best measure among them with a weight of 49.8%. Community development fund was ranked second with a weight of 34.8%. Similar to other concerns, closing down the power plant seemed to be the last choice for the interviewees. It weighted at 15.4% as shown in Figure 4

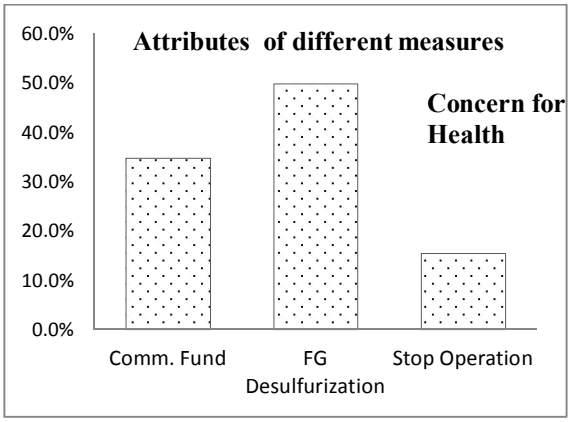

Figure 4: Percentages of attributes given for different measures for the concern for health.

3.1.4 Concern 4: Public acceptance

The interviewees preferred that flue gas desulfurization units and community development fund would help in gaining back public acceptance of the area, with the weights of 47.0% and 40.6% respectively. Shutting down the plant was weighted as 12.4% as the last among all of the choices.

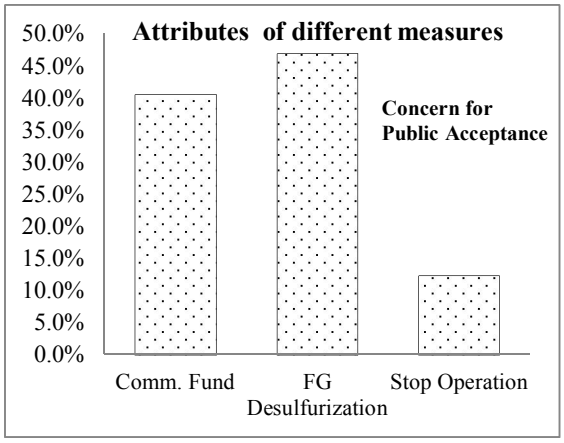

Figure 5: Percentages of attributes given for different measures for the concern for public acceptance

The percentages for different measures are consolidated by the inclusion of the weights of the concerns, as given in Table 1 The community development fund and flue gas desulfurization units are confirmed to be the public's preferences with weights of 44.0% and 42.1% respectively. The option of turning off the operation of the plant is the last with 13.9% weight as shown in Table 2 and Figure 6

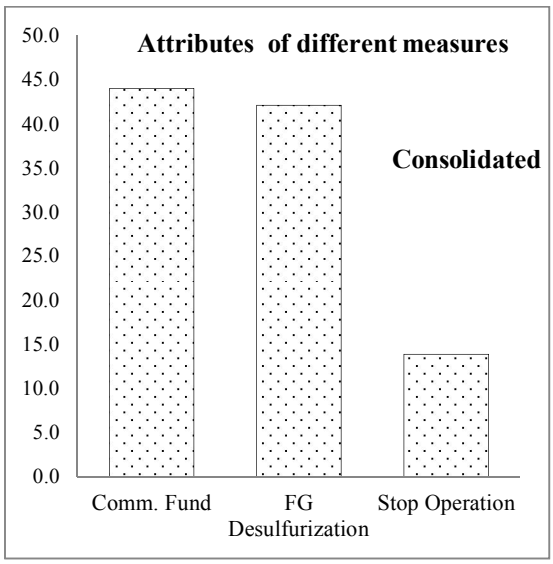

Figure 6: Consolidated percentages of attributes given for different measures for all concerns.

3.2 Random Utility Model for Public preferences

The attributes given by interviewees indicate their preferences for different measures. The measure with higher attributes is preferred by interviewees as the measure with more potential to solve the environmental problem or more capability to mitigate the adverse effects caused by the power plant. It implies that more units of the measure with less preferences or lower attributes are required for a substitution for other measures with higher attributes in order to gain the same level of preference. The *unit for substitution* is inversely related with the *attributes*. In this study, the community development fund (CDF) is preferred with higher level of attributes than shut-off the power plant. Implicitly, more units of shut-off the power plant are needed to compensate the reduction of the community development fund in order to remain the same satisfaction.

Table 2: Consolidated percentages given for the measures

	Concerns				
Measures	Health	Agriculture	Income	Public	Total
	43.6	9.1	41.8	5.5	(%)
Comm. Fund	34.8	44.7	53.9	40.6	44.0
FG Desulfurization	49.8	41.0	33.7	47.0	42.1
Stop Operation	15.4	14.3	12.4	12.4	13.9
					100.0

The preference scores or *attributes* retrieved from the survey were converted into *units for substitution* by switching the scores between the measures. That is, for an example, a pairwise preference comparison between a measure A and another measure B is 4 and 1, which can be interpreted as the particular interviewee prefers measure A over measure B by 4 times. The interviewee gives 4 attributes to A and one attribute to B. Inversely, four (4) units of B are required to substitute one (1) unit of A to maintain the same level of preference. The units for substitution are tabulated for different concerns as in Table 3

Table 3: Units for substitution of measures for different concerns

Concerns	Health	Agriculture	Income	Public acceptance
	H	A	I	P
Comm. Fund (CF)	324	241	163	278
FGD	178	232	326	202
STOP	490	532	591	579

By using Excel solver to calculate coefficients of the utility function vj with the application of the units for substitution in Table 3 and the numbers of interviewees choosing them as the most concerns in Table 1. The coefficients β1, β2, and β3, defined in eq.(3), were calculated and found to be 0.0789, 0.0858, and 0.0001, respectively. The utility function can be rewritten with the calculated coefficients as follows:

V =.0.0789 CF + 0.0858FGD + 0.0001 STOP (5)

An example of calculation of the substitution possibilities between CF and

STOP, given that FGD is constant, at different arbitary utility levels U1, U2, and U3 was carried out. The results are plotted as shown in Figure 7 and Figure 8

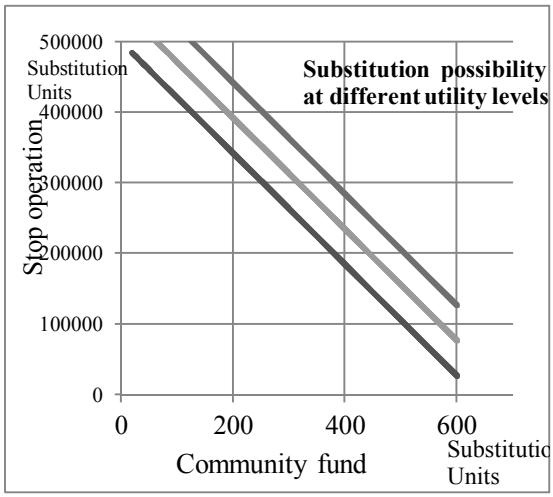

Figure 7: An example of substitution possibilities between community evelopment (CF) and stopping the plant operation (STOP) at different arbitary utility levels.

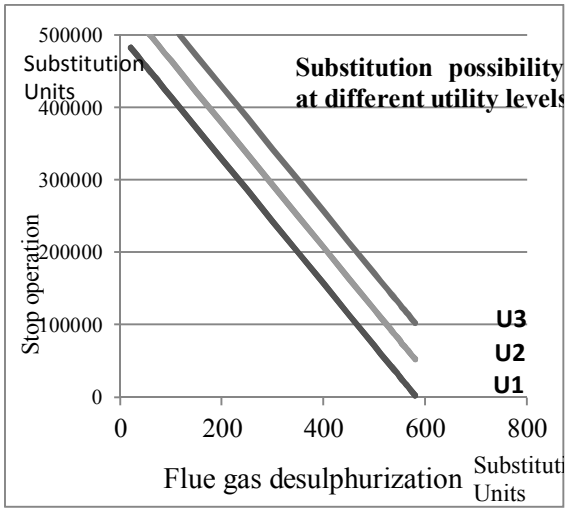

Figure 8: An example of substitution possibilities between flue gas desulphurization (FDG) and stopping the plant operation (STOP) at different arbitary utility levels.

4. Discussions

Pollution in the surroundings of the coal-fired power plant at Mae Moh has caused damage to agriculture, health, and properties of the people who live in the vicinity of the power plant for a long time. Complaints and resistance from the local people resulted in initiation of mitigating measures by the power plant. Even though the mitigating measures including flue gas desulphurization installation, community fund establishment, etc. have been launched and in effect for many years, there are from time to time complaints and protest against the power plant operation. In order to find out which measures are satisfactorily acceptable to people who are really affected by the emissions from the power plant, the survey was conducted and allowed them to express their opinions. It found that the mitigation measures like flue gas desulphurization units and community fund are preferred by the people in the vicinity, while stopping the operation of the power plant is the least preferable choice. The results of the survey indicate that regardless of the concerns of income, agriculture, health, and public acceptance, community fund and flue gas

desulphurization units are acceptable as effective mitigation measures.

The random utility model is applied with the results from the survey to compare and illustrate public preference on different mitigating measures. The substitution possibility curves show much higher level of significance of community fund and flue gas desulphurization units than stopping the operation of the power plant, and reinforce the public selections of community fund and flue gas desulphurization units as the most effective mitigation measures.

The results of the study can be used for future planning of new power plant establishment. Emission mitigation measures have to be set forth and inclusive in the feasibility study and planning. Early information and transparency in communication with local people will be useful for minimizing resistance of the local people and promoting public acceptance in the construction and operation of the power plant. The procedure is not limited to coal-fired power plants, but it is applicable to any other type of power plant including biomass power plants, gas-fired power plants, refuse derived fuel (RDF) power plants, etc.

5. Conclusions

The results can be concluded as follows:

1. Out of 55 interviewees, twenty four and twenty three of them gave their votes to the concerns for income/job opportunity and health respectively. The other five and three interviewees indicated their concerns for agriculture and public acceptance, respectively.

2. Community development fund and flue gas desulfurization were voted by most of the interviewees to be the effective measures in relieving most of the concerns.

3. Stopping the plant operation is the least preferred measure by the interviewees for the mitigation of the pollution. The attributes dedicated to the measure, stopping the plant operation, are small compared with other measures.

4. It can be elaborated by using the derived utility function that community development fund and flue gas desulfurization are much more significant than stopping the plant operation in terms of substitution for the same level of utility preference.

5. The findings from this study are useful for the design and management of future power plants. Power plants are

acceptable to local residents if proper environmental impact mitigating components are installed and social responsibility programs are arranged.

6. Acknowledgement

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