ENVIRONMENTAL COST OF HYDROPOWER DEVELOPMENT CASE STUDY: XAIYABURI HYDROPOWER DAM, LAO PDR.

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A Thesis Submitted in Partial
Fulfillment of the Requirements for the Degree of
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ABSTRACT

Title of Thesis	Environmental Cost of Hydropower Development Case Study: Xaiyaburi Hydropower Dam, Lao PDR.
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The controversial impacts of hydropower development are still debatable, especially when dams are constructed in the mainstream of multinational rivers. This study examines the impacts of the Xaiyaburi hydropower project constructed in the mainstream of the Mekong River in Bolikhamxay province, Lao PDR. Results from our Cost and Benefit Analysis indicated that the Xaiyaburi Dam is financially feasible with a positive financial net present value (FNPV) of $5,797,169,153 in its lifetime. In addition, this project is expected to earn an 8.26% financial internal rate of return (FIRR) per year; $1 spent as an investment in this project is expected to generate financially $2.18 in return. However, only the result from the financial cost and benefit analysis (FCBA) might not be enough to fully understand the impacts of hydropower development. We, therefore, extended the CBA analysis into broader issues by including the opportunity cost related to environmental impacts caused by the project into consideration. The opportunity cost considered in this study consisted of 2 categories, Used and Non-Used Value. While the Used Value is measured by the opportunity cost related to land loss, fish stock reduction and CO2 emission, Non-Used Value is measured by opportunity cost related to the local peoples' willingness to pay (WTP) for environmental attributes improvement. Similar to the FCBA, we found economic feasibility for the project. It is estimated to yield an economic net present value (ENPV) of $545,113,968 in its lifetime, and $1 spent as an investment in this project is expected to generate only $1.05 in return. However, when considering the economic IRR value, we found infeasible growth of the project

(0.96% of economic IRR). Moreover, the project NPV is highly sensitive to the change of revenue (1% reduction in revenue is expected to decrease the value of the ENPV by 19.60%) and the change of the Carbon tax (1% reduction in revenue is expected to decrease the value of the ENPV by 5.06%) respectively. Results of this study provided us with useful quantitative information for the government of Laos and other countries along the Lower Mekong Basin (LMB) to assist in decision making on the hydropower production plan, especially, to a project that will be constructed in the mainstream of a multinational river to ensure the implementation of an environmentally friendly hydropower program.

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CHAPTER 1

INTRODUCTION

1.1 Rationale of the Study

The rapid growth of ASEAN-Association of South East Asia Nations – has made it become the major economic force of the region. With a population of 600 million and a 300% economic expansion, it has become the 3rd largest economy in Asia and 7^{th} of the world. Recently, ASEAN has been able to draw a huge volume of investment from all around the world, especially, the US which is shifting its focus to the West. However, the increasing investment and economic growth could end up with more demand for energy in every sector. Additionally, the majority of our energy production and consumption is based on fossil fuel energy. As the fossil energy is unsustainable and polluting, it is increasing the concern of global warming. Therefore, it is necessary for us to find other cleaner and sustainable sources of energy for our future.

The renewable energy is now becoming an alternative source of energy. This situation is presenting the opportunity for Lao PDR (Laos) to develop the hydropower sector to contribute to meet the higher demand for energy of ASEAN. Laos has been fast growing in the last decade, 8% average economic growth, and is targeted to continue growing to achieve its social-economic development plan to move out from the list of LDCs (Least Development Countries) in 2020 (NSEDP, 2001; NSEDP, 2006; NSEDP, 2010; NSEDP, 2015). It is in the center of the region sharing borders with Thailand, Cambodia, Vietnam, China and Myanmar, and its geography is highly mountainous, with plenty of river flow, receiving around 35% of the total Mekong River flow; hence, hydropower development could be the most appropriate for Laos's future energy (Ministry of Energy and Mines, 2014).

Due to its limited resources of energy diversification, all petroleum products have to be imported in Laos. In the current situation, hydropower development seems to stress its importance for Laos's social-economic development, especially for its rural area electrification due to lower operation cost, reliability, cleanliness and sustainability. Not only will it serve the domestic demand, but it will also bring the ambition of the Government of Laos (GOL) to act as ASEAN's battery by becoming the major electricity exporter in the region (NSEDP, 2015). Therefore, hydropower will be one of the main sources of income of Laos after natural resource exports (timber and minerals).

Laos's hydropower sector has been developed for a long time since its first hydropower plant, Nam Ngum 1, was finished in 1971. At the end of 2014, Laos exported around 12.5 billion KW of electricity; earning the foreign exchange over US$610 million. Presently, there are 36 operating hydropower plants with a total electricity generation capacity of 5,806MV or 31,430 GWh per Year. In addition, 35 projects are under construction, 16 are preparing for the construction process and 55 are planning to be constructed before 2020, in addition, 22 projects are under the Concession Agreement (CA) process. Feasibility Studies (FS) have already been accepted for 27 projects and another 234 are under the FS process (Ministry of Energy and Mines, 2014) as shown in Table 1.1.

The Xaiyaburi hydropower plant is the very first among 11 purposed dams planned to be constructed in the Lower Mekong mainstream (its construction specifications are shown in Table 1.2). They are raising controversy for the public due to the concern of environmental impacts expressed by the government of Thailand, Vietnam, and Cambodia as well as general people and international NGOs (Herbertson, 2011). Even though those 11 purposed dams are expected to generate around 15,000 MW of electricity, equal to 8% of the regional demand by 2025 (MRC, 2010), the opportunity cost related to social and environmental impacts of those hydropower projects should be strict in order to maintain the balance of economic development and ecosystem sustainability. Hydropower development would affect local inland fisheries, flooding farmland, and loss of nutrients for local people (Baran & Myschowoda, 2009). Moreover, the aquatic ecosystem of the Mekong river has the second highest worldwide fish species diversity, 229 species. The habitat for spawning and/or for dry season refuge (70 of them are migratory species) would also be dramatically affected due to the change of water conditions. (Baran, Larinier, Ziv,

& Marmulla, 2011; Baran, 2006). Also, 55% of the lower mainstream would be turned to reservoirs with slow-moving water and more than 50% of the total river sediments would be blocked and prevented from moving downstream, which will directly affect river productivity and floodplain farms which would be expected to affect 2.1 million people who are farming, fishing and living downstream (Kummu, Lu, Wang, & Varis, 2010). Further impacts caused by hydropower is during the construction process, for instance, forced population displacement, deforestation, air, soil and water pollution, loss of farmland, methane emission and the reduction of fish population downstream (Commerford, 2011). Therefore, when the opportunity costs of hydropower development are fully considered, hydropower construction in the Lower Mekong mainstream are not the most beneficial solution for the ASEAN's future energy.

Table 1.1 Hydropower Development in Laos

Hydropower in Laos	**Number of Dams**	**Capacity (MW)**	**Capacity per Year (GWh/Year)**
Operating Project (Capacity>1MW)	23	5,806	31,403
Under-Construction Process	35	4,471	22,267
Preparing to be Constructed	22	1,757	6,991
To be Constructed before 2020	55	4,130	21,856
FS Approved	27	3,351	14,703
Under the FS process	234	9,085	36,653
Total	409	28,600	133,874

Table 1.2 Xaiyaburi Hydropower Characteristics

Characteristics	**Measurement**
Location	Xaiyaburi Province
Length of dam (m)	830
Height of dam (m)	36
Turbines	8
Installed Capacity (MW)	1,260
Total annual energy (GWh)	7,406
Reservoir area (Km2)	49

1.2 Research Question and Objectives of the Study

Hydropower generation is very important for Laos's social-economic development. It also plays a major role in the government of Laos's ambition to become ASEAN's battery. However, the rapid growth of hydropower plants is raising two considerable questions that operators, planners, and policymakers need to take into account in order to achieve the maximum benefit from hydropower development.

Firstly, how are the opportunity costs related to social and environmental impacts of the Xaiyaburi project?

Secondly, once all opportunity costs of Xaiyaburi project are taken into consideration, is the Xaiyaburi Dam economically feasible?

The reasons for raising the two questions above are to figure out the whole picture of all costs caused by Xaiyaburi Dam and to provide quantitative information to Lao policy makers to set the most appropriate framework for hydropower development in Laos.

This study is conducted with the 2 objectives below;

1) To estimate the value of opportunity cost or the cost related to the society and environment of Xaiyaburi Dam;

2) To assess the financial and economical Cost and Benefit Analysis (CBA) of the Xaiyaburi hydropower project.

1.3 Scope of the Study

This study aimed to cover both the financial and economic cost and benefit analysis of the Xaiyaburi hydropower project using both primary and secondary data.

1.4 Contributions of the Study

This study expects to expand the scope of CBA analysis to cover broader issues by involving opportunity cost related to environmental impacts caused by the project into the model. Results from this study are also expected to provide numerical information to assist planners, operators, and policymakers, directly and indirectly, responsible for hydropower development in Laos and other developing countries to carefully consider environmental impacts caused by hydropower development in the Lower Mekong mainstream.

CHAPTER 2

THEORETICAL AND LITERATURE REVIEW

2.1 Cost and Benefit Analysis

The cost and benefit analysis (CBA) is important in the economics field; it is motivated by the increase of demand for evaluating impacts associated with our economic activities and CBA is now providing a key piece of important information for many public projects' decision making (Mitchell & Carson, 1989). Cost-Benefit Analysis (CBA) estimates the total value of benefits and costs of the project in order to assist whether or not policymakers should embark on the project. For reaching a conclusion of the project's desirability in every aspect, positive and negative, all costs and benefits must be expressed in terms of a common unit, and most CBA studies suggested that money is the most convenient common unit (Watkins & Alley, 2011). Moreover, CBA not only reflects the value of costs and benefit in terms of equivalent money value, but they also have to be expressed in terms of a unit of money (e.g. USD, EUR, and THB) of a particular time. The reasons timeframe should be considered when conducting a CBA are (1) the differences in the value of money in different periods caused by inflation; i.e., the value of money in the future is not as high as the value of money available today, and (2) we can invest money available now in the bank and earn interest rates of (1+r)t. This is called the discounted value or present value of money available at t years in the future (Belli, Anderson, Barnun, Dixon, & Tan, 2001).

In neoclassical economic theory, the value that society places on goods or services is usually measured by the market price. With typical goods and services, which has market value, its price will be the amount of money that people are willing to forgo for acquiring it, reversely, to accept or to be compensated for its loss or damage. In common markets, the price paid for goods or services is the measurement of its value. However, the imperfect nature of the market will distort the environmental goods and services making them unable to be fully observed by using only the market price. Market imperfection can be found not only in environmental resources, but also in many social programs such as education, transportation, health, etc. which produce benefits or costs in which appropriate price could not be provided by the ordinary market.

2.2 The Theory of Environmental Economics

The economic system is more than financial flows within the market; the un-priced or non-market services provided by the environment are also the concern of it. Inside the environmental systems are the economic systems operations, with conditions in the two systems being determined in an evolving dynamic way (Henley, Wright, & Adamowicz, 1998). Hydropower development, for instance, is usually regarded as clean energy and claims many benefits for our social-economic development (Claudia & Renuad, 2012). However, its negative impacts on biodiversity, landscape, water quality, habitat, estuary sedimentation, as well as local peoples' health during the process of development have been critically studied in the past. (Wang, Fang, Zhang, Chen, Chen, & Hong, 2010). Such an environmental impact is called "Externality", that is, when the one identity's activity has, direct or indirect, effects on the wellbeing of another and such an effect is not reflected in the market price (Harvey & Gayer, 2014). In this case, when the hydropower project construction affects downstream fish population and, hence, directly affects the food security of people downstream, or during the construction process deforestation and pollution released will directly affect local welfare. (Belli et al., 2001). The private cost would not reflect the cost of externality such as the reduction of fish populations and deforestation, but its costs to society. In Figure 2.1, where MPC is the marginal cost of producing electricity as reflected in private cost, MEC is reflected in the marginal cost of externality or pollution released during the construction and production process. Therefore, MSC is the marginal social cost of producing electricity, which will include private and external cost together and MSC would be higher than MPC. Hence, when MSC is ignored, it would result in the overproduction of electricity.

In order to find the true value of environmental goods and services, the concept of total economic value (TEV) plays an important role. TEV of goods or services are the combination of different parts—some of which are directly used and tangible; some are intangible or very remote (Turner, Georgiou, Clark, Brouwer, & Burke, 2004). Traditionally, TEV, as shown in Figure 2.2, is the combination of used and non-used values. Used-Values are based on actual use or consumption of the environmental goods and services, where, Non-Used values are values that are not associated with actual use of an ecosystem or its services. Therefore, Used-Value is defined as the value of environmental goods and services actually used or consumed, such as firewood for local people, food gathering, hunting, sightseeing, and natural traveling. However, the Used-Value may also include Indirect-Uses, for instance, the Mekong River View may provide Direct-Used value for tourists who visit Vientiane, but other people may enjoy watching TV show about the Mekong River View too, thus, those people are receiving the Indirect-Used value of the Mekong River View.

Option-Value is the value that people place on having the option to enjoy something in the future, although they may not currently use it. For example, a foreigner may look for an opportunity to visit a Natural Park in Laos. Thus, they would be willing to pay some amount of money to preserve that Natural park to maintain that option.

Another type of environmental value is a Non-Used value or “Passive Use” value. This type of value is not associated with actual use, or even the option to use a good or service. Existence-Value is the Non-Used value that people place on simply knowing that something exists, even if they will never see it or use it and Bequest-Value, which is the value that people in this generation place on knowing that future generations would have the opportunity to enjoy it (King & Mazzotta, 2000).

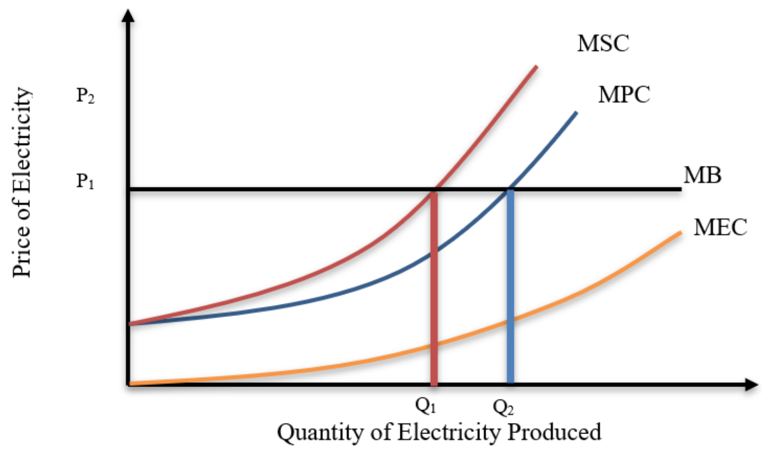

Figure 2.1 Private and Social Cost

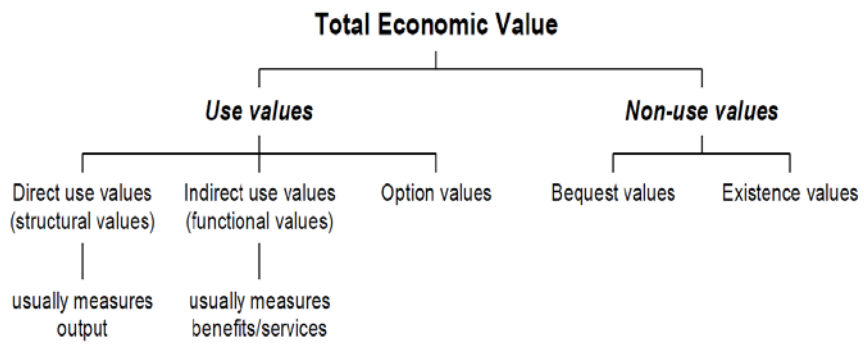

Figure 2.2 The Environmental Economic Value

2.3 Valuation for Environmental Goods and Services

Typically, economic valuation methods have 2 main categories; revealed preference methods and stated preference methods (Merino-Castelló, 2003). These two systems are primarily different in the data used. Data based on actual behavior in existing markets, whether directly used as the need for firewood consumption, or indirectly used like the WTP for watershed protection, is normally used for Revealed preference methods, whilst the stated preference techniques will be used to handle the valuation of goods and services that have no direct market price in ordinary markets. Its advantage is to handle the absence of markets by creating scenarios where people are making decisions that mimic the reality of markets. It also provides the opportunity of evaluating both used and non-used values. All the stated preference methods will typically collect data by using surveys to ask respondents to state their preferences in scenarios or choices that capture the fundamentals of a given situation. A classification of stated preference methods has been classified by (Merino-Castelló, 2003) (Figure 2.3).

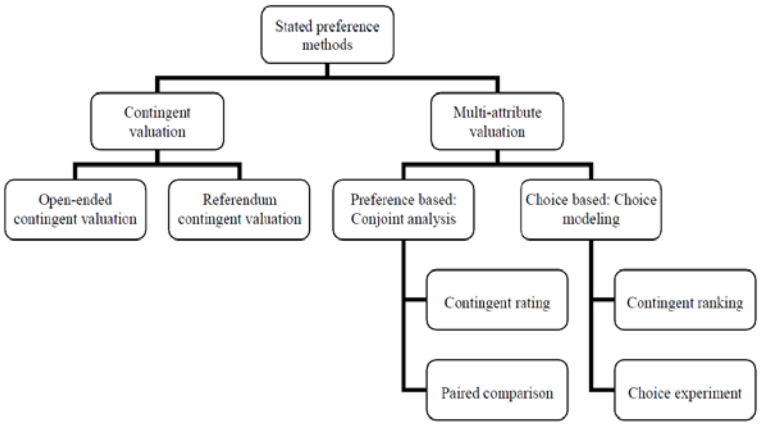

Figure 2.3 Family of Stated Preference Method

2.4 Literature Review

The arguments about hydropower and its impact have been increasingly important. Many researches claimed that hydropower, on the one hand, has potential to achieve the increasing needs of electricity in many countries, which will be the important part of the sustainable social-economic development and increase the living standard (Dursun & Gokcol, 2011). Furthermore, they are labor-intensive while being constructed and operated. In addition, in the case of Laos, they provide many positive impacts in many aspects of Laos's social-economic development (Kuenzer, Campbell, Roch, Leinenkugel, Tuan, & Dech, 2013) such as achieving the country's electrification program, which will improve the standard of living of rural people in Laos, export electricity to the neighboring countries and draw a huge volume of Foreign Direct Investment (FDI) into Laos. Because water is considered a renewable, clean and green energy source (Egré & Milewski, 2002; Bartle, 2002), it is less harmful than fossil fuel sources which emit many dangerous gas (the emissions caused by natural gas is approximately 0.6 and 2 pounds of CO2E/kWh, and coal is approximately 1.4 and 3.6 pounds while hydropower emits only 0.1 and 0.5 (Dursun & Gokcol, 2011; Yüksel, 2008; Bird, 2012) (IPCC, 2011). Furthermore, when we compare water with nuclear and fossil fuels, water is more widely spread around the world (Bahtiyar & Gokcolb, 2011) and now hydropower is considered the most efficient type of electricity generation compared to the fossil fuel plants (the best fossil fuel plants are only about 50% efficient at converting available energy into electricity, while modern hydro turbines can convert as much as 90%), which is also an environmental benefit (IHA, 2016). A hydropower plant has the longest plant life and lowest operating cost compared with other types of electricity generation as water is the only resource used in hydropower generation leading to no fuel cost, and the market price fluctuation is not related to water quantity (Kaygusuz, 2004). Additionally, hydropower seems to keep growing and is a crucial source of electricity generation all over the world, especially in developing countries; (Balat, 2006). Moreover, some empirical studies support that hydropower plants are beneficial to natural disaster reduction. Zsuffa (1999) had studied the impact of hydropower plants on flood control in Hungary for the periods of 1957-1976 and 1977-1996. During the past 40 years, they found that the number of small and medium floods had increased, but the flood load maxima have decreased. These changes indicated that the hydropower plants can decrease the rate of flood superposition or, in other words, the Austrian barrage system has a positive impact on the flood control safety of the Hungarian Danube reach.

On the other hand, along with many social and economic benefits of the hydropower project, the existence of adverse environmental impacts was observed in many areas. Zhai, Cui, Hu, and Zhang (2010) mentioned that such large-scale projects of hydropower always heavily impact elements of the ecosystem, and the relocation for creating a large reservoir directly affects the livelihood of the rural population. These naturally lead to environmental and social costs which results in the public controversy about hydropower's net benefit (Berkun, 2010). For example, Merowe Dam in Sudan contains 12.5 km3 (approximately 20% of the Nile's annual flow) and it requires a large area of land to create the reservoir, which greatly reduces the farmland and habitat for humans as well as animals; 55,000 to 77,000 people had to be relocated and many tributes and cultural landmarks were destroyed (Commerford, 2011). Grumbine, Dore, and Xu (2012) reported many cases where dam construction is the cause of local community loss in Laos, Vietnam and Cambodia, for instance, around 50,000 and 60,000 people had to be resettled because of the Hoa Binh Dam project in Vietnam and up to 100,000 people (mainly of an ethnic minority) had to be resettled because of Son La Dam. In Laos, 13 villages are affected by Nam Song Diversion Dam and approximately 2,000 ha of protected forest in the Bokor National Park will be flooded by the Kamchay Dam in Cambodia, which will affect the habitat of 31 mammals and 10 endangered species. The salinization caused by large-scale irrigation leads to soil erosion, reduction of water quality, detrimental effect on plant growth and reduced final yield. Large water reservoirs affect the local climate and are a source of pollution, including greenhouse gases (Berkun, 2010). Methane is emitted when reservoirs are built without prior deforestation and removal, thus without oxygen, plants will decompose into methane and carbon dioxide (CO_2). Methane is a very important greenhouse gas that can dramatically increase climate change (Berkun, 2010; Commerford, 2011). Changing in land use patterns have the potential to deprive plants and animals of their natural habitat; discontinuing the river caused by the dam's blocking could result in the reduction of the persistence of habitat features (Matisoff, Bonniwell, & Whiting, 2011) or a reduction of fish biomass and population (Dugan et al., 2010). Several important species require a free flow of the river, among them the tropical Asian catfish, Pangasius Krempfi. The Mekong region's catch of 2.1 million tons annually could drop to 1.4 million tons if all proposed mainstem dams are built (Vaidyanathan, 2011). This impact on food security would lead to a loss of livelihood for over 1 million Cambodians (Kuenzer et al., 2013) Moreover, urbanization and industrialization, following social and economic development, bring about increased pollution levels such as degrading air and water quality (Islam & Tanaka, 2004).

Not only the used value of the environment, but the non-used value of environment should be taken into consideration. Over the past 10 years, there have been increasing needs of environmental valuation in the monetary term (Carpenter & Georgakakos, 2009). There are several attributes used as the measurement of environmental quality changes, for instance, the change in the abundance of fish population or fauna species can be related to the change of water quality or river condition (Kataria, 2009; Han, Kwak, & Yoo, 2008). In addition, the change of species richness, e.g. the population of wild elephants, birds, and tigers, can be the measurement of the result of the change of forest quality or, in other words, change of their habitat condition (Kataria, 2009). Also, the change in sediment movement may be the cause of land degradation in the lower mainstream. Specifically, a variety of attributes can be used in the CE depending on the characteristics of the environment being valued, for example, water quality improvement, increment of gue abundance (rattan, vine, and proximity), type of garden (cocoa garden or food garden), which can represent the livelihood and tropical forest linkage for people in the Solomon Islands; increasing fish stock, improved conditions for bird life, species richness and land erosion reduction can represent the environmental condition in hydropower regulated rivers; forest, fauna species, flora species, and the protection of historical remains can also be the representatives of the impact of hydropower development. At the same time, we can use a monthly incremental rate of water, electricity fees, income tax, VAT or even direct payment as a measurement of the cost of environmental improvement (Kataria, 2009; Kenter, Hyde, Christie, & Fazey, 2011; Wang et al., 2010). Using the CE for environmental valuation has been done by prior research in many regions of the world. In the Solomon Islands, people were asked for their WTP to value the tropical forest ecosystem. The results showed that people in the Solomon Islands are willing to pay around 30% of the people's income for the improvement of the tropical forest ecosystem; with $33 per household/year as the WTP for water quality improvement, $29 and $11 for the increase of food over cash crop garden and for the improvement for gue (rattan, vine and proximity) abundance respectively (Kataria, 2009). Residents of Ireland are willing to pay € 196 million for landscape improvement (Kenter, Hyde, Christie, & Fazey, 2011). People in Staffanstorp (Sweden) are willing to pay around €71 per year for high biodiversity improvement, €54 for medium biodiversity improvement and €37 for better fish habitat (Carlsson, Frykblom, & Liljenstolpe, 2003). Therefore, if there is any development project that has a negative impact on the environment, such biodiversity or environmental loss has to be considered as a part of the projects' cost. Sang-Yong Han and team (Han, Kwak,

& Yoo, 2008) have employed the Choice Experiment (CE) to measure the environmental value of large dam construction in the Tong River of Korea. Local people were asked to choose one of the following environmental attributes; forest, fauna, flora, and remains and 1 price attribute. The result shows that respondents are willing to pay for mitigating the environmental impact of large dam construction calculated at about 2.12 USD with a range of $1.52-$2.73 by adding up the WTP of each attribute. The total WTP is annually about $174 million. Once this WTP was added up into the CBA table, they claimed the negative NPV to be the result of a large hydropower dam. Similarly, Commerford (2011) estimated the environmental cost of the Three Gorgas Dam in the Hubei province of China. Once the environmental costs are taken into consideration, the Three Gorgas dam needs 852.28 years to meet its breakeven point, while it needs only 8.53 years if all environmental costs are excluded. Additionally, the sensitivity of his study shows that the Carbon Tax (price of CO_2) significantly affects the cost of the hydropower dam; with a high Carbon Tax scenario, the Three Gorgas dam needs 4,539.25 years to meet its breakeven point. In Vietnam, the Yali Hydropower Plant’s (YHPP) CBA was done by Nguyen Van Hanh et al (Nguyen, Nguyen, Do, & Tran, 2002); their estimation showed the NPV has reduced around 27% when environmental and social costs are incorporated.

CHAPTER 3

METHODOLOGY

3.1 Methodology

Tools used in this study consisted of 3 parts, as shown in Table 3.1. In the first part, the economic and financial Cost and Benefit Analysis (CBA) has played a role in acquiring the net benefit generated by the project to examine if the project was feasible. In the second part, the Benefit Transfer and Market Based Analysis were used to elicit the used-value of the opportunity cost related to the environmental cost related to the land lost, fish stock reduction and CO2 emission caused by the project. In the last part, the CE method was employed to elicit the non-used value of the opportunity cost related to local people WTP for environmental attributes improvement (the increment of protected forest area, fish species, protected wild elephants and local ancient heritage protection program).

Table 3.1 Methodology of this Study

Methodology	Attributes	Source
CBA		Empirical Study
Benefit Transfer	Forest (Land)	(Roderick, 2009)
Market-Based	Fish	ICEM, 2009; On field Survey
	CO2	Xaiyaburi Dam EIA
Choice Experiment	Forest	On field Survey
	Fish species	
	Elephant	
	Ancient	

3.2 Cost and Benefit Identification

With and Without Concept was employed to identify the elements of cost and benefit caused by the Xayaburi hydropower project. With the project, the Lao Government can enjoy the benefit from electricity generation (both for export and domestic consumption), which is expected to generate a huge amount of income for Lao social-economic development. However, the Lao government or Lao people must burden the cost caused by this project (both directly and indirectly), for instance, cost of construction and maintenance, effects of the reservoir for water storage, the higher water level, decreasing water flow rate, sediment movement and water quality in the Mekong River, which affects many aquatic faunas and millions of people living along the Mekong River. Conversely, without the project, conditions of the Mekong River ecosystem will remain the same, but the Lao government will lose the opportunity for electricity generation (Figure 3.1).

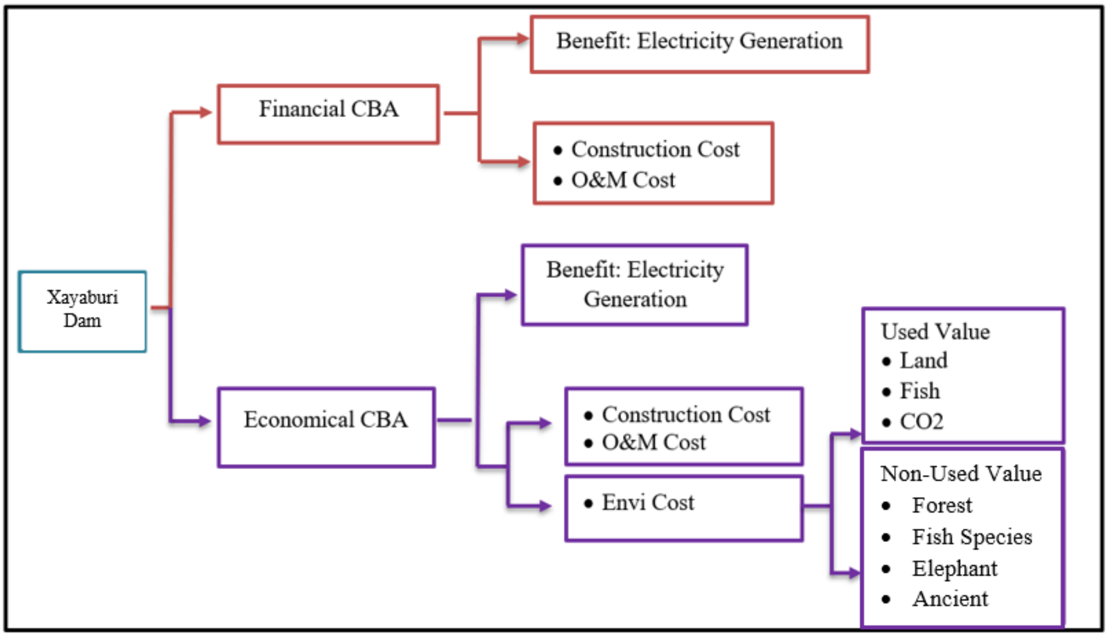

Figure 3.1 Cost and Benefit Identification

3.3 Current Price VS Constant Price

There are two types of prices used in CBA analysis, Current Price and Constant Price. Current Price, on the one hand, is the price influenced by the inflation effect. It is used to measure the nominal growth of cost and benefit of the project with the rate of real growth and inflation. On the other hand, the Constant Price is the price used to measure the true growth of the cost and benefits of the project by eliminating the inflation effect. In a CBA analysis, both prices can be employed. However, due to the difficulties of future inflation prediction, especially 30 years from now (30 years is the concession period of Xaiyaburi Dam), the Constant Price was used in this study using 2015 as a base year.

3.4 Discount Rate

The discount rate has a very important role in our analysis because it is the connection between today's value and the future's value of money. It is represents the urgency of the project (more urgent projects require a higher discount rate) and the project's opportunity cost relative to other investments.

The nominal discount rate included the inflation effect that makes the amount of money increase every year, but not the real value. This effect tends to distort the picture about the project and tends to mislead decision making. In this study, we adopted 2% of the real discount rate.

3.5 Present Value (PV)

Present value (PV) is the current worth of the money made in the future. In our project, costs and benefits will occur in the future since the beginning (1st Year) until the end (30th Year) of the project. Hence, using the discounting method to transfer all the Future Value (FV) into Present Value (PV) allows us to extract the real value of money made by the project.

$$PV = (FV^t)/(1+r)^t \quad \text{Eq. 1}$$

Where:

PV = Present Value

FVt = Future Value at Year t

r = Real Discount Rate

t = The project's timeframe (30 years)

3.6 Net Present Value (NPV)

NPV is the return of investment at the total period of the project. The decision maker, on the one hand, should decide to invest when the total present value of the benefit is greater than the total present value of cost (NPV>0). On the other hand, the decision maker should not invest in the project when the total present value of cost is greater than the total present value of benefit generated (NPV<0). However, when there are no differences between the total present value of benefit and cost (NPV=0), the decision maker requires more information to assist his/her decision making.

$$NPV = \sum_{t=o}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=o}^{n} \frac{C_t}{(1+r)^t} \quad \text{Eq. 2}$$

Where:

NPV = Net Present Value of the project

Bt = Benefit of the project at year t

Ct = Cost of the project at year t

r = Real Discount rate

t = The project period, starts from 0,1, 2, …., n

3.7 Internal Rate of Return (IRR)

IRR is the rate of return that the project is expected to generate annually. The decision maker should decide to invest in such a project when the project is estimated to generate income at a rate higher than the discount rate (IRR>r). The decision making should be made in the opposite direction when the project's growth rate is less than the discount rate (IRR<r) and the decision making should not be made at the moment or additional information is needed in order to make a clear decision when there are no differences between the IRR and discount rate (IRR=r).

$$IRR = \sum_{t=o}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=o}^{n} \frac{C_t}{(1+r)^t} = 0; or$$

$$IRR = \sum_{t=o}^{n} \frac{B_t}{(1+r)^t} \qquad \text{Eq. 3}$$

Where:

IRR = Internal Rate of Return

Bt = Benefit of the project at year t

Ct = Cost of the project at year t

r = Real Discount Rate

t = The project period, starts from 0,1, 2,….,n

3.8 Benefit-Cost Ratio (B/C)

B/C is the ratio between benefit and cost of the project. It shows the benefit gained per cost invested. The decision maker should decide to invest when benefit gained is greater than cost invested (B/C>1). However, the decision making should be made in the opposite direction when benefit gained is less than cost invested (B/C<1) and the decision making should not be made at the moment when there are no differences between benefit gained and cost invested (B/C=1).

$$\mathrm{B}/C = \frac{\sum_{t=o}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=o}^{n} \frac{C_t}{(1+r)^t} + C_0} \qquad \text{Eq. 4}$$

Where:

B/C = Benefit gained per cost invested

Bt = Present value of benefit at year t

Ct = Present value of Cost at year t

C0 = Cost of the project at year 0

r = Real Discount rate

t = The project period, starts from 0, 1, 2, …, n

3.9 Sensitivity Analysis

Sensitivity analysis refers to an analysis of how sensitive NPV is to given variables. It is useful because it provides the decision maker with information about how sensitive NPV is in each variable. In this study, the sensitivity analysis was conducted using 3 following variables that were expected to impact the value of NPV most:

1) Reduction of the Total Income: Income of the project totally depends on the electricity generation capacity. Decreasing of the water volume will directly affect the income (benefit) of the project. However, due to the lack of data on the relationship between water volume and electricity generation, we used the income as the proxy to examine the sensitivity of NPV on water volume reduction.

2) Increase of the carbon tax: The concern of global warming would affect the carbon tax in the future. Increase of the carbon tax would increase the opportunity cost related to CO2 emissions of the project.

3) Increase of the O&M cost: If an unexpected disaster occurred during the project operation period, for instance, huge flood, long period drought etc., these events could affect the structure of the dam and would rapidly increase O&M cost.

3.9.1 Switching Value

After conducting the sensitivity test, we conducted Switching Value Analysis (SVT) to calculate the changed value to make NPV equal to zero. The SVT was performed under 2 perspectives; Switch Value Test of Cost (SVT_C) and Switch Value Test of Benefit (SVT_B).

1) SVT_C is the changed value that made the NPV equal to zero and CBR equal to 1.

$$SVT_C = (NPV/PVC) \times 100 \qquad \text{Eq. 5}$$

Where:

SVT_C = Switch Value Test of Cost

NPV = Net Present Value

PVC = Present Value of Cost

2) SVTB is the changed value that made the NPV equal to zero and CBR equal to 1.

$$SVT_B = (NPV/PVB) \times 100 \qquad \text{Eq. 6}$$

Where:

SVT_B = Switch Value Test of Benefit

NPV = Net Present Value

PVB = Present Value of Benefit

3.10 The Cost and Benefit Calculation

3.10.1 Financial CBA

The first step of this study is to examine the financial feasibility of the project. According to the project feasibility study, we found that this project consisted of 2 sources of income, electricity exported to Thailand, which will be bought by the Electricity Generating Authority of Thailand (EGAT), and domestically consumed electricity, which will be bought by Electricite du Laos (EDL). In addition, Construction cost ($\boldsymbol{C_{con}}$), Operation and Maintenance Cost ($\boldsymbol{C_{O\&M}}$) and Selling and Administration Cost ($\boldsymbol{C_{S\&A}}$) are 3 sources of financial cost burdened by this project.

3.10.1.1 Total Financial Benefit

Total financial benefit is estimated by Eq. 6;

$$B = (P_{EGAT} * q_{EGAT} * t) + (P_{EDL} * q_{EDL} * t) \qquad \text{Eq. 7}$$

P_{EGAT} and q_{EGAT} stand for electricity selling to EGAT, P_{EDL} and q_{EDL} stand for electricity selling to EDL, and *t* stands for time period.

3.10.1.2 Total Financial Cost

Total financial cost combined with Construction Cost ($\boldsymbol{C_{Cons}}$), Operation and Management Cost ($\boldsymbol{C_{O\&M}}$) and Selling and Administration Cost ($\boldsymbol{C_{S\&A}}$).

$$\boldsymbol{C_{Total} = C_{Cons} + C_{O\&M} + C_{S\&A}} \qquad \text{Eq. 8}$$

3.10.2 Economic CBA

The Economic CBA was calculated by using the following sources of data. Similar to the financial CBA, there are 2 sources of income generated by the projects, electricity sold to the Electricity Generating Authority of Thailand (EGAT) and electricity sold to Electricite du Laos (EDL) respectively. Moreover, on the cost side, we extended our analysis by including costs related to environmental impacts caused by the project, that is, Construction Cost, O&M Cost, and $C_{S\&A}$ Cost (referred to as Actual Cost), and opportunity cost related to land loss, opportunity cost related to fishery stock reduction, opportunity cost related to CO2 Emission and opportunity cost related to local people WTP for environmental attributes improvement (referred to as Opportunity Cost).

3.10.2.1 Total Economic Benefit

Total Economic benefit is similar to financial benefit because the main objective of the Xaiyaburi dam is to produce electricity.

$$B = (P_{EGAT} * q_{EGAT} * t) + (P_{EDL} * q_{EDL} * t) \qquad \text{Eq. 9}$$

P_{EGAT} and q_{EGAT} stand for electricity sold to EGAT, P_{EDL} and q_{EDL} stand for electricity sold to EDL, and *t* stands for time period.

3.10.2.2 Total Economic Cost

There are 2 sources of total economic cost; actual cost actually paid by the project (it is referred to as financial cost) and opportunity cost or the cost related to environmental impacts caused by the project.

$$\boldsymbol{C_{Total} = C_{Actual} + C_{Oppor}} \qquad \text{Eq. 10}$$

$\boldsymbol{C_{Total}}$ is total economics cost of hydropower, $\boldsymbol{C_{Atual}}$ is the Actual cost, and $\boldsymbol{C_{Oppor}}$ stands for the Opportunity cost.

Actual Cost Consisted of Construction Cost ($\boldsymbol{C_{Cons}}$)**,** Operation and Management Cost ($\boldsymbol{C_{O\&M}}$) and Selling and Administration Cost ($\boldsymbol{C_{S\&A}}$).

$$\boldsymbol{C_{Actual} = C_{Cons} + C_{O\&M}} \qquad \text{Eq. 11}$$

In addition, Opportunity cost related to environmental impacts caused by Xaiyaburi dam was expressed in both used and non-used value of the environment.

$$\boldsymbol{C_{Oppor} = C_{Used} + C_{Non-used}} \qquad \text{Eq. 12}$$

Where $\boldsymbol{C_{Used}}$ is the used value of environmental cost, $\boldsymbol{C_{Non\text{-}used}}$ is the non-used value.

Used value of the environment consists of opportunity cost related to land lost ($\boldsymbol{C_{Land}}$)**,** fish stock reduction ($\boldsymbol{C_{Fish}}$) and cost related to CO_2 emission.

$$\boldsymbol{C_{Used} = C_{Land} + C_{Fish} + C_{CO_2}} \qquad \text{Eq. 13}$$

3.10.2.3 Opportunity Cost related to Land Lost

The price of land can't be calculated directly as it is public land. Hence, we employed the price of the forest as its representative. The price of the forest was obtained by using the Benefit Transfer Method. It was transferred from the result of (Roderick, 2009), who performed a study on valuing the Non-Timber Forest Products (NTFP) in Bolikhamxai Province, Lao PDR. Due to the difference in the period of time, the value was adjusted by the inflation rate to capture the change of time.

Assuming that $\boldsymbol{P_{Land}}$ is price of land used as a reservoir, X_i is the area of the reservoir and t_i is time or period of the project. Opportunity cost related to land lost is estimated by Eq. 14;

$$C_{Land} = P_{Land} * X_i * t_i \qquad \text{Eq. 14}$$

3.10.2.4 Opportunity Cost related to Fish Stock Reduction

The opportunity cost related to fish stock reduction is estimated by Eq. 15;

$$C_{Fish} = (P_{Fish} - L_{Fish}) * Q_{Fish} * t_i \qquad \text{Eq. 15}$$

$\boldsymbol{C_{Fish}}$ is the cost of fish stock reduction, $\boldsymbol{P_{Fish}}$ is the average price of fish per kilogram, $\boldsymbol{L_{Fish}}$ is the fisherman's operation cost, $\boldsymbol{Q_{Fish}}$ is the quantity of reduced fish, and $\boldsymbol{t_i}$ is the project's lifetime. The estimation of MRC indicated that when all 11 lower Mekong mainstreams finish construction; the amount of fish population would decrease by 340,000 tons (MRC, 2010). Moreover, the price pf fish, P_{Fish}, was obtained by the Market Based Method using average price of fish from the local fisherman in Xaiyaburi province.

3.10.2.5 Opportunity Cost related to CO2 Emission

The chemical reaction of anaerobic decomposition is shown in Eq. 16.

$$C_6H_{12}O_6 = 3CO_2 + 3CH_4 \qquad \text{Eq. 16}$$

Glucose($\boldsymbol{C_6H_{12}O_6}$) will be decomposed to carbon dioxide ($\boldsymbol{CO_2}$) and methane ($\boldsymbol{CH_4}$). The biomass of plants varies from 7 kg C/m^2 in grasslands to 20 kg C/m^2 in tropical rain forests depending on its ecosystems (Commerford, 2011). Vicharnakorn et al estimated the biomass of the mixed deciduous forest (MDF) in Savanhnakhet province, Lao PDR. They found that the average biomass of mixed deciduous forest (MDF) is 146.59 tonnes per hectare (t/ha) or 14.66 Kg/m^2 (Vaidyanathan, 2011). According to the Northern Woodland Organization, the hardwood species typically take 46 to 71 years to completely decompose. Warmer, more humid environments promote faster decay than cooler, drier climates (NorthernWoodland, 2016). We assumed the decomposition period in the Xayabyri dam's reservoir, X Km^2. Hence, the calculation of the amount of Carbon equivalent is performed as in Eq. 17.

$$\mathrm{CO_2} = \mathrm{X} * 10^6\mathrm{m}^2 * 14.66KgC/m^2 \qquad \text{Eq. 17}$$

CO_2 and CH_4 will equally contribute in CO_2 equivalent;

$$CO_2\ Equivalent = (X/2 * 10^6 m^2 * 14.66KgC/m^2) + (X/2 * 10^6 m^2 * 14.66KgC/m^2) \qquad \text{Eq. 18}$$

The Global Warming Potential (GWP) of *CH4* is 30 times that of CO_2 (per g basis), so the percentage of CH_4 released is important (Rosenberg, et al., 1997). The final calculation of CO2 equivalent volume is calculated as seen in Eq. 19.

$$CO_2\ Equivalent = (X/2 * 10^6 m^2 * 14.66KgC/m^2) + 30(X/2 * 10^6 m^2 * 14.66KgC/m^2) \qquad \text{Eq. 19}$$

Opportunity Cost related to CO_2 emission is all emitted CO_2 equivalent multiplied by Price of CO_2 ($\boldsymbol{P_{CO_2}}$), at the period *t*.

$$CO_2\ Equivalent = P_{CO_2}((X/2 * 10^6 m^2 * 14.66 KgC/m^2) + 30(X/2 * 10^6 m^2 * 14.66 KgC/m^2))^* t_i \quad \text{Eq. 20}$$

3.10.2.6 Opportunity Cost related to WTP for Environmental Improvement

1) Random Utility Model

The stated preference market can be used to acquire the value of non-market goods and services such as the value of clean air, healthy fish, wildlife populations, pollution emitted into environment, etc. The CVM[1] has been widely employed to estimate used or non-used values for environmental goods and services by presenting a scenario exactly described by one option and the based option (Kwak & Russell, 1994). However, if several attributes or multiple options are being considered and the costs involved in surveys are different, then using the CVM is generally problematic (Streever, Callaghan-Perry, Searles, Stevens, & Svoboda, 1998). CE provides us with various environmental attributes and costs measurement. Instead of estimating Willingness to Pay (WTP) for a single option, it is concerned with a variety of choices set over a range of characteristics. The CE, as CVM, was theoretically backed up by the random utility model (Train, 2002). The total utility of respondent *i* from alternative *j* can be expressed as;

$$U_{ij} = V_{ij} + e_{ij} \quad \text{Eq. 21}$$

U_{ij} is the total utility of respondent *i* from choosing alternative *j*. It is comprised of observable ($\boldsymbol{V_{ij}}$) and unobservable($\boldsymbol{e_{ij}}$) part of utility.

$$Pr_i(j|C_i) = Pr\{V_{ij} + e_{ij} > V_{ik} + e_{ik}\} \quad \text{Eq. 22}$$

Equation 17 states that respondent *i* will choose alternative *j* over all other alternatives if the sum of observable and unobservable utility from

[1] CVM-Contingent Valuation Method

alternative j is greater than the sum of observable and unobservable utility from other alternatives (k) in the choice set $\boldsymbol{C_i}$.

Under the Multinomial Logit Model (MNL), the unobservable part of utility must be assumed as independent and identical in accordance with the extreme value (Gumbell) distribution. This implies that the probability of respondent *i* will choose alternative j over alternative k if:

$$Pr_i(j|C_i) = exp(V_{ij}) / \sum_{k \in C_i} exp(V_{ik}) \quad \text{Eq. 23}$$

The linear in parameter estimation of the utility function for the j^{th} alternative is specified as:

$$V_{ij} = ASC_j + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_k X_k + \gamma_1 (S_1 * ASC_j) + \cdots + \gamma_p (S_p * ASC_j) \quad \text{Eq. 24}$$

The alternative numbers, variables of attribute and social-economics in the utility function are represented by j, k, and p respectively. $\boldsymbol{\beta}$ are often specified to be constant with alternatives in the choice set (it shows the implication that the effect of a choice-specific variable of a given option being chosen is the same regardless of which alternatives are being chosen). Where j is a total number of alternatives in the choice set. It is common to estimate a set of $j - 1$, because the constant value will equal to one for the j^{th} alternative and zero for otherwise. These are referred to as alternative-specific constant (ASCs), which provide a zero mean for unobserved utilities and causes an average probability over the sample for each alternative equal to the proportion of respondents actually choosing the alternative.

Social economic variables are included into utility functions by interacting them with either the ASCs or the attributes. ASCs will help to mitigate inaccuracies due to violations in the assumption of IIA. This assumption requires the ratio of the choice probabilities for any two alternatives to be unaffected by the addition of or removal of alternatives. This is implied, assuming, that the random error components of utility are uncorrelated between choices and have the same variance (Train, 2002).

Welfare estimation or Marginal Willingness To Pay (MWTP) can be obtained by using the formula described by Adamowicz, Louviere, and Williams (1994).

$$WTP = 1/\mu^1[ln\sum_{j\in C_i} e^{v_{i1}} - ln\sum_{j\in C_i} e^{v_{i0}}] \qquad \text{Eq. 25}$$

Where μ^1 is the marginal utility of income, v_{i0} and v_{i1} represent the utility before and after the change, and C_i is the policy-relevant choice set presented to the $i^{t\square}$ respondent. In choice experiments, the coefficient of the price attribute is taken as an estimate of μ^1. Changing in v_{i0} or v_{i1} can arise from changing in attributes of alternatives or the addition (or removal) of alternatives. When a single solution must be chosen from a set of feasible mutually exclusive solutions, the removal of alternatives can be used to estimate the selection probabilities and welfare implications based on a different choice set configurations.

In the case of changing a single attribute, *k*, this can further be reduced to β_k/β_{Cost} when a linear in parameters utility function is employed. This is equivalent to calculating the ratio of marginal utilities for the attribute in question and the price attribute (Train, 2002).

When the choice set includes a single before and after policy option, Eq. 25 can be reduced to

$$W = MWTP = 1/\mu^1[ln(e^{v_{i1}}) - ln(e^{v_{i0}})]$$
$$= 1/\mu^1[v_{i1} - v_{i0}] \qquad \text{Eq. 26}$$
$$=\beta_k/\beta_{Cost}$$

2) Environment Attributes and Payment Vehicle

Attributes used in this study were identified by the literature review on environmental impacts of dam construction extension (Han, Kwak, & Yoo, 2008; World Commission on Dam, 2000) to identify the most meaningful attributes. As shown in Table 3.2, four environmental attributes and one price variable are (1) Forest represented by the increment of the protected forests area, (2) Fish represented by the incremental number of protected of endangered Aquatic-Fauna species, (3) Elephants represented by the number of protected wild elephants and (4) Ancient represented by the ancient protection program. The Cost variable is measured by the increment of the monthly rate of electricity. Moreover, social economic characteristic variables (Sex, Age, Number of Children, Education Level, and Net-Income) are included into this model to examine effects of those social-economic characteristics on their decision making (Table 3.2).

Table 3.2 Types of Variable

Variable	Detail
Dependent Variable	
V	Choice set chosen by the respondent (4 Choice sets, A[b], B, C and D)
Independent Variable	
Forest	Increment of protected forest area (Km^2)
Fish	Number of protected Fish species (Species)
Elephant	Incremental number of protected elephant (Elephant)
Ancient	Ancient protection program (1 = Yes, 0 = No)
Cost	Additional monthly electricity (USD/month)
Social-Economics Characteristics	
Sex	Gender of respondent (1= Male, 0 = Female)
Age	Age of respondent (Age)
Children	Respondent having children (1= Male, 0 = Female)
Education	Higher degree graduation (1 = Yes, 0 = No)
Income	Net income of respondent (USD/Month)

Note: [b] indicates the base case (the current situation of each environmental attribute)

3) Protest Bid Identify

Protest respondents are those who oppose or do not approve of the survey mechanism and fail to respond to the valuation question, giving either positive but invalid responses or allocating a non-true zero value to a product or service (Halstead, Luloff, & Stevens, 1992). When respondents chose the status-quo option, the follow-up questions were presented to identify whether their no-vote are true zero or protests. The set of statements are presented in Table 3.3.

Table 3.3 Statements Used to Identify Protest Bid

Follow-up Question	**Considered as Protest**
I prefer if there no initiative for environmental improvement strategy is undertaken.	Yes
I support the environmental improvement strategy, but could not afford the cost.	No
I support the environmental improvement strategy, but object to paying for it.	Yes
I support the environmental improvement strategy, but I have already paid a very high price for my electricity.	Yes
I support the environmental improvement strategy, but I don't think this project will benefit environment conservation.	Yes
I support the environmental improvement strategy, but I already support other environmental conservation agencies.	No
I found that the alternatives provided are confusing; hence, I always choose the base case.	No
Other	No

4) The Choice Set

Environmental attributes variables (Forest, Fish, and Elephants) were specified at 4 levels, one status quo of environmental conditions and 3 other levels showing the states of incremental improvement. The Ancient attribute variable is a dummy variable, 0 stands for the status quo and 1 stands for alternative change.

Cost level was determined by using the pre-test to examine the most appropriate level specified at 4 levels, one status quo and other 3 levels show the states of the monthly electricity bill increment (Table 3.4).

Table 3.4 Attributes and Level Used in CE

Attributes	**Definition (Unit)**	**Levels**
Environmental Attribute and Cost		
Forest	The increment of protected forest area (Km^2)	0^b, 10, 20, 30
Fish	Number of protected Fish species (Species)	0^b, 15, 25, 35
Elephant	The incremental number of protected elephants (Number of Elephants)	0^b, 10, 15, 20
Ancient	The ancient protection program	0^b = No, 1 = Yes
Cost	The additional monthly electricity rate (USD/month)	0^b, 1, 3, 5

Note: ^{b} indicates to the status-quo (the current situation of each environmental attribute)

Choice sets involved in the CE approach are carefully designed to help explain the factors influencing choice. Normally, multiple choice sets (they might be two or more options) will be presented to the respondent. In this study, there are three main options involved in each choice set: the status quo scenario will be represented in option A and environmentally improved scenarios will be represented in options B, C and D. There are five attributes involved; each attribute consisted of 4 levels; all possible combinations will equal to $4^5 \times 4^5$. It was impractical for asking the respondent to choose among all combinations, therefore, a subset of all possible choices sets was randomly drawn by using the orthogonal design in the SPSS package to enable the parameters of the model to be estimated. The result from the SPSS orthogonal design was cleaned up to eliminate unreasonable choice sets (the choice set that gives very high environmental improvement with a low cost and vice versa). The result shows that there are 48 versions of the choice constructed (as shown in appendix A), which were divided into 4 blocks randomly. Each respondent was presented with 3 choice scenarios and was asked to choose one among four options.

5) Questionnaire Design

Our questionnaire will consist of three parts. The detailed descriptions of the concern about the environmental impact of Xaiyaburi Dam will be provided in the first part to make respondents familiar with the attributes being evaluated. The second part will contain the CE questions which will ask about respondent's WTP for mitigating environmental impacts of Xaiyaburi Dam construction. The last part will deal with the socio-economic characteristics of the respondent (e.g., age, sex, income, education, etc.).

Table 3.5 Sample Choice Set Involved in this Study

Attributes	**Choice A**[b]	**Choice B**	**Choice C**	**Choice D**
Forest	0 Km^2	10 Km^2	20 Km^2	5 Km^2
Fish	0 Species	5 Species	15 Species	35 Species
Elephants	0	5	15	10
Ancient	No	Yes	No	Yes
Cost	0 USD	1 USD	3 USD	5 USD
	▢Option A	▢Option B	▢Option C	▢Option D

Note: [b] indicates the status-quo (the current situation of each environmental attribute)

6) Data Coding

We used average coding in our study by generating L-1 variables for each attribute including Forest Good (ForestG), Forest Better (ForestB), Forest Best (ForestBe), Fish Good (FishG), Fish Better (FishB), Fish Best (FishBe), Elephant Good (ElephantG), Elephant Better (ElephantB), Elephant Best (ElaphantBe) and Ancient Good (AncientG) respectively.

Where:

1) ForestG is the increasing number of forests from 0 Km^2 to 10 $Km^{2.}$

2) ForestB is the increasing number of forests from 0 Km2 to 20 Km2.

3) ForestBe is the increasing number of forests from 0 Km2 to 30 Km2.

4) FishG is the increasing number of fish species from 0 species to 15 species.

5) FishB is the increasing number of fish species from 0 to 25 species.

6) FishBe is the increasing number of fish species from 0 to 35 species.

7) ElephantG is the increasing number of wild elephants from 0 to 10 elephants.

8) ElephantB is the increasing number of wild elephants from 0 to 15 elephants.

9) ElephantBe is the increasing number of wild elephants from 0 to 20 elephants.

10) AncientG refers that the ancient protection program included into the choice.

11) Cost is the cost of choosing choice.

The effect coding was generated with the following criteria: if the choice consists of Good level, then ForestG, FishG and ElepantG is 1, if the choice consists of status-quo level (Average), then ForestG, FishG and ElephantG is -1, and if the choice does not follow the above criteria, then ForestG, FishG and

ElephantG is 0. Similar to Better and the Best level, if the choice consists of Better level, then ForestB, FishB and ElepantB is 1; if the choice consists of status-quo level (Average), then ForestB, FishB and ElepantB is -1; if the choice does not follow the above criteria, then ForestB, FishB and ElepantB is 0; if the choice consists of the Best level, then ForestBe, FishBe and ElepantBe is 1; if the choice consists of status-quo level (Average), then ForestBe, FishBe and ElepantBe is -1; if the choice does not follow the above criteria, then ForestBe, FishBe and ElepantBe is 0. For the Ancient attribute, if the choice consists of Ancient protection program, then AncientG is 1, and if not AncientG is -1 respectively.

7) CE Model

Two models were constructed to elicit monthly WTP per household for mitigating environmental impacts of Xaiyaburi Dam as follows:

(1) CE Model Without Interaction Effects

In a simple model without interaction effects, the observable deterministic component of the indirect utility function can be expressed as follows;

$$V = \beta_0 + \beta_1 ForestG + \beta_2 ForestB + \beta_3 ForestBe + \beta_4 FishG + \beta_5 FishB + \beta_6 FishBe + \beta_7 ElephantG + \beta_8 ElephantB + \beta_9 ElephantBe + \beta_{10} AncientG + \beta_{11} Cost \qquad \text{Eq. 28}$$

(2) CE Model with Interaction Effects

In the model without interaction effects, respondents' utility is directly affected by environmental attributes and cost variables. However, while respondents are making a decision, their utility would also indirectly be affected by their social-economic characteristics. This paper considers co-effects between respondents' social-economics characteristics and environmental attributes to their decision making by including the following interaction terms into the models;

$$
\begin{aligned}
V = {} & \beta_0 + \beta_1 ForestG + \beta_2 ForestB + \\
& \beta_3 ForestBe + \beta_4 FishG + \beta_5 FishB + \\
& \beta_6 FishBe + \beta_7 ElephantG + \beta_8 ElephantB + \\
& \beta_9 ElephantBe + \beta_{10} AncientG + \beta_{11} Cost + \\
& \gamma_1 (Sex*Forest) + \gamma_2 (Sex*Fish) + \\
& \gamma_3 (Sex*Elephant) + \gamma_4 (Sex*Ancient) + \gamma_5 \\
& (Age*Forest) + \\
& \gamma_6 (Age*Fish) + \gamma_7 (Age*Elephant) + \gamma_8 \\
& (Age*Ancient) + \\
& \gamma_9 (Chil*Forest) + \gamma_{10} (Chil*Fish) + \gamma_{11} \\
& (Chil*Elephant) + \\
& \gamma_{12} (Chil*Ancient) + \gamma_{13} (Edu*Forest) + \\
& \gamma_{14} (Edu*Fish) + \\
& \gamma_{15} (Edu*Elephant) + \gamma_{16} (Edu*Ancient) + \\
& \gamma_{17} (Inc*Forest) + \\
& \gamma_{18} (Inc*Fish) + \gamma_{19} (Inc*Elephant) + \gamma_{20} \\
& (Inc*Ancient)
\end{aligned}
\qquad \text{Eq. 29}
$$

8) Data

The data used in this study consists of both primary and secondary data. Choice experiment survey at the Southern bus station, Northern bus station, and Wattai International Airport was the source of the primary data. The secondary data were obtained from many sources of publication, especially the Xaiyaburi hydropower Power Feasibility Study done by Ch. Karnchang Public Company Limited and other research papers.

CHAPTER 4

RESULTS

4.1 Costs and Benefits Calculation

This session presents results of the CBA analysis to assess numerical information of environmental impacts on the project decision making. As its concession agreement, this project has a 30-year project lifetime. We adopted the constant price method to forecast future cost and benefit of the project using 2.00% of the real discount rate as a discount factor for present value calculation and using 2015 as a base year.

4.1.1 Financial CBA

The first step of our CBA analysis is to examine the financial feasibility of the project. According to the project feasibility study, we found that this project has 2 sources of income, electricity sold to the Electricity Generating Authority of Thailand (EGAT) and electricity sold to Electricite du Laos (EDL). In addition, Construction, Operation and Maintenance (O&M) and Selling and Administration Costs are sources of financial cost burdened by this project (Table 4.1).

Financial Benefit of the project was calculated by using information from the following sources of data. The amount of electricity production was obtained from the Xaiyaburi Feasibility Study which estimated the generation of 7,406 GWh per year. According to the estimation of OptAsia, within the concession period (30 Years), total revenue from selling electricity to EGAT is PV $10,149,395,105 while revenue from selling electricity to EDL is PV $534,178,690 respectively.

The Financial Cost of Xaiyaburi Dam was calculated by using information from the Xayaburi Dam feasibility study for Construction Costs, while O&M and Selling and Administration Cost data was obtained from OptAsia. Table 4.1 shows that, this project burden PV is $3,800,000,000 as Construction Cost, expect to burden

PV is $762,085,591 as O&M Cost and PV is $324,319,051 as Selling and Administration Cost respectively.

In a conclusion, the Xayaburi hydropower project is expected to earn a financial net present value (FNPV) of $5,797,169,153, yielding 8.26% of financial internal rate of return (FIRR) and is expected to earn $2.18 for $1 spent respectively.

Table 4.1 Financial Cost and Benefit Analysis

Activity	Total Value (FV)	Total Value (PV)
Benefit		
EGAT	$13,726,240,259	$10,149,395,105
EDL	$722,433,698	$534,178,690
Cost		
Construction	$3,800,000,000	$3,800,000,000
O&M	$1,122,278,164	$762,085,591
Selling and Administration	$451,143,251	$324,319,051
FNPV		$5,797,169,153
FIRR		8.26%
FB/C Ratio		2.18

4.1.2 Economic CBA

In the previous analysis, we found that this project is financially feasible with a positive NPV, the IRR is greater than the discount rate and the B/C ratio is greater than 1. However, the financial CBA does not cover the area of environmental impacts caused by the project. Making a decision based on only financial CBA could mislead our conclusion. In order to assess the whole picture of the project feasibility study, we extended our analysis into a wider area and established an Economic CBA.

The Economic CBA was calculated by using the following sources of data. Similar to the financial CBA, there are 2 sources of income generated by the projects, electricity exported to Thailand and electricity domestically consumed. However, on the cost side, we extended our analysis by including costs related to environmental impacts caused by the project into our model, that is, Construction Cost, O&M Cost

(Actual Cost), opportunity cost related to land loss ***(C_{Land})***, opportunity cost related to fishery reduction ***(C_{Fish})***, opportunity cost related to CO_2 emission ***(C_{CO2})*** and opportunity cost related to electrified households' Willingness to Pay ***(C_{WTP})*** (Opportunity Cost).

Because the main objective of the Xayaburi Dam is to generate electricity for export and domestic consumption, we determined that the Economic Benefit is similar to the Financial Benefit. The Economic Benefit of the project was calculated by using information from the following sources of data. The amount of electricity production was obtained from the Xaiyaburi Feasibility Study which is estimated to generate 7,406 GWh per year. According to the estimation of OptAsia, within the concession period (30 Years), Total revenue from selling electricity to EGAT is PV $10,149,395,105, while revenue from selling electricity to EDL is PV $534,178,690 respectively.

On the cost side, the Economic actual cost of this project is also similar to Financial cost, that is, the Economic Actual Cost of Xaiyaburi Dam was calculated by using information from the Xayaburi Dam feasibility study for Construction Cost, while the O&M Cost data was obtained from OptAsia. Table 4.2 shows that, this project burden PV $3,800,000,000 as Construction Cost, expected to burden PV $762,085,591 as O&M Cost and PV $ 324,319,051 as Selling and Administration Cost respectively.

Opportunity Cost is calculated by using the following sources of data. The first type of opportunity cost related to the value of deforestation in the construction site and the reservoir area above the dam is the Cost of Land. The area of deforestation was obtained by the project Feasibility Study which estimated that the reservoir of Xayaburi Dam will flood around 42 Km^2 above the construction site once it is in operation. Additionally, the price of the forest was obtained by using the results of Roderick who performed the study on valuing the Non-Timber Forest Products (NTFP) in Ban Souphouan Village, Bolikhamsai Province, Lao PDR. The estimation covered 2 areas, Nong Kan and Phu Sangnoy. The study estimated that the value of NTFP in Ban Souphouan Village was $1,095 per hectare per year (Roderick, 2009). However, due to the difference in the period of time, the value was adjusted by using the inflation rate in 2015 (base year), which made the value increase from $1,095 to

1,258 per hectare per year. By using the above information, we estimated that the opportunity Cost of the Land caused by the project is PV $138,058,124 in the project's lifetime.

The second type of opportunity cost related to environmental impacts caused by the dam is the Cost of Fishery Reduction. According to the report of the Mekong River Commission (MRC) who estimated the scenario if 11 dams in the mainstream of LMB were in place, the loss of fish resources in LMB was estimated to be approximately 340,000 tons (MRC, 2010). As electricity generation capacity is determined by the size of the dam (higher capacity required a larger size of the dam), we, therefore, used the catchment area above the construction site as a proxy of Xayaburi Dam's effect on the fish stock reduction. The proportion of Xayaburi dam's catchment area is 42 Km^2 equal to 0.0062% of the total catchment area in the Mekong (the total catchment area in the Mekong River is 795,000.00 Km^2). Therefore, the amount of fish stock reduction caused by Xayaburi Dam is approximately 20.96 tons per year (Table 4.2). The price of the Mekong fish is the average fish price deducted from the fisherman's operation cost. The final calculation of Cost of Fishery Reduction is $23,042 per year or PV $516,051 in the project lifetime.

The third type of opportunity cost is opportunity cost related to CO_2 emissions, which is another impact of the hydropower plant. Carbon dioxide (CO_2) and methane (CH4) is created by the decomposition process of Glucose ($C_6H_{12}O_6$) when the reservoir is built without deforestation and removal of plants in such areas, thus plant lives were trapped underwater which in turn decomposes without oxygen. The release of CH_4 is important, as it has 30 times the global warming potential (GWP) than CO_2 (Rosenberg, Berkes, Bodaly, Heeky, Kelly, & Rudd, 1997). Biomass of plants varies from 7 kg C/m^2 in grasslands to 20 kg C/m^2 in tropical rainforests, depending on its ecosystems (Commerford, 2011). According to the work of Vicharnakorn et al, who estimated the biomass of the mixed deciduous forest (MDF) in Savanhnakhet province, Lao PDR, the average biomass of mixed deciduous forest (MDF) is 146.59 ton per hectare (t/ha) or 14.65 Kg/m^2. The reservoir above the dam site is estimated to release 10,452,580,000 tons of CO_2 equivalent per year, divided into 337,180,000 tons of CO_2 and 10,115,400,000 tons of CO2 equivalent from CH_4 respectively. Another component to elicit the value of opportunity cost related to CO2 emission is the price.

This study used the price from the CO2 closing price of European Emission Average Allowance in 2015. The final calculation of Xayaburi opportunity cost related to CO2 Emission is $122,933,839 per year or PV $2,753,282,253 in the project lifetime.

The last component of the opportunity cost of Xayaburi dam in this study is the cost related to the Willingness to Pay (WTP) from local people. The WTP represents the utility of local people to a foregone fraction of their income for environmental attributes improvement. The source of data used in the WTP calculation was obtained by an empirical survey conducted from 6 January – 21 January 2017. The questionnaire consists of 3 parts. The first part is the introduction which aimed to collect general information about respondents and their acknowledgment about Xayaburi hydropower project. The second part presented respondents with 3 environmental scenarios containing 4 choice sets in each scenario. This part aimed to ask respondents to state their preference on environmental attributes improvement by choosing their most preferred choice set in each scenario. The third part is the part that aimed to collect social-economic characteristics of respondents.

4.1.2.1 Descriptive Analysis

The results of the completed 411 person-to-person interviews were investigated. Each individual response to twelve choices yielded a total of 4,932 observations. Table 4.2 shows the socio-economic characteristics of respondents. The number of male respondents was 47.69%. The average age was 28.24 years; the youngest respondent was 20 and the oldest was 50. The average household net income was $196.52 per month and the average number of children of respondents was 1.50.

Table 4.2 Scio-economic Characteristics of Respondents

Variable	**Observation**	**Mean**	**Std. Dev.**	**Min**	**Max**
Sex	4,932	0.48	0.50	0	1
Age	4,932	28.24	8.30	20	50
Status	4,932	0.73	0.44	0	1
Children	4,932	1.51	1.55	0	9

Education	4,932	0.37	0.48	0	1
Income	4,932	196.52	225.76	1.4	1750

4.1.2.2 Protest Bid Identify

Protest bidders are identified using the statements in Table 3.3. Using the follow-up questions allows us to identify the reasons behind the response and, hence, we can classify them as protest bidders. Two classifications were attempted in order to investigate the impact of protest bids in our model; firstly, protest bids were treated as true zero and included in the dataset and, second, protest bids were differentiated and excluded from the dataset.

In the overall sample, we found 3.16% of respondents always choose status-quo with the following reasons. 15.38% of respondents prefer if there is no initiative for environmental improvement strategy undertaken, 38.46% supported the environmental improvement strategy, but object to pay for it and 46.15% supported the environmental improvement strategy, but they don't think this project will benefit to environment conservation respectively.

4.1.2.3 Multinomial Logistics Model for the Full Sample

The MNL models for the full sample were employed and run by using STATA 14. We found no multicollinearity problems between variables. Table 4.1 indicated that, altogether independent variables are statistically significantly different from zero at 1% in both models with and without interactions. In the model without interaction effects, judging from the value of the *t-statisitc, the* coefficient of fish attributes in the better and the best levels (Fishbetter and Fishbest), elephant attributes in the better level (Elephantbetter) and Ancient attributes are positively highly significant. The coefficient of the above attributes indicated that the level of environmental attributes is positively related to choosing alternative options rather than status quo options. On the contrary, the coefficient on price attribute is significantly negative, which indicated that the alternative option is likely to be chosen when the cost increased.

In the model with interaction, coefficient of forest attribute in the good level (Forestgood), fish attributes in the better and the best levels (Fishbetter and Fishbest), elephant attributes in the better level (Elephantbetter) and Ancient attributes are positively significant. The coefficient of the above attributes indicated that the level of environmental attributes is positively related to choosing alternative options rather than status quo options. In opposition, the coefficient on price attributes is significantly negative, indicating that the alternative option is less likely to be chosen when the cost increases.

In the interaction terms, we found no relationship respondent's social-economic characteristics and their utilities except for the income to protected fish species and ancient protection program attributes. That is, respondents with higher incomes are more likely to choose alternative choices even though they faced a lower number of protected fish species and have a higher opportunity to choose alternative choices when there is an ancient protected program included in the choice set respectively.

Table 4.3 The MNL Model for the Full Sample

Variable	Without Interaction		With Interaction	
	Coefficient	**t-statistic**	**Coefficient**	**t-statistic**
Forestgood	0.0667	0.98	0.2025	1.75*
Forestbetter	0.0230	0.26	-0.1068	-0.86
Forestbest	-0.0128	-0.12	-0.3779	-1.30
Fishgood	0.1147	1.29	0.1083	1.03
Fishbetter	0.4757	7.09***	0.4573	4.03***
Fishbest	0.3094	3.09***	0.2912	1.10
Elephantgood	0.0822	1.07	0.0819	1.00
Elephantbettter	0.2292	3.29***	0.2670	2.16**
Elephantbest	-0.1058	-1.19	-0.0821	-0.34
Ancientgood	0.2525	4.77***	0.3616	2.11**
Cost	-0.3409	-10.79***	-0.3377	-10.56**
Cons	-0.3416	-3.53***	-0.5757	-2.84***
Sex_forest			-0.0011	-0.13
Sex_fish			-0.0008	-0.12
Sex_elep			0.0057	0.45
Sex_ancent			-0.0508	-0.32
Age_forest			0.0008	1.16

Table 4.3 (Continued)

Variable	Without Interaction		With Interaction	
	Coefficient	**t-statistic**	**Coefficient**	**t-statistic**
Age_fish			0.0003	0.49
Age_elep			0.0001	0.13
Age_ancient			-0.0192	-1.41
Chil_forest			-0.0033	-0.81
Chil_fish			-0.0003	-0.11
Chil_elep			-0.0036	-0.62
Chil_ancient			0.0575	0.76
Edu_forest			-0.0032	-0.52
Edu_fish			0.0005	0.09
Edu_elep			0.0034	0.34
Edu_ancient			-0.0985	-0.80
Inc_forest			0.00003	1.59
Inc_fish			-0.00003	-1.89*
Inc_elep			-0.00004	-1.32
Inc_ancient			0.0016	3.96***
Observation	4,932		4,932	
Ch2	324.65***		351.4***	
Pseudo R2	0.0584		0.0632	
Log likelihood	-2616.5935		-2603.2158	

Note: * indicates statistical significance at the 90% significant level, ** indicates statistical significance at the 95% significant level and *** indicates statistical significance at the 99% significant level respectively

4.1.2.4 Multinomial Logistics Model Per Treatment of Protest

Table 4.3 presents the results of the multinomial logistics model per treatment of the protest. Similar to the model with the full sample size, we found no multicollinearity problem between variables. Altogether independent variables are statistically significantly different from zero at 1% in both models with and without interactions. In the model without interaction effects, on the one hand, the coefficient of the fish attribute in the better and the best level (Fishbetter and Fishbest), elephant attribute in the better level (Elephantbetter) and Ancient attribute are positively highly significant. The coefficient of the above attributes indicated that the level of environmental attributes is positively related to choosing alternative options rather than the status quo option. On the other hand, the coefficient on price attribute is significantly negative, which indicated that it is less likely for the alternative option to be chosen when the cost increases.

In the model with interaction, the coefficient of forest attribute in the good level (Forestgood), fish attribute in the better and best levels (Fishbetter and Fishbest), elephant attribute in the better level (Elephantbetter) and Ancient attribute are positively significant. The coefficient of the above attributes indicated that the level of environmental attributes is positively related to choosing alternative options rather than the status quo option. In opposition, the coefficient on the price attribute is significantly negative, which indicated that is less likely to be chosen when the cost increased.

In addition, we found no relationship respondent’s social-economic characteristics and their utilities except for the income from protected fish species and ancient protection program attributes. That is, respondents with higher income are more likely to choose alternative choices even though they faced a lower number of protected fish species and have a greater opportunity to choose alternative choices when there is an ancient protected program included into the choice set respectively.

Both models, the model with the full sample size and the model per treatment of the protest, presented similar results in term of environmental attributes significance, however, we found that the model per treatment of the protest has better performance in terms of goodness of fit of the model. We, therefore, used such a model to estimate WTP in the next step.

Table 4.4 The MNL Model Per Treatment of Protest

Variable	Without Interaction		With Interaction	
	Coefficient	**t-statistic**	**Coefficient**	**t-statistic**
Forestgood	0.0649	0.94	0.2258	1.93*
Forestbetter	0.0062	0.07	-0.1472	-1.17
Forestbest	0.0006	0.01	-0.4258	-1.45
Fishgood	0.1399	1.56	0.1356	1.27
Fishbetter	0.4935	7.24***	0.4746	4.12***
Fishbest	0.3365	3.30***	0.3332	1.24
Elephantgood	0.0800	1.03	0.0665	0.80
Elephantbettter	0.2345	3.33***	0.2974	2.38**
Elephantbest	-0.1196	-1.33	-0.0367	-0.15
Ancientgood	0.2524	4.71***	0.3330	1.92*
Cost	-0.3421	-10.73***	-0.3393	-10.50***
Cons	-0.3458	-3.53***	-0.5801	-2.83***
Sex_forest			-0.0007	-0.09
Sex_fish			-0.0021	-0.29
Sex_elep			0.0072	0.56
Sex_ancent			-0.0689	-0.43
Age_forest			0.0011	1.49
Age_fish			0.0003	0.47
Age_elep			-0.0002	-0.23
Age_ancient			-0.0168	-1.21
Chil_forest			-0.0045	-1.11
Chil_fish			-0.0007	-0.21
Chil_elep			-0.0007	-0.12
Chil_ancient			0.0391	0.51
Edu_forest			-0.0050	-0.56
Edu_fish			0.0045	0.61

Edu_elep			-0.0024	-0.19

Table 4.4 (Continued)

Variable	Without Interaction		With Interaction	
	Coefficient	**t-statistic**	**Coefficient**	**t-statistic**
Edu_ancient			-0.0793	-0.48
Inc_forest			0.0000	1.33
Inc_fish			-0.0000334	-2.02**
Inc_elep			-0.00003	-1.08
Inc_ancient			0.0016	3.90***
Observation	4,776		4,776	
Ch2	336.70		361.93	
Pseudo R2	0.0626		0.0672	
Log likelihood	-2458.6534		-2510.2275	

Note: * indicates statistical significance at the 90% significant level, ** indicates statistical significance at the 95% significant level and *** indicates statistical significance at the 99% significant level respectively

The last step in the MNL analysis is to elicit the Marginal Willingness to Pay (MWTP) from our model. We used the result of the model per treatment of protests with interaction effects because it is the best model (judging from the value of Pseudo R2 and maximum likelihood). MWTP is equivalent to calculating the ratio of marginal utilities for the attribute in question and the price attribute as shown in Table 4.5.

Table 4.5 Marginal Willingness to Pay Estimation

Attribute/Level	Average	Good	Better	Best
Model per treatment of protests				
Forest	-0.6654	0.6654	NA	NA
Fish	-1.3989	NA	1.3989	NA
Elephant	-0.8765	NA	0.8765	NA
Ancient	-0.9814	0.9814	NA	NA

From Equation 24, we now can elicit the WTP for changing environmental attributes from the status-quo to the highest level as follows:

1) WTP for increasing of protected forest from average to good level is 0.6654-(-0.6654) = $1.3309.

2) WTP for increasing of protected fish species from average to better level is 1.3989-(-1.3989) = $2.7978.

3) WTP for increasing of protected wild elephants from average to better level is 0.8765-(-0.8765) = $1.7531.

4) WTP for having ancient protection program included into the choice is 0.9814-(-0.9814) = $1.9628.

5) In conclusion, the total WTP for the environmental protection of the Lao population is $7.8445 per household per month or $94.1343 per household per year.

The total value of opportunity cost related to local people's WTP was calculated by multiplying the WTP by the total number of electrified households. In 2015, there were a total of 1,236,010 households in Laos and the electrified rate was 90.51% (EDL, 2015).

Hence, the environmental cost related to local people's WTP to improve environmental attributes is $105,309,173 per year or PV $2,360,198,758 in the project's lifetime.

The CBA estimation claims, on the one hand, a positively Financial NPV of $4,586,531,023, 7.21% of IRR and 1.97 of B/C Ratio. On the other hand, when we take opportunity cost related to environmental impacts caused by the project into consideration, we found similar results for the Financial CBA. This project is expected to yield an Economic NPV of $545,113,968 in its lifetime, and yield 0.96% of IRR and 1.05 of B/C Ratio.

In conclusion, the Xayaburi Dam project is both financially and economically feasible, judging from the NPV and B/C ratio. However, in the economic CBA table, we found that the project is expected to grow at the rate of 0.96% which is less than the discount rate (2%).

Table 4.6 Economic Cost and Benefit

Activity	Total Value (FV)	Total Value (PV)
Benefit		
EGAT	$13,726,240,259	$10,149,395,105
EDL	$722,433,698	$534,178,690
Cost		
Construction	$3,800,000,000	$3,800,000,000
O&M	$1,122,278,164	$762,085,591
Selling and Administration	$451,143,251	$324,319,051
Forest Loss	$184,928,535	$138,058,124
Fish Reduction	$691,249	$516,051
CO2 Relate cost	$3,688,015,159	$2,753,282,253
WTP	$3,161,480,734	$2,360,198,758

4.1.3 Sensitivity Analysis

The last part of this study is to conduct the sensitivity analysis in order to examine the sensitivity of the NPV to each variable that is expected to impact the value of NPV most, including reduction of project's revenue, increase of carbon tax and increase of O&M cost respectively. Results in Table 4.7 indicated the relationship between NPV and the change of the above variables. While keeping other factors the same, a 10% decrease in the project's benefit is expected to decrease the project's benefit from $10,683,573,795 to $9,615,216,416, reduce the value of NPV from 545,113,968 to -$523,243,411, reduce the B/C Ratio from 1.05 to 0.95 and reduce the

IRR from 0.96% to -1.01% respectively. On the cost side, a 10% increase in O&M Cost is expected to increase the cost of the project from $10,138,459,827 to $10,214,668,386, reduce the value of NPV from $545,113,968 to $468,905,409, reduce the B/C Ratio from 1.05 to 0.95 and reduce the IRR from 0.96% to 0.84% respectively. The last factor tested on the sensitivity analysis is the change of the carbon tax. A 10% increase of the carbon tax is expected to increase the cost of the project from $10,138,459,827 to $10,414,441,193, reduce the B/C Ratio from 1.05 to 1.03 and 0.96% to 0.48% respectively.

In addition, we examined the sensitivity of the NPV to each factor input and found that the change in benefit is the most sensitive while changing in the carbon tax and O&M Cost is the second and the third most sensitive respectively. Changing 10% of the benefit reduced the value of the NPV by 195.99% or 19.59 times, while a 10% change in carbon tax reduced the NPV by 50.63% or 5.06 times, and a 10% change in O&M Cost reduced the NPV by 13.98% or 1.39 times respectively.

The last step in this session is to examine the Switching Value of Benefit (STVB) and Switching Value of Cost (STVP). We found that the project has 5.10% of STVB while having -5.38% of STVC respectively. These values indicated the value change of benefits or cost to make the NPV value of the project become zero. On the one hand, the project can burden the reduction of benefits at most 5.10% before the number of NPV becomes zero. On the other hand, the project can burden the increase of cost at a maximum of 5.38% before the number of NPV becomes zero.

Table 4.7 Cost and Benefit Analysis

Assumption		
Inflation Rate (2015 Base)	2.34%	2.34%
Real Discount Rate	2.00%	2.00%
Time Frame (Year)	30	30
Type of Cost (USD)	**Financial**	**Economic**
Construction Cost	$3,800,000,000	$3,800,000,000
O&M	$762,085,591	$762,085,591

Table 4.7 (Continued)

Assumption		
Selling and Administration	$324,319,051	$324,319,051
Land		$138,058,124
Fish Reduction		$516,051
CO2 Relate cost		$2,753,282,253
WTP for environmental improvement		$2,360,198,758
Total Cost	$4,886,404,642	$10,138,459,827
Type of Benefit (USD)	**Financial**	**Economic**
EGAT	$10,149,395,105	$10,149,395,105
EDL	$534,178,690	$534,178,690
Total Benefit	$10,683,573,795	$10,683,573,795
CBA Analysis		
NPV	$5,797,169,153	$545,113,968
IRR	8.26%	0.96%
B/C Ratio	2.1864	1.0538

Table 4.8 Sensitivity Analysis Table

Sensitivity Analysis							
Value Change	**PVB**	**PVC**	**NPV**	**B/C Ratio**	**IRR**	**Change in NPV**	**Sensitiveness**
Initial Value	$10,683,573,795	$10,138,459,827	$545,113,968	1.05	0.96%	NA	NA
10% Decrease in Benefit	$9,615,216,416	$10,138,459,827	-$523,243,411	0.95	-1.01%	-195.99%	19.60
10% Increase in O&M Cost	$10,683,573,795	$10,214,668,386	$468,905,409	0.95	0.84%	-13.98%	-1.40
10% Increase in Carbon Tax	$10,683,573,795	$10,414,441,193	$269,132,602	1.03	0.48%	-50.63%	-5.06

Table 4.9 Sensitivity Analysis Table

Switching Value	
Switching Value of Benefit (STVB)	5.10%
Switching Value of Cost (STVC)	-5.38%

CHAPTER 5

CONCLUSION

5.1 Conclusion

While most hydropower feasibility studies in Laos focus on the financial cost and used-value of environmental costs to access the CBA. This paper extended the scope of a feasibility study to cover the non-used value of environmental attributes. The MNL model was used to estimate the relationship between environmental attributes and the opportunity of choosing the alternative choice of respondents. Furthermore, the MWTP was elicited from respondents' marginal utility function as a representative of the environmental non-used value. In the final step, we included all elements, financial and environmental, into our CBA table to examine whether or not the Xayaburi Dam is feasible.

The findings in the MNL model indicated the problem of including protest bids in the model by comparing results between the model with the full sample and the model per treatment of protest. We found better performance in terms of goodness of fit of the model after eliminating the protest bids from the sample size. This finding is consistent with the previous studies which indicated better performance of the model after the elimination of protest bids from their samples.

In the model without the interaction effect, we found a positive relationship between the respondent's utility and the increase of environmental attributes in at least one level except for the forest attribute. Unlike the results from the model with the interaction effect, we found positive relations in all attributes in at least one level.

Also, the net income of respondents is the only social economic characteristic that has relationship on environmental attribute improvement (Fish and Ancient).

The CBA analysis presents decision making criteria in both financial and economic aspects. In the financial CBA, Xayaburi Dam is feasible with a positive

NPV, the IRR is greater than the discount rate and the B/C ratio is greater than one. Similarly, when we include environmental costs into the CBA analysis, we found that the positive NPV and B/C ratio is greater than 1. However, when considering the value of the IRR, the IRR value of the project is less than the discount rate. Moreover, after conducting the sensitivity analysis, we found that the project is mostly sensitive to the change of revenue and Carbon tax respectively, and the project seems to be risky due to the low value of the switching value.

5.2 Policy Implications

There are several policy implications based on these empirical results. First, the numerical results obtained from the study indicated that respondents are willing to pay for fish species protection at the highest rate, followed by ancient protection, wild elephant protection and forest protection respectively. The results indicated the importance of each attribute that respondents chose, and the Lao government should implement environmental protection strategy accordingly.

Second, it is important for the Lao government to implement a wider and more detailed public hearing process to ensure that the local community and general people are thoroughly informed.

Third, even though, the Xayaburi project is both financially and economically feasible, the high value of the sensitivity value of income and the low level of the switching value in the sensitivity analysis should be considered by the Lao government and they should find a reliable approach to water management in order to maintain the balance of electricity generation and quality of life of the local population in the lower Mekong.

Lastly, our results support the Lao government in strengthening the effectiveness and enforcement of environmental protection rules and regulations to ensure environmentally friendly hydropower development, and especially to ensure the proper management of the hydrology ecosystem protection program.

5.3 Limitations of the Study

We encountered several limitations while conducting this study. The first limitation is a lack of data about sediment reduction on the local farming sector in LMB and the data of compensation cost of the project. Extending the scope of the study to a wider area by doing a multinational survey project could provide a clear picture of the sediment reduction effect. In addition, due to the limitation of time, the questionnaire was designed without considering if respondents have ever been to Xayaburi province before the survey. Hence, the results of the WTP from the CE model could consist of a fraction of the Used Value. Lastly, the respondents have no property rights over environmental resources measured in the study. Therefore, we used the WTP as the measurement of the non-used environmental value in the study.

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APPENDICES

Appendix A

Orthogonal Design

Forest	Fish	Elephant	Ancient	Cost
0	0	0	0	0
0	15	15	1	1
0	25	0	0	1
0	15	15	1	1
10	15	10	1	1
0	15	10	1	1
0	15	10	1	1
0	25	20	0	1
10	15	15	1	1
20	15	10	1	1
0	25	0	0	1
10	0	20	0	1
0	35	20	1	1
0	15	10	1	1
0	35	0	1	1
0	25	0	0	1
30	25	0	0	1
10	15	15	0	3
0	25	10	0	3
10	15	10	1	3
10	25	15	1	3
20	25	10	0	3
10	25	15	0	3
10	15	15	1	3
10	15	10	1	3

Forest	Fish	Elephant	Ancient	Cost
0	0	0	0	0
10	25	10	0	3
10	15	15	0	3
10	15	10	1	3
30	25	15	1	3
20	25	10	0	3
10	25	15	0	3
20	15	15	1	3
10	15	10	1	3
10	15	20	1	5
30	15	10	0	5
20	25	15	0	5
10	35	20	1	5
10	25	20	1	5
30	25	15	0	5
20	25	15	0	5
10	35	20	1	5
10	25	20	1	5
30	25	15	0	5
20	15	15	0	5
10	35	20	1	5
10	35	20	1	5
30	15	10	0	5
20	35	15	0	5
10	25	20	1	5

STATA Results

```
. *discriptive analysis
. sum sex age status children edu inc
```

Variable	Obs	Mean	Std. Dev.	Min	Max
sex	4,932	.4768856	.4995161	0	1
age	4,932	28.2425	8.304756	20	50
status	4,932	.7347932	.441488	0	1
children	4,932	1.506083	1.549613	0	9
edu	4,932	.3673966	.4821447	0	1
inc	4,932	196.5215	225.7593	1.4	1750

Figure A.1 Descriptive Analysis for the Full Sample Size

```
. *multi testing
. corr forest fish elephant ancient cost sex age children edu inc
(obs=4,932)
```

	forest	fish	elephant	ancient	cost	sex	age	children
forest	1.0000							
fish	0.4496	1.0000						
elephant	0.4445	0.6299	1.0000					
ancient	0.0461	0.3793	0.5346	1.0000				
cost	0.6255	0.6691	0.7199	0.3011	1.0000			
sex	-0.0196	-0.0028	0.0082	0.0172	-0.0002	1.0000		
age	0.0249	0.0197	-0.0376	-0.0042	-0.0002	0.0189	1.0000	
children	0.0139	0.0212	-0.0217	-0.0001	-0.0009	-0.0666	0.7017	1.0000
edu	0.0027	0.0008	-0.0192	-0.0152	0.0007	-0.0405	0.0075	0.0117
inc	0.0696	0.0389	-0.0790	-0.0178	-0.0001	-0.0803	0.2507	0.1830

	edu	inc
edu	1.0000	
inc	0.1228	1.0000

Figure A.2 Multicollinearity Testing for the Full Sample Size

```
. mlogit choice forestgood forestbetter forestbest fishgood fishbetter fishbest
> elephantgood elephantbetter elephantbest ancientgood cost

Iteration 0:   log likelihood = -2691.1918
Iteration 1:   log likelihood =  -2527.045
Iteration 2:   log likelihood =  -2522.845
Iteration 3:   log likelihood = -2522.8411
Iteration 4:   log likelihood = -2522.8411

Multinomial logistic regression                 Number of obs     =      4,776
                                                LR chi2(11)       =     336.70
                                                Prob > chi2       =     0.0000
Log likelihood = -2522.8411                     Pseudo R2         =     0.0626
```

choice	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
0	(base outcome)					
1						
forestgood	.0649219	.0687976	0.94	0.345	-.0699189	.1997627
forestbetter	.0062193	.0899769	0.07	0.945	-.1701322	.1825708
forestbest	.0005945	.1076316	0.01	0.996	-.2103596	.2115486
fishgood	.1398617	.0897951	1.56	0.119	-.0361335	.3158569
fishbetter	.4935261	.0681944	7.24	0.000	.3598676	.6271846
fishbest	.3365421	.1020436	3.30	0.001	.1365404	.5365438
elephantgood	.0800295	.0776963	1.03	0.303	-.0722524	.2323113
elephantbet~r	.2344804	.0704618	3.33	0.001	.0963778	.372583
elephantbest	-.1195805	.0897883	-1.33	0.183	-.2955624	.0564013
ancientgood	.2523535	.0535546	4.71	0.000	.1473885	.3573185
cost	-.3421392	.0318966	-10.73	0.000	-.4046554	-.2796231
_cons	-.3457716	.0980603	-3.53	0.000	-.5379663	-.1535768

Figure A.3 MNL without Interaction for the Full Sample Size

```
. mlogit choice forestgood forestbetter forestbest fishgood fishbetter fishbest
> elephantgood elephantbetter elephantbest ancientgood cost sex_forest sex_fish
> sex_elep sex_ancent age_forest age_fish age_elep age_ancient chil_forest chil_
> fish chil_elep chil_ancient edu_forest edu_fish edu_elep edu_ancient inc_fores
> t inc_fish inc_elep inc_ancient

Iteration 0:   log likelihood = -2691.1918
Iteration 1:   log likelihood = -2515.0167
Iteration 2:   log likelihood = -2510.2324
Iteration 3:   log likelihood = -2510.2275
Iteration 4:   log likelihood = -2510.2275

Multinomial logistic regression                 Number of obs     =      4,776
                                                LR chi2(31)       =     361.93
                                                Prob > chi2       =     0.0000
Log likelihood = -2510.2275                     Pseudo R2         =     0.0672
```

choice	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
0	(base outcome)					
1						
forestgood	.2257741	.1167491	1.93	0.053	-.0030498	.454598
forestbetter	-.1471538	.1255766	-1.17	0.241	-.3932795	.0989719
forestbest	-.4258417	.2932574	-1.45	0.146	-1.000616	.1489322
fishgood	.1356165	.1064485	1.27	0.203	-.0730187	.3442517
fishbetter	.4746266	.1151197	4.12	0.000	.2489963	.700257
fishbest	.3331912	.2687749	1.24	0.215	-.1935979	.8599803
elephantgood	.0665122	.0830461	0.80	0.423	-.0962552	.2292796
elephantbet~r	.2973897	.1249214	2.38	0.017	.0525482	.5422311
elephantbest	-.0367365	.2464421	-0.15	0.882	-.519754	.4462811
ancientgood	.332964	.1730554	1.92	0.054	-.0062184	.6721465
cost	-.3392824	.0322994	-10.50	0.000	-.402588	-.2759768
sex_forest	-.0007412	.0085774	-0.09	0.931	-.0175526	.0160703
sex_fish	-.0020736	.0071976	-0.29	0.773	-.0161807	.0120335
sex_elep	.0072381	.0128591	0.56	0.574	-.0179653	.0324414
sex_ancent	-.0688516	.1619562	-0.43	0.671	-.3862798	.2485767
age_forest	.0010917	.000731	1.49	0.135	-.000341	.0025243
age_fish	.0002778	.0005942	0.47	0.640	-.0008869	.0014425
age_elep	-.000249	.001087	-0.23	0.819	-.0023794	.0018814
age_ancient	-.0168035	.0138445	-1.21	0.225	-.0439381	.0103312
chil_forest	-.0045435	.0040861	-1.11	0.266	-.0125521	.0034651
chil_fish	-.0006653	.0031442	-0.21	0.832	-.0068279	.0054972
chil_elep	-.0007041	.005911	-0.12	0.905	-.0122894	.0108813
chil_ancient	.0391251	.0767801	0.51	0.610	-.1113611	.1896113
edu_forest	-.0049781	.0088594	-0.56	0.574	-.0223423	.0123861
edu_fish	.0044569	.0072871	0.61	0.541	-.0098256	.0187393
edu_elep	-.0024345	.0130734	-0.19	0.852	-.0280579	.023189
edu_ancient	-.0792592	.1667854	-0.48	0.635	-.4061525	.2476342
inc_forest	.0000258	.0000194	1.33	0.184	-.0000123	.0000639
inc_fish	-.0000334	.0000165	-2.02	0.043	-.0000657	-1.05e-06
inc_elep	-.0000325	.0000302	-1.08	0.281	-.0000917	.0000266
inc_ancient	.001609	.0004129	3.90	0.000	.0007998	.0024182
_cons	-.5801076	.205007	-2.83	0.005	-.981914	-.1783012

Figure A.4 MNL with Interaction for the Full Sample Size

```
. corr forest fish elephant ancient cost sex age children edu inc
(obs=4,776)
```

	forest	fish	elephant	ancient	cost	sex	age
forest	1.0000						
fish	0.4499	1.0000					
elephant	0.4438	0.6289	1.0000				
ancient	0.0457	0.3799	0.5336	1.0000			
cost	0.6239	0.6680	0.7178	0.3010	1.0000		
sex	-0.0219	-0.0037	0.0092	0.0179	-0.0002	1.0000	
age	0.0256	0.0209	-0.0387	-0.0043	-0.0003	0.0123	1.0000
children	0.0158	0.0229	-0.0238	-0.0005	-0.0009	-0.0624	0.7105
edu	0.0052	0.0017	-0.0196	-0.0157	0.0007	-0.0369	0.0063
inc	0.0764	0.0432	-0.0823	-0.0188	-0.0001	-0.0775	0.2509

	children	edu	inc
children	1.0000		
edu	0.0043	1.0000	
inc	0.1786	0.1084	1.0000

Figure A.5 Multicollinearity Testing Per Treatment of Protest

```
. mlogit choice forestgood forestbetter forestbest fishgood fishbetter fishbest
> elephantgood elephantbetter elephantbest ancientgood cost

Iteration 0:   log likelihood = -2691.1918
Iteration 1:   log likelihood =  -2527.045
Iteration 2:   log likelihood =  -2522.845
Iteration 3:   log likelihood = -2522.8411
Iteration 4:   log likelihood = -2522.8411

Multinomial logistic regression                 Number of obs     =      4,776
                                                LR chi2(11)       =     336.70
                                                Prob > chi2       =     0.0000
Log likelihood = -2522.8411                     Pseudo R2         =     0.0626
```

choice	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
0	(base outcome)					
1						
forestgood	.0649219	.0687976	0.94	0.345	-.0699189	.1997627
forestbetter	.0062193	.0899769	0.07	0.945	-.1701322	.1825708
forestbest	.0005945	.1076316	0.01	0.996	-.2103596	.2115486
fishgood	.1398617	.0897951	1.56	0.119	-.0361335	.3158569
fishbetter	.4935261	.0681944	7.24	0.000	.3598676	.6271846
fishbest	.3365421	.1020436	3.30	0.001	.1365404	.5365438
elephantgood	.0800295	.0776963	1.03	0.303	-.0722524	.2323113
elephantbet~r	.2344804	.0704618	3.33	0.001	.0963778	.372583
elephantbest	-.1195805	.0897883	-1.33	0.183	-.2955624	.0564013
ancientgood	.2523535	.0535546	4.71	0.000	.1473885	.3573185
cost	-.3421392	.0318966	-10.73	0.000	-.4046554	-.2796231
_cons	-.3457716	.0980603	-3.53	0.000	-.5379663	-.1535768

Figure A.6 MNL without Interaction Per the Treatment of Protest

```
. mlogit choice forestgood forestbetter forestbest fishgood fishbetter fishbest
> elephantgood elephantbetter elephantbest ancientgood cost sex_forest sex_fish
> sex_elep sex_ancent age_forest age_fish age_elep age_ancient chil_forest chil_
> fish chil_elep chil_ancient edu_forest edu_fish edu_elep edu_ancient inc_fores
> t inc_fish inc_elep inc_ancient

Iteration 0:   log likelihood = -2691.1918
Iteration 1:   log likelihood = -2515.0167
Iteration 2:   log likelihood = -2510.2324
Iteration 3:   log likelihood = -2510.2275
Iteration 4:   log likelihood = -2510.2275

Multinomial logistic regression                 Number of obs     =      4,776
                                                LR chi2(31)       =     361.93
                                                Prob > chi2       =     0.0000
Log likelihood = -2510.2275                     Pseudo R2         =     0.0672

------------------------------------------------------------------------------
      choice |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
0            |  (base outcome)
-------------+----------------------------------------------------------------
1            |
  forestgood |   .2257741   .1167491     1.93   0.053    -.0030498     .454598
forestbetter |  -.1471538   .1255766    -1.17   0.241    -.3932795    .0989719
  forestbest |  -.4258417   .2932574    -1.45   0.146    -1.000616    .1489322
    fishgood |   .1356165   .1064485     1.27   0.203    -.0730187    .3442517
  fishbetter |   .4746266   .1151197     4.12   0.000     .2489963     .700257
    fishbest |   .3331912   .2687749     1.24   0.215    -.1935979    .8599803
elephantgood |   .0665122   .0830461     0.80   0.423    -.0962552    .2292796
elephantbet~r|   .2973897   .1249214     2.38   0.017     .0525482    .5422311
elephantbest |  -.0367365   .2464421    -0.15   0.882     -.519754    .4462811
 ancientgood |    .332964   .1730554     1.92   0.054    -.0062184    .6721465
        cost |  -.3392824   .0322994   -10.50   0.000     -.402588   -.2759768
  sex_forest |  -.0007412   .0085774    -0.09   0.931    -.0175526    .0160703
    sex_fish |  -.0020736   .0071976    -0.29   0.773    -.0161807    .0120335
    sex_elep |   .0072381   .0128591     0.56   0.574    -.0179653    .0324414
  sex_ancent |  -.0688516   .1619562    -0.43   0.671    -.3862798    .2485767
  age_forest |   .0010917    .000731     1.49   0.135     -.000341    .0025243
    age_fish |   .0002778   .0005942     0.47   0.640    -.0008869    .0014425
    age_elep |   -.000249    .001087    -0.23   0.819    -.0023794    .0018814
 age_ancient |  -.0168035   .0138445    -1.21   0.225    -.0439381    .0103312
 chil_forest |  -.0045435   .0040861    -1.11   0.266    -.0125521    .0034651
   chil_fish |  -.0006653   .0031442    -0.21   0.832    -.0068279    .0054972
   chil_elep |  -.0007041    .005911    -0.12   0.905    -.0122894    .0108813
chil_ancient |   .0391251   .0767801     0.51   0.610    -.1113611    .1896113
  edu_forest |  -.0049781   .0088594    -0.56   0.574    -.0223423    .0123861
    edu_fish |   .0044569   .0072871     0.61   0.541    -.0098256    .0187393
    edu_elep |  -.0024345   .0130734    -0.19   0.852    -.0280579     .023189
 edu_ancient |  -.0792592   .1667854    -0.48   0.635    -.4061525    .2476342
  inc_forest |   .0000258   .0000194     1.33   0.184    -.0000123    .0000639
    inc_fish |  -.0000334   .0000165    -2.02   0.043    -.0000657   -1.05e-06
    inc_elep |  -.0000325   .0000302    -1.08   0.281    -.0000917    .0000266
 inc_ancient |    .001609   .0004129     3.90   0.000     .0007998    .0024182
       _cons |  -.5801076    .205007    -2.83   0.005     -.981914   -.1783012
------------------------------------------------------------------------------
```

Figure A.7 MNL with Interaction Per the Treatment of Protest

Appendix B

CBA Calculation

Table B.1 CBA Calculation (FV)

Year	Construction	O&M	Selling&Admin	Land	Fish	CO2	WTP	EGAT	EDL
0	(3,800,000,000)	-	(2,789,982)	-	-	-	-	-	-
1		(2,084,469)	(1,859,988)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	77,016,323	4,053,491
2		(9,556,489)	(11,384,408)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	464,596,094	24,452,426
3		(10,005,452)	(11,576,821)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	467,033,319	24,580,701
4		(10,518,552)	(11,769,233)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	468,708,912	24,668,890
5		(11,031,652)	(11,993,715)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	468,708,912	24,668,890
6		(13,180,258)	(12,186,127)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	468,708,912	24,668,890
7		(26,071,898)	(12,410,608)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	468,708,912	24,668,890
8		(26,713,273)	(12,667,158)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	468,708,912	24,668,890
9		(23,089,504)	(12,891,640)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	468,708,912	24,668,890
10		(23,827,085)	(13,148,190)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	468,708,912	24,668,890
11		(25,398,454)	(13,404,740)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	469,226,822	24,696,149
12		(30,304,974)	(13,693,359)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458

Year	Construction	O&M	Selling&Admin	Land	Fish	CO2	WTP	EGAT	EDL
13		(31,138,762)	(13,981,977)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
14		(32,068,755)	(14,270,596)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
15		(33,030,818)	(14,591,284)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
16		(34,858,737)	(14,911,971)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
17		(39,989,738)	(15,232,659)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
18		(41,144,213)	(15,585,415)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
19		(46,660,039)	(15,970,240)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
20		(47,974,858)	(16,355,065)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
21		(45,922,458)	(16,739,890)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
22		(51,438,284)	(17,156,784)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
23		(53,041,721)	(17,605,747)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
24		(54,709,297)	(18,054,709)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
25		(56,505,147)	(18,503,672)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
26		(58,429,272)	(19,016,772)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
27		(60,449,604)	(19,529,872)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
28		(62,598,211)	(20,042,972)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
29		(68,947,824)	(20,620,210)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
30		(91,588,365)	(21,197,447)	(6,164,285)	(23,042)	(122,933,839)	(105,382,691)	471,968,701	24,840,458
Total	(3,800,000,000)	(1,122,278,164)	(451,143,251)	(184,928,535)	(691,249)	(3,688,015,159)	(3,161,480,734)	13,726,240,259	722,433,698

Table B.2 CBA Table (PV)

Year	Construction	O&M	Selling&Admin	Land	Fish	CO2	WTP	EGAT	EDL
0	(3,800,000,000)	-	(2,789,982)	-	-	-	-	-	-
1		(2,023,756)	(1,805,813)	(5,984,742)	(22,371)	(119,353,241)	(102,313,292)	74,773,129	3,935,428
2		(9,007,908)	(10,730,897)	(5,810,429)	(21,719)	(115,876,933)	(99,333,294)	437,926,378	23,048,757
3		(9,156,406)	(10,594,431)	(5,641,194)	(21,086)	(112,501,877)	(96,440,091)	427,401,647	22,494,824
4		(9,345,597)	(10,456,811)	(5,476,887)	(20,472)	(109,225,123)	(93,631,156)	416,441,797	21,917,989
5		(9,516,000)	(10,345,884)	(5,317,366)	(19,876)	(106,043,809)	(90,904,035)	404,312,425	21,279,601
6		(11,038,259)	(10,205,690)	(5,162,491)	(19,297)	(102,955,154)	(88,256,345)	392,536,335	20,659,807
7		(21,198,839)	(10,090,960)	(5,012,127)	(18,735)	(99,956,461)	(85,685,772)	381,103,238	20,058,065
8		(21,087,705)	(9,999,572)	(4,866,143)	(18,189)	(97,045,107)	(83,190,070)	370,003,143	19,473,850
9		(17,696,182)	(9,880,368)	(4,724,411)	(17,659)	(94,218,551)	(80,767,058)	359,226,353	18,906,650
10		(17,729,589)	(9,783,488)	(4,586,807)	(17,145)	(91,474,321)	(78,414,619)	348,763,449	18,355,971
11		(18,348,384)	(9,683,869)	(4,453,210)	(16,646)	(88,810,021)	(76,130,698)	338,979,440	17,841,023
12		(21,255,299)	(9,604,246)	(4,323,505)	(16,161)	(86,223,321)	(73,913,299)	331,029,351	17,422,597
13		(21,203,981)	(9,521,046)	(4,197,578)	(15,690)	(83,711,962)	(71,760,485)	321,387,719	16,915,143
14		(21,201,225)	(9,434,545)	(4,075,318)	(15,233)	(81,273,750)	(69,670,374)	312,026,912	16,422,469
15		(21,201,225)	(9,365,590)	(3,956,620)	(14,790)	(78,906,553)	(67,641,139)	302,938,749	15,944,145
16		(21,722,813)	(9,292,647)	(3,841,378)	(14,359)	(76,608,304)	(65,671,009)	294,115,291	15,479,752
17		(24,194,449)	(9,216,009)	(3,729,494)	(13,941)	(74,376,994)	(63,758,261)	285,548,826	15,028,886
18		(24,167,889)	(9,154,789)	(3,620,867)	(13,535)	(72,210,674)	(61,901,225)	277,231,870	14,591,151
19		(26,609,568)	(9,107,605)	(3,515,405)	(13,140)	(70,107,450)	(60,098,276)	269,157,155	14,166,166

Year	Construction	O&M	Selling&Admin	Land	Fish	CO2	WTP	EGAT	EDL
20		(26,562,516)	(9,055,403)	(3,413,015)	(12,758)	(68,065,486)	(58,347,841)	261,317,626	13,753,559
21		(24,685,584)	(8,998,516)	(3,313,607)	(12,386)	(66,082,996)	(56,648,389)	253,706,433	13,352,970
22		(26,845,255)	(8,953,997)	(3,217,094)	(12,025)	(64,158,248)	(54,998,436)	246,316,926	12,964,049
23		(26,875,803)	(8,920,687)	(3,123,392)	(11,675)	(62,289,562)	(53,396,540)	239,142,646	12,586,455
24		(26,913,349)	(8,881,721)	(3,032,420)	(11,335)	(60,475,303)	(51,841,301)	232,177,326	12,219,859
25		(26,987,173)	(8,837,457)	(2,944,097)	(11,005)	(58,713,886)	(50,331,360)	225,414,880	11,863,941
26		(27,093,346)	(8,817,977)	(2,858,346)	(10,684)	(57,003,773)	(48,865,398)	218,849,398	11,518,389
27		(27,213,750)	(8,792,135)	(2,775,093)	(10,373)	(55,343,469)	(47,442,134)	212,475,144	11,182,902
28		(27,360,223)	(8,760,317)	(2,694,265)	(10,071)	(53,731,523)	(46,060,324)	206,286,547	10,857,187
29		(29,257,758)	(8,750,111)	(2,615,792)	(9,778)	(52,166,527)	(44,718,762)	200,278,201	10,540,958
30		(37,733,194)	(8,733,068)	(2,539,604)	(9,493)	(50,647,114)	(43,416,273)	194,444,856	10,233,940
Total	(3,800,000,000)	(635,233,023)	(278,565,630)	(120,822,697)	(451,626)	(2,409,557,494)	(2,065,547,257)	8,835,313,191	465,016,484

Appendix C

Questionnaire: The Environmental Cost of Hydropower Development Case Study: Xaiyaburi Hydropower Project

This study is a Master's Degree thesis of a student from the National Institution of Development Administration (NIDA); Thailand. The objective of this thesis is to estimate the environmental impacts of the Xaiyaburi Hydropower project.

All information provided **will be only used** for academic purposes and **will not be used** for financial or other purposes.

All information provided **will be kept** in secret and **will not** have any effect to you**.**

This questionnaire consists of 3 parts as follows:

Part 1: Introduction
Part 2: Choice Experiment
Part 3: Social-Economic Characteristics

Part 1: Introduction

In this part, we would like to introduce you to understand about our study's purpose and also would like to know how the project's information is provided to general people.

Question 1: What is your favorite travelling style?

Cultural Tourism Ecotourism

Modern town tourism Other…………………

Question 2: Are you concerned about the deforestation problem in Laos?

No Not Sure Yes

Question 3: Are you concerned about the effects of hydropower development on the environment?

No Not Sure Yes

Question 4: Have you ever seen the information about Xaiyaburi Hydropower Dam?

Yes No

If Yes go to **Questions 5, 6 and 7**

Question 5: What kind of media do you usually see that information?

Internet/Online Source TV Books/Project Report

Advertising Board Other……………

Question 6: 95% of electricity generated from the Xaiyaburi Dam will be exported, do you know what country we will export to?

…………………………. I don't know

Question 7: In your opinion, does Xaiyaburi Hydropower provide more benefits (Income from electricity) or is it more costly (Financial and environmental cost)

Benefit Cost Not sure

Part 2: Choice Experiment

In this part we are going to ask you to make some choices among alternatives to measure the environmental value. Each alternative in the choice set will have different impacts on the future environmental improvement strategy and will ask for your preference on each alternative.

Option and Choice

Option A is the same in each choice set. This option shows no increment on environmental attributes in the future; this option involves no environmental improvement and no cost as well.

Other options (B, C and D) involve incremental change on each attribute in the future; 4 environmental attributes are involved in each option

Forest: increment of the protected forests area

Fish: the incremental number of protected endanger Aquatic-Fauna species

Elephants: the number of protected wild elephants

Ancient: the increment of the degree of ancient place protection

Cost attribute: the extra charge from your monthly electricity

Making a Choice

We ask you to make a choice on your preferred option, when deciding which of the following options you prefer, please consider the following conditions:

- Our prediction will mainly depend on your decision making.
- Your decision making will have impact on the future environmental conservation strategy in Xaiyaburi province, Lao PDR.
- Please take your monthly electricity rate, personal income and other expenses into consideration.
- Other issue that you care about.

Important Note

The questions are hypothetical, but based on current scientific knowledge. Your decision making will provide very important information to decision makers who are responsible for the environmental improvement strategy in Xaiyaburi province, Lao PDR.

- Please consider each question carefully.
- Some of the following choice sets might seem unrealistic for you; however, please consider that all alternative choices are realistic and please just choose your most preferred choice in each choice set.
- Please answer each question independently from other questions.

Before making a decision, it is important that you review the poster provided.

Please answer all questions form **8-10**. You will find it useful to refer to your considerations of the information provided on the poster**.**

Question 8:

Attributes	***Choice A***	***Choice B***	***Choice C***	***Choice D***
	0 Km^2	0 Km^2	10 Km^2	10 Km^2
	0 Species	15 Species	35 Species	25 Species
	0	15	20	0
	No	Yes	Yes	No
	0 USD	1 USD	3 USD	5 USD
	☐*Option A*	☐*Option B*	☐*Option C*	☐*Option D*

Question 9:

Attributes	***Choice A***	***Choice B***	***Choice C***	***Choice D***
	0 Km^2	0 Km^2	30 Km^2	20 Km^2
	0 Species	15 Species	15 Species	15 Species
	0	15	0	20
	No	Yes	No	Yes
	0 USD	1 USD	3 USD	5 USD
	☐*Option A*	☐*Option B*	☐*Option C*	☐*Option D*

Question 10:

Attributes	***Choice A***	***Choice B***	***Choice C***	***Choice D***
	0 Km^2	0 Km^2	30 Km^2	30 Km^2
	0 Species	25 Species	0 Species	15 Species
	0	20	10	10
	No	Yes	Yes	YEs
	0 USD	1 USD	3 USD	5 USD
	☐Option A	*☐Option B*	*☐Option C*	*☐Option D*

We would now like to know further information from your decision making:

Question 11: Did you choose option A for every question you answered?

Yes (go to question 11)   No (go to question 12)

Question 12: If Yes, which of the following statements mostly describes your reason to do so?

I prefer if there is no initiative for environmental improvement strategy undertaken.

I support the environmental improvement strategy, but could not afford the cost.

I support the environmental improvement strategy, but object paying for it.

I support the environmental improvement strategy, but I have already paid a very high price on my electricity rate.

I support the environmental improvement strategy, but I don't think this project will benefit environment conservation.

I support the environmental improvement strategy, but I already support other environmental conservation agencies.

I found that alternatives provided are confusing; hence, I always chose the base case.

Other:

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

If No, please answer the following question:

Question 13:

13.1. Which alternative did you consider the most when you made decisions?

Forest   Fish   All the same

Elephant   Ancient

13.2. Which alternative did you ignore the most when you made decisions?

Forest   Fish

Elephant   Ancient   None of them

Part 3: Social-Economic Characteristics

Question 14: What is your gender?

Male Female

Question 15: Which province were you were born?

Province: ……………………………….

Question 16: What is your age?

Age: ……………. Year

Question 17: What is your marital status?

Single Not Single

Question 18: If you are not single, how many children do you have?

Number of children: …………………….... people

Question 19: What is your highest education level?

No Schooling Primary School Lower Secondary School

Upper Secondary School Bachelor Degree Master Degree

Doctoral Degree Other……………………………….

Question 20: What is your monthly income?

Income per month: ……………………………….

Question 21: What is your monthly expenditure?

Expenditure per month: …………………………

BIOGRAPHY

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