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Environmental Cost of Hydropower Development Project: Case Study from the Xaiyaburi Hydrapower Dam

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Abstract

The controversial impacts of hydropower development are still debatable. This study examines the impacts of the Xaiyaburi hydropower project constructed in the mainstream of the Mekong River in Bolikhamxay province in Lao PDR. Even though the results from cost and benefit analysis indicated that the Xaiyaburi Dam is financially feasible with a positive financial net present. Further analysis by including the opportunity cost related to environmental impacts caused by the project into consideration also shows the project is still economical 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 the economic IRR. Results of this study provides useful quantitative information for the government of Lao PDR to ensure the implementation of an environmentally friendly hydropower program.

Keywords: Cost and Benefit Analysis, Environmental Cost, Choice Experiment, Xaiyaburi hydropower project, Lao PDR

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ต้นทุนทางสิ่งแวดล้อมของโครงการพัฒนาไฟฟ้าพลังน้ำ: กรณีศึกษาจากโครงการเขื่อนไฟฟ้าพลังน้ำไซยะบุรี

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บทคัดย่อ

ผลกระทบของการพัฒนาไฟฟ้าพลังงานน้ำยังคงเป็นที่ถกเถียงกันอยู่จนถึงปัจจุบัน การศึกษาครั้งนี้ได้ทำการศึกษาผลกระทบทางสิ่งแวดล้อมของโครงการพัฒนาเขื่อนไฟฟ้าพลังงานน้ำไซยะบุรี ที่ถูกสร้างขึ้นในแม่น้ำโขงตอนล่าง ณ แขวงบอลิคำไซ ประเทศ สปป.ลาว ผลการศึกษาจากการใช้เครื่องมือการวิเคราะห์ต้นทุน และผลตอบแทนพบว่า โครงการเขื่อนไซยะบุรี มีความคุ้มค่าทางการเงินที่สามารถยอมรับได้ นอกจากนี้ เมื่อมีการคำนวณโดยใช้ต้นทุนทางสิ่งแวดล้อมเอาเข้ามาคิดคำนวณด้วยก็ยังพบว่าโครงการเขื่อนไซยะบุรีนี้ยังคงมีความคุ้มค่าทางเศรษฐศาสตร์ที่สามารถยอมรับได้ โดยโครงการดังกล่าวมีมูลค่าปัจจุบันสุทธิทางเศรษฐศาสตร์คิดเป็น 545,113,968 เหรียญสหรัฐฯ ตลอดอายุของโครงการ และมีอัตราส่วนผลตอบแทนต่อต้นทุนทางคิดเป็น 1.05 อย่างไรก็ดี โครงการฯ มีอัตราผลตอบแทนภายในทางเศรษฐศาสตร์คิดเป็น ร้อยละ 0.96 ซึ่งน้อยกว่าอัตราคิดลดที่ใช้ในการวิเคราะห์ ผลการศึกษานี้จะเป็นโยชน์แก่ผู้กำหนดนโยบายของ สปป.ลาว ในการได้รับทราบข้อมูลเชิงปริมาณที่จะช่วยในการตัดสินใจในการสร้างเขื่อนโดยนำผลกระทบของสิ่งแวดล้อมมาอยู่ในการตัดสินใจด้วยเช่นกัน

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1. Introduction (บทนำ)

Due to its limited resources of energy diversification, hydropower development seems to be an important factor for Laos's social-economic development, especially for its rural area electrification, which has a lower operation cost, is reliable, and is a clean and sustainable source of energy (NSEDP, 2015). The hydropower development in Laos started in 1971 and at the end of 2014, there were 409 hydropower plants in Laos (Ministry of Energy and Mines, 2014). Xaiyaburi hydropower plant is the first among 11 purposed dams planned to be constructed in the Lower Mekong mainstream. They are raising controversy for the public due to the concern of environmental impacts expressed by related stakeholders (Herbertson, 2011). Hydropower development would affect local inland fisheries, flood farmland, and result in the loss of nutrients for local people (Baran & Myschowoda, 2009). The aquatic ecosystem of Mekong river would be dramatically affected due to the change of water conditions (Baran, Larinier, Ziv, & Marmulla, 2011; Baran E., 2006). Also, the slow-moving water and sediments blocked the waterway (Kummu, Lu, Wang, & Varis, 2010).

The objective of this paper is to examine whether or not the Xayaburi Dam is feasible by estimating the financial and economic Cost and Benefit Analysis (CBA). The financial CBA focused on the actual payment toward the project such as construction costs, operation and maintenance costs and sales and administrative costs. The economic CBA extended the estimation into a broader area by considering the environmental impacts (opportunity costs) of the project, land loss, fish stock reduction and global warming gas emissions, referred to as used value, and opportunity costs related to willingness to pay for environmental protection by local people in Laos, referred as non-used value.

The remainder of the study is organized as follows: Section 2 explains the theoretical and literature review, Section 3 explains the methodology used in the study, and results and concluding remarks and policy recommendation are made in Section 4.

Table 1 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

Source: World Wildlife Great Mekong, 2011

2. Theoretical and Literature Review (ทฤษฎีและทบทวนวรรณกรรม)

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 piece of key information for many public projects' decision making (Mitchell & Carson, 1989). CBA estimates the total value of benefits and costs of the project in order to assist policymaker decisions on whether or not to continue 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 suggest that money is the most convenient common unit (Watkins & Alley, 2011).

Typically, economic valuation methods have 2 main categories; those are revealed preference methods and stated preference methods (Merino-Castelló, 2003). These two systems are primarily different in the data used. Where the data is based on actual behavior in existing markets, whether directly used or indirectly used, they are 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, and it also provides the opportunity for evaluating both used and non-used values. All the stated preference methods will typically be data collected 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).

The arguments about hydropower and its impacts are of increasing interest. Prior syudies, on one hand, claimed the potential of hydropower to achieve the increasing needs of electricity in many countries, which will be an 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 Laos's social-economic development such as achieving the country's electrification program and exporting electricity to the neighboring countries (Kuenzer, et al., 2013). 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 gasses (Dursun & Gokcol, 2011; Yüksel, 2008; Bird, 2012; IPCC, 2011). Furthermore, hydropower is considered the most efficient type of electricity generation and has the longest plant life, and compared to the fossil fuel plants, it is a crucial source of electricity generation, especially in developing countries. In addition, hydropower is beneficial to natural disaster reduction (IHA, 2016; KAYGUSUZ, 2004; Balat, 2006).

On the other hand, the existence of adverse environmental impacts was observed in many areas. For instance, large-scale projects of hydropower always heavily impact on elements of the ecosystem, for example, the relocation for creating large reservoirs directly affects the livelihood of the rural population (Zhai, Cui, Hu, & Zhang, 2010). These naturally lead to environmental and social costs and create public controversy about hydropower net benefit (Berkun, 2010; Commerford, 2011; Grumbine, Dore, & Xu, 2012). Methane is emitted when reservoirs are built without prior deforestation and removal, thus without oxygen, plants will decompose into Methane and Carbon dioxide (CO2) (Berkun, 2010; Commerford, 2011). Changing of land use patterns has the potential to deprive plants and animals of their natural habitat, and discontinuing the river caused by the dam's blocking could result in the reduction of habitat features (Matisoff, Bonniwell, & Whiting, 2000) or a reduction of fish biomass and population (Dugan, et al., 2010). Several important species such as the tropical asian catfish, Pangasius Kremfi, require a free flow of river water. The Mekong region's catch of 2.1 million tons annually could drop to 1.4 million tons if all proposed mainstream dams are built (Vaidyanathan, 2011).

Not only is the used value of the environment important, but the non-used value of the environment should also be taken into consideration. Over the past 10 years, there have been increasing needs for environmental valuation in the monetary term (Carpenter & Georgakakos, 2006, 2009). There are several attributes used as the measurement of environmental quality change, for instance, the change in fish population or fauna species abundance can be representative to the change of water quality or river condition (Kataria, 2009; Han, Kwak, & Yoo, 2008); the change of species richness can be a measurement of the change of forest quality or, in other words, change of their habitat condition (Kataria, 2009). In addition, 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 choice experiment (CE) depending on the characteristics of the environment being valued (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 and the results showed that 30%of people are willing to spend money for the improvement of tropical forest ecosystem; with $33 per household/year as the WTP for water quality improvement, $29 for the increasing food over cash crop garden and $11 for the improvement of gue (rattan, vine and proximity) abundance respectively (Kataria, 2009). In Ireland, people are willing to pay € 196 million for landscape improvement in Ireland (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). In the work of Sang-Yong Han et al, local people were asked to choose their preferred alternative in the choice set; the attributes of the choice set consisted of 4 environmental attributes Forest, Fauna, Flora, and Remains and there was 1 price attribute. The result showed that respondents are willing to pay for mitigating the environmental impact of large dam construction $2.12, with the range from $1.52-$2.73 or $174 million annually (Han, Kwak, & Yoo, 2008). These results are similar to Commerford, who estimated the environmental cost of the Three Gorgas Dam in Hubei province 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 and team (Nguyen, Nguyen, Do, & Tran, 2002); their estimation showed the NPV are reduced around 27% when environmental and social costs are incorporated (Commerford, 2011).

3. Methodology (วิธีการศึกษา)

Tools used in this study consisted of 3 parts, as shown in Table 2. 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 whether or not 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 of the project, land lost, fish stock reduction and CO2 emission. 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.

Table 2 Methodology

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	

3.1. Cost and Benefit Analysis

There are 2 types of cost and benefit analysis in this study, financial and economic CBA. The financial CBA focused on the actual expense occurred by the project implement, construction cost, operation and maintenance cost and selling and administration cost. The economic CBA extended the CBA analysis into broader issues by considering the opportunity costs related to land loss, fish stock reduction and global warming emission (referred to as used-value) and opportunity costs related to local peoples' willingness to pay (WTP) for environmental improvement (referred to as non-used value)

3.1.1. Present Value (PV)

Present value (PV) is the current value of the money made in the future. In our project, costs and benefits will occur in the future from the beginning until the end of the project. Hence, the discounting method is used to transfer all the Future Value (FV) into Present Value (PV). PV is approximated using equation 1:

$$PV = (FV^t)/(1 + r)^t \tag{1}$$

Where *PV* is the present value, FV^t is the future value at Year *t, r* is the real discount rate (2%), and *t* is the project's timeframe (30 years) respectively.

3.1.2. Net Present Value (NPV)

NPV is the return of investment during the total period of the project. The project is worth investing if NPV>0, not worth investing if NPV<0 and more information is required for making decision if NPV=0. NPV is approximated using equation 2:

$$NPV = \sum_{t=o}^{n}(B_t/(1+r)^t - \sum_{t=o}^{n}(C_t/(1+r)^t \tag{2}$$

Where *NPV* is the net present value of the project, B_t is the benefit of the project at year t, *Ct* is ùost of the project at year t, *r* is real discount rate (2%) and *t* is the project period (30 years) respectively.

3.1.3. Internal Rate of Return (IRR)

IRR is the rate of return that the project is expected to generate annually. The project is worth investing if IRR>r, not worth investing if IRR<r and more information is required for making a decision if IRR=r. IRR is approximated using equation 3:

$$IRR = \sum_{t=o}^{n}(B_t/(1+r)^t - \sum_{t=o}^{n}(C_t/(1+r)^t = 0; or$$
$$IRR = \sum_{t=o}^{n}(B_t/(1+r)^t = \sum_{t=o}^{n}(C_t/(1+r)^t \tag{3}$$

Where *IRR* is internal rate of return, B_t is the Benefit of the project at year t, C_t is the cost of the project at year t, *r* is the real discount rate and t is the project period (30 years) respectively.

3.1.4. Benefit-Cost Ratio (B/C)

B/C is the ratio between the benefit and cost of the project. It shows the benefit gained per cost invested. The project is worth investing if B/C>1, not worth investing if B/C<1 and more information is required for making a decision if B/C=1. B/C ratio is approximated using equation 4:

$$\mathrm{B}/C = \frac{\sum_{t=o}^{n}(B_t/(1+r)^t}{\sum_{t=o}^{n}(C_t/(1+r)^t} \quad (4)$$

Where *B/C* is the benefit gained per cost invested, *Bt* is the Present value of the benefit at year t, C_t is the Present value of Cost at year t, C_0 is the Cost of the project at year 0, *r* is the Real Discount rate and *t* is he project period (30 years) respectively.

3.1.5. Senility Analysis

Sensitivity analysis refers to an analysis of the sensitivity of NPV to given variables. In this study, the sensitivity analysis is conducted by using 3 following variables that are expected to impact the value of NPV most, reduction of the total income, increase of the carbon tax and increasing of the O&M cost.

3.1.6. Switching Value

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

1) SVT_C is the changed value that made the NPV equal to zero and B/C ratio equal to 1. SVT_C is approximated using equation 5:

$$SVT_C = (NPV/PVC) \times 100 \quad (5)$$

Where SVTC is the switch value test of cost, NPV is the net present value and PVC is the present value of cost respectively.

2) SVT_B is the changed value that made the NPV equal to zero and B/C ratio equal to 1. SVT_B is approximated using equation 6:

$$SVT_B = (NPV/PVB) \times 100 \tag{6}$$

Where SVT_B is the switch value test of benefit, *NPV* is the net present value and *PVB* is the present value of benefit respectively.

3.2. The Cost and Benefit Calculation

3.2.1. Financial CBA

Benefit of the project totally comes from electricity sales to the Electricity Generating Authority of Thailand (EGAT) and to Electricite du Laos (EDL). Financial benefit is approximated using equation 7:

$$B = (P_{EGAT} * q_{EGAT} * t) + (P_{EDL} * q_{EDL} * t) \tag{7}$$

P_{EGAT} and q_{EGAT} is used for electricity's price and quantity sold to EGAT, P_{EDL} and q_{EDL} stand for electricity's price and quantity selling to EDL and *t* stands for time period.

The amount of electricity production is obtained from the Xaiyaburi Feasibility Study, which estimated to generate 7,406 GWh per year. The estimation of OptAsia (OptAsia, 2018), 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.

Total financial cost is combined with Construction Cost (C_{Cons}), Operation and Management Cost ($C_{O\&M}$) and Selling and Administration Cost ($C_{S\&A}$). Total financial cost is approximated using equation 8:

$$C_{Total} = C_{Cons} + C_{O\&M} + C_{S\&A} \tag{8}$$

The project is expected to burden PV $3,800,000,000 as construction cost, PV $762,085,591 as O&M cost and PV $324,319,051 as selling and administration cost respectively.

In conclusion, the Xayaburi hydropower project is expected to earn a financial net present value (FNPV) of $5,797,169,153, yield 8.26% of financial internal rate of return (FIRR) and is expected to earn $2.18 for $1 spent respectively (Table 3).

Table 3 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

3.2.2. Economic CBA

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 to Electricite du Laos (EDL). However, on the cost side, we included the costs related to environmental impacts caused by the project into consideration.

Total economic benefit is similar to financial benefit because the main objective of the Xaiyaburi Dam is to produce electricity. Economic benefit is approximated using equation 9:

$$B = (P_{EGAT} * q_{EGAT} * t) + (P_{EDL} * q_{EDL} * t) \quad (9)$$

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 respectively.

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.

There are 2 sources of total economic cost, actual cost actually paid by the project (it is referred as financial cost) and opportunity cost or the cost related to environmental impacts caused by the project. Total cost is approximated using equation 10:

$$C_{Total} = C_{Actual} + C_{Oppor} \quad (10)$$

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

Actual Cost consisted of Construction Cost (C_{Cons}), Operation and Management Cost $(C_{O\&M})$ and Selling and Administration Cost $(C_{S\&A})$; Actual Cost is approximated using equation 11:

$$C_{Actual} = C_{Cons} + C_{O\&M} \quad (11)$$

In addition, the Opportunity cost related to environmental impacts caused by Xaiyaburi Dam was expressed in both used and non-used value of environment. The Used value was approximated using equations 12 – 20:

$$C_{Oppor} = C_{Used} + C_{Non-used} \quad (12)$$

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

Used value of environmental cost consists of opportunity cost related to land lost (C_{Land}), fish stock reduction (C_{Fish}) and cost related to CO_2 emission.

$$C_{Used} = C_{Land} + C_{Fish} + C_{CO_2} \quad (13)$$

1) 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. Assuming that P_{Land} is the price of land used as reservoir, X_i is the area of the reservoir and t_i is the time or period of the project. Opportunity cost related to land lost is approximated using equation 14:

$$C_{Land} = P_{Land} * X_i * t_i \quad (14)$$

The area of the reservoir of Xayaburi Dam is 42 Km^2 above the construction site, while the price of the forest is $1,095 per hectare per year obtained from the results of a previous study on valuing the Non-Timber Forest Products (NTFP) in Bolikhamsai Province, Lao PDR, (Roderick, 2009). The value was adjusted by using the inflation rate in 2015 (base year) and increased from $1,095 to 1,258 per hectare per year. The opportunity cost related to land loss caused by the project is PV $138,058,124 in the project's lifetime.

2) Opportunity Cost related to Fish Stock Reduction

The opportunity cost related to fish stock reduction is approximated using equation 15:

$$C_{Fish} = (P_{Fish} - L_{Fish}) * Q_{Fish} * t_i \quad (15)$$

Where C_{Fish} is the cost of fish stock reduction, P_{Fish} is the average price of fish per kilogram, L_{Fish} is the fisherman's operation cost, Q_{Fish} is the quantity of reduced fish and t_i is the project's lifetime.

According to the report of the Mekong River Commission (MRC), it is estimated that if the scenario of 11 dams in the mainstream of LMB were in place, the loss of fish resources in LMB is estimated to be reduced by approximately 340,000 tons (MRC, 2010). However, the proportion of Xayaburi Dam's catchment area is 42 Km^2 which is equal to 0.0062% of the total catchment area in the Mekong River. Therefore, the amount of fish stock reduction caused by Xayaburi Dam is approximately 20.96 tons per year. The price of the Mekong fish is the average fish price deducted by the fisherman's operation cost. The final calculation of the Cost of Fishery Reduction is $23,042 per year or PV $516,051 in the project's lifetime.

3) Opportunity Cost related to CO_2 Emissions

The chemical reaction of anaerobic decomposition is

$$C_6H_{12}O_6 = 3CO_2 + 3CH_4 \tag{16}$$

Glucose $(C_6 H_{12} O_6)$ will be decomposed to carbon dioxide (CO_2) and methane (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). 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 tons per hectare (t/ha) or 14.66 Kg/m^2 (Vaidyanathan, 2011). The Northern Woodland Organization indicated that 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 based on the area of the reservoir, X Km^2. Hence, the calculation of the amount of carbon equivalent can be performed as in Equation 17:

$$CO_2 = X * 10^6 m^2 * 14.66 KgC/m^2 \tag{17}$$

CO_2 and CH_4 will equally contribute in CO_2 Equivalent;

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

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 can be calculated as seen in Equation 19:

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

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

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

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 CH4 respectively. This study used the price from CO2 closing price of International Emissions Trading Association in 2015 (IETA, 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's lifetime.

4) Opportunity Cost related to WTP for Environmental Improvement

4.1) Random Utility Model

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). Total utility of respondent i from choosing alternative *j* can be expressed as;

$$U_{ij} = V_{ij} + e_{ij} \quad (21)$$

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

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

Equation 22 states that respondent *i* will choose alternative *j* over all other alternatives if the sum of observable and unobservable utility from alternative *j* is greater than the sum of observable and unobservable utility from other alternatives (*k*) in the choice set C_i.

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

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

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

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

The alternative numbers, variables of attributes and social-economics in the utility function are represented by j, k, and p respectively. β 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 be equal to one for the j^{th} alternative and zero for otherwise. These are referred to as alternative-specific constants (ASCs), which provide a zero mean for unobserved utility and causes the average probability over the sample for each alternative to be equal to the proportion of respondents 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 be unaffected by additional 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 Hanemann (Adamowicz, Louviere, & Williams, 1994).

$$WTP = 1/\mu^1 [ln \sum_{j \in C_i} e^{v_{i1}} - ln \sum_{j \in C_i} e^{v_{i0}}] \quad (25)$$

Where μ^1 is the marginal utility of income, v_{i0} and $vi1$ represent the utility before and after the change, and C_i is the policy-relevant choice set presented to the i^th respondent. In choice experiments, the coefficient of the price attribute is taken as an estimate of μ^1. Changing of 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 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, equation 25 can be reduced to

$$W = MWTP = 1/\mu^1[ln(e^{v_{i_1}}) - ln(e^{v_{i_0}})] \qquad (26)$$
$$= 1/\mu^1[v_{i_1} - v_{i_0}] = \beta_k/\beta_{Cost}$$

- ***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 4, four environmental attributes and one price variable are (1) Forest represented to the incremental amount of the protected forests area, (2) Fish represented to the incremental number of protected or endangered Aquatic-Fauna species, (3) Elephants represented the number of protected wild elephants and (4) Ancient represented the ancient protection program. 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 in this model to examine effects of those social-economic characteristics on their decision making (Table 4).

Table 4 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 elephants (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)

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

- ***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-votes are true zeros or protests. The set of statements is presented in Table 5.

Table 5 Statements used to identify protest bids

Follow-up question	Considered as Protest
I prefer if there is no initiative for environmental improvement strategy undertaken.	Yes
I support the environmental improvement strategy, but could not afford for the cost.	No
I support the environmental improvement strategy, but object to pay for it.	Yes
I support the environmental improvement strategy, but I have already paid a very high price for my electricity rate.	Yes
I support the environmental improvement strategy, but I don't think this project will benefit environmental 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

- ***The Choice Set***

Environmental attributes variables were specified at 4 levels, one status quo of environmental condition and other 3 levels show the states of improvement. Ancient attribute variable is a dummy variable, 0 stands for 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 monthly electricity bill increments (Table 6).

Table 6 Attributes and level used in CE

Attributes	Definition (Unit)	Levels
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 Elephant)	0^b, 10, 15, 20
Ancient	The ancient protection programs	0^b = No, 1 = Yes
Cost	The additional monthly electricity rate (USD/month)	0^b, 1, 3, 5

^{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 to ask the respondent to choose among all combinations, a subset of all possible choice sets was randomly drawn by using 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 low cost and vice versa). The results show that there are 48 versions of the choices 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.

- ***Questionnaire design***

Our questionnaire consists 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 the 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 7 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
Elephant	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

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

- ***Data Coding***

We used average coding in our study by generating L-1 variables for each attribute including ForestG, ForestB and ForestBe indicating the increasing number of forests from 0-10 Km^2, 0-20 Km^2 and 0-30 Km^2 respectively. FishG, FishB and FishBe indicated the increasing number of fish species from 0-15 species, 0-25 species and 0-35 species respectively. ElephantG, ElephantB, and ElephantBe indicated the increasing number of wild elephants from 0-10 elephants, 0-15 elephants and 0-20 elephants respectively. AncientG refers to the ancient protection program included in the choice.

- ***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;

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

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-economic characteristics and environmental attributes to their decision making by including the following interaction terms into the models;

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

- **Data**

The data used in the CE estimation came from on-field surveys at the Southern bus station, Northern bus station, and Wattai International Airport.

- **CE results**

1) Descriptive Analysis

A result of the completed 411 person-to-person interviews of each individual response to the twelve choices yielded a total of 4,932 observations. Table 8 shows the socio-economic characteristics of respondents. The number of male respondents is 47.69%. The average age is 28.24 years and the youngest respondent was 20 while the oldest was 50. Average household net income is $196.52 per month and the average number of children of respondent is 1.51.

Table 8 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

- **Protest bid identification**

Using follow-up questions allow us to identify the reasons behind the responses and, hence, we can classify protest bidders. In the overall sample, we found 3.16% of respondents always choose the status-quo for 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 paying for it and 46.15% supported the environmental improvement strategy, but they don't think this project will benefit environment conservation.

Two classifications were attempted in order to investigate the impact of protest bids on our model. Firstly, protest bids were treated as true zero and included in the dataset. Second, protest bids were differentiated and excluded from the dataset.

- **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 problem between variables. Table 9 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 *t-statistic*, coefficient of Fishbetter, Fishbest and Elephantbetter and Ancient attributes are positively highly significant. On the contrary, the coefficient on price attributes is significantly negative.

In the model with interaction, coefficient of Forestgood, Fishbetter, Fishbest, Elephantbetter and Ancient attributes are positively significant. Conversely, the coefficient on price attribute is significantly negative.

In the interaction terms, we found no relationship respondent's social-economic characteristics and their utility except for the income to protected fish species and ancient protection program attributes.

Table 9 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
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.

- **Multinomial Logistics model per treatment of protest**

Table 10 presented the results of the multinomial logistics model per treatment of protests. Similar to the model with 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 Fishbetter, Fishbest, Elephantbetter and Ancient attributes are positively highly significant, while the coefficient on price attributes is significantly negative.

In the model with interaction, coefficient of Forestgood, Fishbetter, Fishbest, Elephantbetter and Ancient attributes are positively significant. Conversely, the coefficient on price attributes is significantly negative.

In addition, we found no relationship respondent's social-economic characteristics and their utility except for the income to protected fish species and ancient protection program attributes.

Even though both models presented similar results in terms of environmental attribute significance, we found that the model per treatment of 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 10 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
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 MNL analysis is to elicit the Marginal Willingness to Pay (MWTP) from our model (model per treatment of protests). MWTP is equivalent to calculating the ratio of marginal utilities for the attribute in question and the price attribute as shown in Table 11.

Table 11 Marginal Willingness to Pay Estimation

Attribute\level	Average	Good	Better	Best
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

We now can elicit the WTP for changing environmental attributes from status-quo to the highest level. WTP for increasing protected forest from average to good level is $1.3309; WTP for increasing of protected fish species from average to better level is $2.7978; WTP for increasing of protected wild elephants from average to better level is $1.7531; and WTP for having ancient protection programs included into the choice is $1.9628 respectively. 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 the opportunity cost related to local people WTP was calculated by multiplying WTP with 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 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 positive 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 the opportunity cost related to the 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, 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 0.96% which is less than the discount rate (2%).

Table 12 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
ENPV		$545,113,968
EIRR		0.96%
EB/C Ratio		1.538

Sensitivity Analysis

The purpose of the last part of this study is to conduct a 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. The results in Table 15 indicated the relationship between the NPV and the change of the above variables. While other factors remain the same, there is an expected 10% decrease in the project's benefit, which will decrease the project's benefit from $10,683,573,795 to $9,615,216,416, reduce the value of the 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 the 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 of each factor input and found that the change in benefit is the most sensitive while changing the carbon tax and the O&M Cost is the second and the third most changed benefits respectively. Changing 10% of the benefit reduced the value of NPV by 195.99% or 19.59 times, while a 10% change in the carbon tax reduced NPV by 50.63% or 5.06 times and a 10% change in the O&M Cost reduced 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 benefit or cost to make the NPV value of the project become zero. On the one hand, the project can burden the reduction of benefit at a maximum of 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 13 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
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 14 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 15 Sensitivity Analysis Table

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

4 Conclusion (บทสรุป)

This paper extended the scope of a feasibility study to cover the non-used value of environmental attributes. The findings in the MNL model indicated the problem of including protest bids into 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 (Barrio & Loureiro, 2011).

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

Also, the net income of respondents is the only social economic characteristic that has a 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, and 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 claimed the positive NPV and B/C ratio is greater than 1. However, when considering the value of IRR, the IRR value of the project is less than the discount rate. Moreover, after conducting a 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 switching value.

There are several policy implications resulting from these empirical results. First, the numerical result 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 result indicated the importance of each attribute that respondents selected, and the Lao government should implement an environmental protection strategy accordingly.

Second, it is important for the Lao government to implement a wider and more detailed public hearing process to ensure it is understood by the local community and Lao citizens.

Third, even though, the Xayaburi project is both financially and economically feasible; however, due to the very high value of the sensitiveness value of income and low level of switching value in the sensitivity analysis, the Lao government should find a reliable approach to water management 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.

We encountered several limitations while conducting this study. First, there was a lack of data about sediment reduction on the local farming sector in LMB and the data of the 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 the opportunity that respondents would have ever been in Xayaburi province before the survey. Hence, the result of the WTP from the CE model could consist of a fraction of the Used Value. Lastly, respondents have no property rights over environmental resources measured in the study. Therefore, we used the WTP as the measurement of non-used environmental value in the study.

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