ECONOMIC ANALYSIS OF CLIMATE PROOFING MEASURES FOR INFRASTRUCTURES: PRELIMINARY RESULTS FROM A CASE STUDY OF CAI LON - CAI BE SLUICE GATES IN VIETNAM

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Abstract

In Vietnam's Mekong Delta, drought and salinity intrusion are among the dominant natural disasters that have a significant impact on the whole region. Cai Lon - Cai Be sluice gate system is being constructed to regulate water resources with the aim of creating stable and sustainable production conditions for agricultural land; proactively responding to climate change, sea level rise, and reducing damages caused by drought and salinity in the dry season to benefit the Ca Mau peninsula with the agricultural area of nearly 350,000 ha. However, the sluice gates can also be exposed to the climate risks which may negatively affect the functions and operation of the infrastructure. Climate proofing measures are necessary to protect the sluice gates from failure due to extreme climatic events. The application of proofing measures requires higher investment and operational cost while the benefit is in question. This paper presents preliminary results of a cost - benefit analysis of applying two climate proofing measures, which are (1) upgrading concrete for pillars and ship locks, and (2) using epoxy coating for the sluice gates. The costs of applying climate proofing measures are the increments in investment and operational costs. The investor's benefits are less repairing cost and less maintenance costs for pillars, ship locks and the *sluice gates. The social benefits also are estimated to include the avoided damages of agricultural households in the area. Using the social discount rate, the net present value (NPV) estimated for two measures are all positive. The results of benefit/cost ratio (BCR) indicate that every dollar spent on the first measure would bring benefit of 17 dollars, and each dollar spent on the second measure would result in 32.5 dollars benefit to the whole society. The results show that the two climate proofing measures for Cai Lon – Cai Be Sluice Gates are very economically efficient.*

Keywords: *cost - benefit analysis, climate proofing, Mekong Delta.*

1. Introduction

Cai Lon – Cai Be (CL-CB) Sluice Gates project is the largest sluice system being conducted in the Mekong Delta of Vietnam, with the estimated cost of VND3.3 trillion (equivalent to US$142 million) (Government of Vietnam, 2017). The main functions of the infrastructure include regulating water sources (e.g. sea water, brackish water, and fresh water), creating stable and sustainable production conditions for production models (fresh, salty - brackish, fresh - brackish alternately) for the beneficiary area with the natural area of 384,120 ha, of which land for agricultural and fishery production is 346,241 ha; combining with the west sea dyke to form a cluster of works proactively responding to climate change, sea level rise and natural disaster prevention; reducing inundation in lowlands in flood season; reducing the damage of drought and salinity intrusion in the dry season for regional production models; and supplying fresh water for domestic use and agricultural production.

However, the Mekong Delta of Vietnam is one of the world's river deltas, most vulnerable to climate change (IPCC, 2007; World Bank, 2011). With the unpredictability of climate change and its impacts, there is worrying that infrastructure projects, such as the CL-CB sluice gate project, might not hold up to its designed function for the lifespan of 100 years. Thus, the United Nations (UN) set Sustainable Development Goal (SDG) 9 to "build resilient infrastructure, promote sustainable industrialization and foster innovation". Many countries, including Vietnam, have committed to achieving this goal and have identified this in their Nationally Determined Contributions (NDCs). To address this objective, it is necessary to assess climate risks on infrastructures and (Comprehensive Climate Risk Assessment13) and analyse cost – benefit of climate proofing measures, as well as mainstreaming these tools into investment planning processes, to secure a resilient future for the country's infrastructures. While CCRAs examine the main climate and hydrological thresholds, probabilities and severity of impacts

[13] The CCRA has been based on the Canadian PIEVC protocol to assess existing and newly planned physical infrastructure in a 5 step process which can be added by a so-called triple-bottom analysis to not only assess current and future risks in relation to climate change, but to provide adaptation options. For further information refer to www.pievc.ca

posing on components of infrastructures and recommend concrete improvements to make the infrastructure more resilient towards climate change and climate variability, an economic analysis helps to ensure the best possible use and allocation of society's limited resources, a concept referred to as economic efficiency.

A climate risk assessment has been conducted for the planning phase of the CL-CB sluice gates since 2018/19 (GIZ, 2019). The CCRA results indicate that the sluice gates will be exposed to the climate parameters such as high temperature, heat wave, heavy rain, tropical storms, drought, high wind, tornadoes, and thunderstorm/lightning. High water level, salinity combined with high temperature and high-water level combined with heavy rain would affect the lifetime and the operation of the structures.

Given the role of the CL-CB Sluice Gates project, it is important to ensure that it operates stably throughout the infrastructure's life cycle against climate impacts. Measures to improve the project's resilience to climate change impacts have been recommended by CCRA, but the question is with limited resources, which measures should be applied from the society's point of view. This study was conducted to perform an economic analysis of CL-CB Sluice Gates climate proofing measures to provide information to decision makers. The analysis provides a means to identify, quantify, and wherever possible value all impacts of each option, including private impacts, which are the cost/benefits of the investor and its social impacts where relevant. The outcome of the analysis will shed light on the economic efficiency of the approved climate proofing measures in Cai Lon – Cai Be Sluice Gates Project.

The detailed objectives of this study are as follows:

1. To review the climate risk of CL-CB Sluice Gates based on Climate Risk Assessment report and the recommended climate proofing measures;
2. To identify and quantify the social cost and benefit of the recommended climate proofing measures for CL-CB sluice gate; and
3. To assess if these climate-proofing measures are socially efficient and make recommendations for the authorities.

2. Method

2.1. Study site

The scope of this study is the area of CL-CB sluice gate project, including the Cai Lon sluice, Cai Be sluice and the dike connecting the sluices to the National Highway 61 and the National Highway 63. The study area is within the Cai San canal in the North – West, Quan Lo – Phung Hiep canal in the South – East, the Hau River (the Bassac River) in the North – East and the West Sea in the West. The total area is 909,248 ha, spreading over 32 districts/cities of 6 provinces of the Mekong Delta of including: Bac Lieu, Ca Mau, Kien Giang, Hau Giang, Soc Trang and Can Tho City.

2.2. Theoretical framework

The climate proofing of infrastructure can be conceptualized from an economics standpoint as insurance against the adverse impacts of climate change (Kotchen, 2011). Determining the right amount of climate proofing requires consideration of both the costs and benefits. Based on Kotchen (2011)'s ideas, the following paragraphs present models of the costs and benefits of climate proofing measures.

- *The costs of climate proofing measure*

Climate proofing measures designed for infrastructure projects (e.g. roads, bridges, etc.) seek to reduce the vulnerability of the investments to changes in climatic conditions (e.g. increased rainfall, high-speed winds, flooding, etc.). In principle, the effectiveness of an infrastructure project can be in the range between 0 and 100 %, where 100 % means that with certainty floods or winds will not damage or destroy the infrastructure. Climate forecasts, as well as input from engineers, can be used to determine such effectiveness and the specifications need. Market valuation can be used to evaluate the direct costs of climate proofing based on the additional costs necessary to increase effectiveness.

- *The benefits of climate proofing measures*

The benefits of climate proofing measures are avoided damages to the property (e.g. structural or operational failures of infrastructures), forgone economic activity as a result of damages (e.g. electrical outages, failed bridges), effects on health and human life, and impacts on environmental services (e.g. erosion, loss of natural capacity to protect from future climate risk). Typically, these benefits are not straightforward to monetize because they are not observable through market transactions and do not have prices. Quantification of them, therefore, usually requires some form of nonmarket valuation.

The benefit and cost of implementing each measure should be adjusted with the time value for money. The introduction of time increases the complexity of the analysis because the monetary value of costs or benefits at some point in the future is not directly comparable to the same monetary value of costs or benefits today mainly due to market changes, individual preferences and inflation. Comparison of measures over time is hence achieved by discounting costs and benefits in each future time period and summing them to arrive at their net present value. The net present value is calculated in the following formula:

$$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t}$$

In which, NPV is net present value;

B_t: total social benefit in the year t;

C_t : total social cost in the year t;

r: social discount rate; and

n: project lifespan.

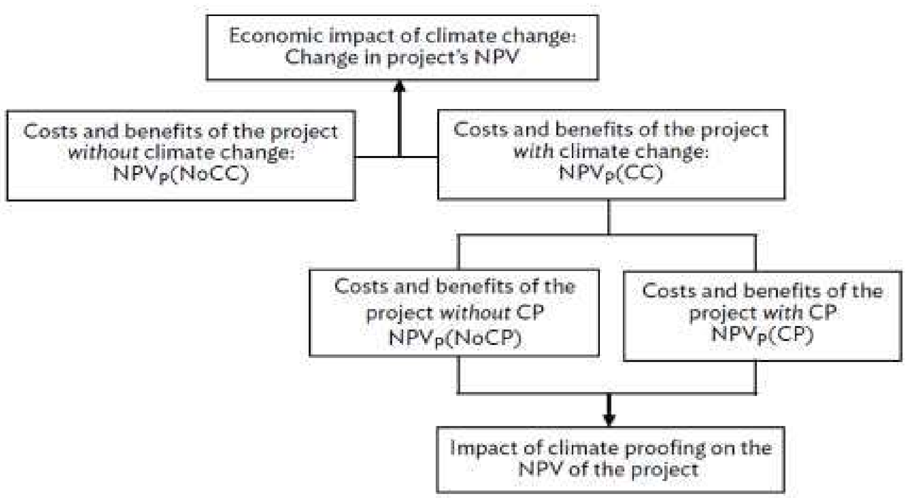
Subject to budget constraints and other considerations, and assuming that there are no alternative measures under consideration, a measure may be accepted if the sum of its discounted benefits exceeds the sum of its discounted costs; that is, where its net present value exceeds zero. Where mutually exclusive measures are under consideration (that is, where projects offer alternative solutions to a single problem), the measures which maximises net present value should be selected.

Another criterion used in CBA is the benefit/cost ratio (BCR). A benefit-cost ratio (BCR) is a ratio used in a cost-benefit analysis to summarize the overall relationship between the relative costs and benefits of a proposed measure. BCR can be expressed in monetary or qualitative terms. If a measure has a BCR greater than 1.0, it is expected to deliver a positive net present value. The formula for BCR is:

$$BCR = \frac{\sum_{t=0}^{n} B_t}{\sum_{t=0}^{n} C_t}$$

According to ADB (2015), a key objective of a cost–benefit analysis is to estimate the net benefits of climate-proofing measures. At the project level, it is important to distinguish between (i) the costs of climate change and (ii) the benefits of climate proofing. As illustrated in Figure 1, given a scenario with climate change, the impact of climate proofing is estimated as the difference between the Net Present Value (NPV) of the project without climate proofing measures (noted NPV_P(NoCP) - where CP stands for climate proofing measures) and the NPV of the project with climate proofing (NPV_P[CP]) - where NPV_P(CP) includes the cost of climate proofing measures.

Figure 5. Impact of Climate Change and of Climate Proofing measures



Source: ADB (2015)

A key feature of the approach is to recognize that the costs and benefits of the climate proofing measures must be assessed by identifying and quantifying the climate change along two scenarios:

➢ Scenario ***without adaptation***: What are the expected of climate change on the project in the future if there were to be no climate-proofing measures in place?

➢ Scenario ***with adaptation***: What are the expected of climate change on the project in the future if there were to be climate-proofing measures in place?

2.3. Data collection

Data for analysis was collected from primary and secondary sources. The secondary data includes the climate risks and their impacts on CL-CB sluice gates as well as on production and properties of residents in Kien Giang provinces; the possible climate proofing measures that can be undertaken; and the additional cost and avoided cost of applying climate proofing measures. They were collected from Kien Giang's General Statistics Office; Kien Giang People's Committees and the Water Resources Investment and Construction Board 10 (PMU10 - the investor). Data on climate risk and its impact were collected through technical reports and interviews with experts from the Southern Institute for Water Resources and Planning (SIWRP) and GIZ on climate risk assessment.

Primary data includes the damages caused by climate change on economic activities when the climate proofing measures are undertaken. In-depth interviews and discussion were conducted with 13 officials, 6 farming households to collect information and opinions on the costs and benefits of sluice gates, production costs and benefits of different farming models and the climate proofing measures for sluice gates. Based on this information, the questionnaire was designed and surveyed by face-to-face interview.

The survey areas include rice farms and shrimp-rice farms. For comparative analysis purpose, the survey focused on the farms within the protected area of CL-CB sluice gates (in Binh An Commune, Minh Hoa Commune of Chau Thanh District and in Hung Yen Commune, Dong Yen Commune of An Bien District) and also the farms outside of the beneficiary area of CL-CB sluice gates (in Binh Giang Commune, Linh Huynh Commune and Son Binh Commune of Hon Dat District. The survey had a total of 213 respondents, consisting of 50 rice farming households and 55 shrimp-rice farming households in the protected area of CL-CB sluice gates and 70 rice farming households and 38 shrimp-rice farming households outside of the protected area of CL-CB sluice gates.

2.4. General assumptions for the economic analysis

Time-horizon

The time-horizon of the evaluation is directly linked to the discount rate. The horizon depends on the lifespan of the options under consideration. The lifespan of CL-CB is expected to be 100 years, which is based on the design of the physical structures (cast-in-situ concrete composition).

Social discount rate

Boardman et al. (2014) suggested that a declining discount rate should be used in long-time project They defined an intragenerational projects as one whose effects occur within a 50-year horizon. Projects with significant effects beyond 50 years are considered intergenerational. They also suggested a social discount rate of 3.5% from year 0 to year 50 and 2.5% from year 50 to year 100. However, the rate of 3.5% is relevant for developed countries. The social discount rate for developing countries should be higher as it ought to incorporate a higher risk premium. In Vietnam, the interest rate of 30-year government bond is 3-4%. The interest rate of social housing loan is 4.8%. Thus, in this analysis, the social discount rate is chosen at 5% for the year 0 to year 50 and 2.5% from the year 50 to year 100.

Exchange rate

The exchange rate used in this report is the average daily central rate of VND versus USD quoted by the State Bank of Vietnam in 2021, which is 23.180.

3. Results

3.1. Economic analysis of the climate proofing measure of upgrading concrete for pillars and ship locks

In order to adapt to the increasing risk due to exposure to high temperature, heat waves and salinity intrusion to pillars and ship locks, the CRA analysis suggested to upgrade the concrete of pillars and ship locks from grade M300 (in the 1st preliminary design) to grade M500 with sulphate resistant cement and anti-corrosion additive mixture. This suggestion has been considered and in fact, the climate proofing measure has turned out as follows:

- M300 concrete was upgraded to M400 concrete (for the pile parts deep below the ground);
- M300 concrete was upgraded to M400 concrete with sulphate resistant and anti-corrosion additive mixture (for the parts in contact with sea water/at risk of corrosion);

Our economic analysis then examines the according actual costs and benefits of the climate proofing measure of CL-CB sluice gates.

Firstly, the according costs can be identified as follows:

- Increased cost to upgrade from M300 concrete to M400 concrete;

- Increased cost to upgrade from M300 concrete to M400 concrete with sulphate resistant and anti-corrosion additive mixture (12 pillars of Cai Lon and Cai Lon ship lock and 3 pillars of Cai Be + Cai Be ship lock).

The increased costs are calculated based on the amount of upgraded concrete, the upgrade level (from M300 to M400, from M300 to M400 with sulphate resistant and anti-corrosion additive mixture), and the prices of different concretes (**Table 1**).

Table 8: Cost identification of upgrading concrete for pillars and ship locks

Item	Cai Lon Sluice Gate	Cai Be Sluice Gate
Amount of M300 concrete updated to M400 concrete (in tons)	11,000	2,200
For the Pillars: Amount of M300 concrete updated to M400 concrete with sulphate resistant and anti-corrosion additive mixture (in tons)	66,000	13,500
For the Ship locks: Amount of M300 concrete updated to M400 concrete with sulphate resistant and anti-corrosion additive mixture (in tons)	20,000	12,500
Price of M300 concrete (VND/ton)	780,000	
Price of M400 concrete (VND/ton)	940,000	
Price of M400 concrete with sulphate resistant and anti-corrosion additive mixture (VND/ton)	1,204,000	
Cost increase (VND)	**49,600,000,000**	
Cost increase (USD)	**2,139,775.6**	

Secondly, the investor's according benefits of the climate proofing measure are identified as follows:

- Benefit from higher endurance to climate risk: less repairing cost for pillars and ship locks during a 100 years' time horizon.
- Benefit from increased expected lifespan: less cost of replacement for pillars and ship locks during a 100 years' time horizon.

In terms of the benefit from increased expected lifespan, our expert consultations (using questionnaire) resulted that the average increase is 21 years, meaning, pillars and ship locks and last 71 years (instead of 50 years) with the upgradation.

In addition, the benefit from higher endurance to climate risk is measured based on the saving of maintenance cost (or sometime called repairing cost). This saving is estimated according to the maintenance cost and the probability of such cost occurs.

- Since the maintenance cost was not identified in the design of CL-CB sluice gates. This cost is expected to be estimated by the management board when needed (after the construction finished), which is very common in the region. In fact, Circular No. 03/2017/TT-BXD on Guideline for determination of costs of maintenance of construction works set the standard maintenance cost from 0.18 to 0.25% of the total investment. In order to avoid over-estimation of the saving, we chose 0.18 % for our calculation.
- The probability of occurring maintenance cost is, in fact, equivalent to the percentage change in risk scores (R) in PIEVC analysis, which reflects how vulnerable a component of CL-CB sluice gate system would be due to effects of climate factors (e.g. heat wave, high temperature, salinity intrusion). According to the formula (R = P*S), R scores take into account both probability (P) of climate extreme occurrence and the severity (S) of impacts associated with individual climatic factor. It is also noteworthy that the application of adaptation measures (including the concrete upgradation) is expected to reduce S but not P. In our calculation, when an adaptation measure is applied, the decrease in the probability of repairing cost occurs is measured as the percentage decrease in R scores from future levels to baseline levels. Accordingly, the average reduction of risk score Δ R is estimated at 2.05% (**Table 2**).

Table 9: The percentage change in risk scores (R) for pillars and ship lock

Climate factor	**Risk Baseline (R0)[a]**	**Risk Future (R1)[a]**	**Standardized[b] change in R: [(R1-R0)/R0]/49**
Pillars			
Heat wave (≥ 8 consecutive days with temperature ≥35°C)	6	12	2.04%
Water level (0.9m)	7	14	2.04%
Salinity (3g/l)	7	14	2.04%
Salinity intrusion + high temperature (Salinity = 3g/l and high temperature ≥ 35°C)	12	20	1.36%

Climate factor	Risk Baseline (R0)[a]	Risk Future (R1)[a]	Standardized[b] change in R: [(R1-R0)/R0]/49
High water level + heavy rain (Water level ≥ 0.9m and heavy rain ≥ 100mm/day)	4	8	2.04%
		Average ΔR of Pillars	**1.90%**
Ship lock			
Lock chamber			
Heat wave (≥ 8 consecutive days with temperature ≥35°C)	3	8	3.40%
Water level (0.9m)	21	28	0.68%
Salinity (3g/l)	7	14	2.04%
Salinity intrusion + high temperature (Salinity = 3g/l and high temperature ≥ 35°C)	12	20	1.36%
High water level + heavy rain (Water level ≥ 0.9m and heavy rain ≥ 100mm/day)	8	20	3.06%
Lock head			
Heat wave (≥ 8 consecutive days with temperature ≥35°C)	3	8	3.40%
Water level (0.9m)	21	28	0.68%
Salinity (3g/l)	7	14	2.04%
Salinity intrusion + high temperature (Salinity = 3g/l and high temperature ≥ 35°C)	12	20	1.36%
High water level + heavy rain (Water level ≥ 0.9m and heavy rain ≥ 100mm/day)	8	20	3.06%
Filling and discharge culverts			
Heat wave (≥ 8 consecutive days with temperature ≥35°C)	3	8	3.40%
Salinity (3g/l)	7	14	2.04%
Salinity intrusion + high temperature (Salinity = 3g/l and high temperature ≥ 35°C)	8	15	1.79%

Climate factor	Risk Baseline (R0)[a]	Risk Future (R1)[a]	Standardized[b] change in R: [(R1-R0)/R0]/49
Leading jetty			
Heat wave (≥ 8 consecutive days with temperature ≥35oC)	3	8	3.40%
Salinity (3g/l)	7	14	2.04%
Salinity intrusion + high temperature (Salinity = 3g/l and high temperature ≥ 35ºC)	12	20	1.36%
Average ΔR of Ship lock			**2.19%**
Average ΔR of Pillars and Ship lock			**2.05%**

[a] Risk score R = P*S, where P: probability of climate extreme occurrence; S: severity of impacts associated with individual climatic factor. The values of P and S were collected from the climate risk assessment results for the planning phase of the CL-CB sluice gates (GIZ, 2019).

[b] Standardized change in R is calculated based on dividing by 49 because both P and S scores are based on the scale of 1 to 7

Increasing the climate-resilience of the sluice gates would also benefit the agricultural production households in the project area. Thanks to the climate proofing measures, the CL-CB sluice gates are resilient enough to work stably, creating favourable conditions for agricultural production households in the project area. The climate proofing measures are to avoid damages because of inadequate water availability for agricultural production when the sluice gates fail due to extreme weather and climate induced hazards. The avoided damage estimate is based on the average household income lost during salinity intrusion.

For rice farming households, the average revenue and cost per hectare per year are shown in the Table 3. The survey shows that the largest percentage of loss that the households have faced in recent years due to salinity intrusion is 35% on average. Taking this as the maximum level and considering the minimum level as 0%, that is, people fully adapt to salinity intrusion by, the average loss is 17.5%. Thus, thanks to the CL-CB sluice, an average of one hectare of production by rice growers will avoid losses of VND 12,474,836. Using the average reduction in risk score Δ R estimated at 2.05% above, the application of climate change adaptation measures for CL-CB project will help rice growers avoid losses. The avoided losses is estimated at 255,734 VND/ha/year (= 12,474,836 x

2.05%) or USD11/ha/year. It is noteworthy to remember that the benefit value of 255,734 VND/ha/year is the benefit of climate proofing measure for CL-CB sluice gates and is not the benefit of the whole CL-CB sluice gate.

Similarly, with shrimp - rice production households, the survey shows that largest percentage of loss that the households have faced in recent years due to salinity intrusion is 26% on average. Taking this as the maximum level and considering the minimum level as 0%, the average loss is 13%. It is notable that the loss reported by the households is for the income from rice crop. With the same calculation method as mentioned above, the application of climate change adaptation measures for the CL-CB project will help shrimp-rice farming households avoid the potential damage of 152,836 VND/ha/year or USD 6.6/ha/year.

Table 10: Benefit of climate proofing measures for rice farming households

Items	Value (VND/hectare)
Annual revenue	71,797,619
Annual cost	28,539,286
The highest loss (in percentage) in recent years due to salinity intrusion	35%
Average loss (in percentage)	17.5%
Decrease in net income due to salinity intrusion or benefit of the Sluice Gates	12,474,836 (17.5% of annual revenue)
Average ΔR	2.05%
Benefit of climate proofing measures	255,734

Table 11: Benefit of climate proofing measures for shrimp-rice farming households

Items	Value (VND/hectare)
Annual revenue	143,174,793
Annual cost	40,535.256
The highest loss (in percentage) in recent years due to salinity intrusion	26%
Average loss (in percentage)	13%

Decrease in net income due to salinity intrusion or benefit of the Sluice Gates	7,455,392
Average ΔR	2.05%
Benefit of climate proofing measures	152,836

According to the Feasibility Study of CL-CB Sluice Gates, the areas affected by drought and salinity intrusion are as follows: Kien Giang province: 65,679 ha of rice crop; Ca Mau province: 35,221 ha of shrimp-rice crop and 14,121 ha of rice crop; Hau Giang province: Total area of damage is 1,203 ha of rice crop; Bac Lieu province: 8,057 ha of shrimp-rice crop and 3,326ha of rice crop; and Soc Trang province: 13,565 ha of rice crop. Using this information and assuming that the provinces near CL-CB including Kien Giang and Ca Mau would suffer the average percentage of loss which is calculated above and the other provinces (Hau Giang, Bac Lieu and Soc Trang) would suffer half of the average percentage of loss, the annual avoided damage of climate proofing measures in CL-CB Sluice Gates is VND 28,719,930,019 or USD 1,238,951.58.

Applying NPV formula with the discount rate as discussed and the original year of 2020, the Present value of the benefit is estimated at VND 843,011,971,718.12 or USD 36,366,767.30.

Recall the cost of VND 49.6 billion or USD 2.14 million, the NPV of the adaptation measure (concrete upgradation for pillars and ship locks) is then estimated at VND 793,411,971,718.12 or USD 34,227,068.56 for the 100 years' time horizon. Comparing to the investor's benefit which is VND 23.6 billion (USD 1.133 million), the society's net benefit is much larger as the benefit of more than 100,000 households in the project area is counted in this analysis. The benefit/cost ratio (BCR) also increases from 1.52 to 17, meaning that every dollar spent on climate proofing would bring 17 dollars benefit to the whole society. This implies that such adaptation measure is economically beneficial from both investor and society's point of view.

Table 12: Benefit identification of upgrading concrete for pillars and ship locks

	Sum value of CL – CB (VND)
PV of maintenance cost saving due to adaptation	435,398,250.65
Cost of replacement in BAU scenario	441,768,000,000*
PV of cost of replacement in BAU scenario	131,742,181,271.2
Cost of replacement in adaptation scenario	441,768,00,000**
PV of cost of replacement in adaptation scenario	78,437,487,979.17

PV of benefits of increase the lifetime of concrete structure	**53,304,693,292.02**
Residual value of adaptation scenario	261,327,549,295.775***
PV of residual value	**22,120,689,335.18**
Annual households' avoided damage in adaptation scenario	28,719,930,019
PV of households' avoided damage in adaptation scenario	**767,151,190,840.28**

*Note: * cost occurs in 50th year; ** cost occurs in 71st year; *** residual value in 100th year*

Another approach to estimate the climate proofing measures' benefit for the agricultural households is using Willingness to Pay (WTP). WTP is a relevant measure of benefit that a good or service brings to the consumers when there is no market for such good/service. The very first estimation of WTP of agricultural households for a better sluice gates system in the project area is VND500,000/hectare or USD21.6/hectare for one year. Using the affected area of salinity intrusion in the Feasibility Study which is 141,172 in total, we can estimate the total WTP or the benefit of a better sluice gate system for the society is VND 57,510,500,000 per year. Then the total PV of benefit would be VND 1,612,050,058,898.29 (USD 69,542,369). With the cost stays the same at VND 49.6 billion, NPV of the adaptation measure (concrete upgrade for pillars and ship locks) is VND 1,562,450,058,898.29, equivalent to USD 67,402,669.97. In this estimation, the BCR is much higher at 32.5, meaning that every dollar spent on climate proofing would bring 32.5 dollars benefit to the whole society. This approach brings higher results because measuring benefit by WTP would capture both use value and non-use value of the sluice gates.

3.2. Economic analysis of the measure of using epoxy coating for the sluice gates

Based on climate risk assessment, the lift gate type was recommended for the design of both Cai Lon and Cai Be sluice gates. The primary duty of this infrastructure component is to control salinity intrusion. The sluice gate will be installed on the sluice gate structure and the gate(s) move up and down vertically along hydraulic cylinders. The three main components of the sluice gate are the gates, watertight gaskets and bolts. As the gates are closed (i.e., they are under water), they may be affected by water pressure (due to water level differences), flow velocity (obstructing the operation), sediment and salinity intrusion (increasing the corrosion). On the other hand, when opened (the gates are hanging), they are likely to be affected by high wind, heavy rain, storms and lightning. Water level affects the function of the sluice if overflowing, and its stability if the water level difference between front and back of the sluice is large. In addition, the water level also indirectly causes physical and chemical corrosion.

Study of mechanisms and causes of metal corrosion in the Mekong Delta showed that the suitable prevention measure is using a stainless steel together with coating method by epoxy.

Economic benefit of using epoxy coating for the sluice gates

Using coating method by epoxy will increase the corrosive-proof properties of the gates, thus increase the lifespan of the sluice gates. Results from interviewing the engineers participated in the climate risk assessment process of CL_-CB project showed that with the normal coating method (i.e. without the climate proofing measure) .e., the duration of the sluice gates is usually 15-20 years. Ackermann (1998) found that in the salty water, normal coatings may last the duration of steel structure to 10–15 years. To avoid overestimating the benefit, the upper value of 20 years is chosen as the lifespan of the sluice gates in the BAU scenario (without adaptation measure), or the sluice gates would be replaced 4 times during the operation of the whole CL-CB works (100 years).

If epoxy coating method is applied, the lifespan of the sluice gates will be longer. Bleile and Rodgers (2001) estimated that the lifespan of the steel with correct coatings would be 20 years. Our expert consultation indicates that with the special materials of the sluice gates (S355R which contains stainless steel, nickel and chromium) the sluice gates in CL-CB project can be used 30 to 40 years before replacement. For the same reason of avoiding overestimating the benefit, we assumed that the lifespan of the sluice gates with climate proofing measure would be 30 years. Therefore, in 100 years, the sluice gates will be replaced 3 times. The first benefit of using epoxy coating for the sluice gates is cost saving, which is the difference in the present value (PV) of replacement cost in BAU scenario and the PV of replacement cost in adaptation scenario.

The cost of replacement of sluice gates is estimated by the investor, PMU10, at VND 250 billion. In BAU scenario, the PV of replacement cost is VND 221,230,830,628.69 while the PV of replacement cost in adaptation scenario is VND 141,754,206,127.46. Then the value of the first benefit is VND 79,476,624,501.24, which is equivalent to USD 3,428,549.

The second benefit is cost saving due to expanding the lifetime of the coating. Using normal coating required that the sluice gates must be repainted every 3 years and in the year of replacement. The cost of normal coating includes cost of two layers of anti-rust coating and cost of one layer of surface coating. This cost which would be incur every 3 years and in the year of replacement in 100 years if no adaptation measure is applied will be discounted to present to calculate the savings.

The prices of anti-rust coating and surface coating were collected from the quotations of different suppliers in the market. The total amount of paint for in CL-CB sluice gates was estimated by the PMU10 as 35,000 liters, of which 3,889 liters would be used for surface coating and the remaining 31,111 liters would be used for anti-rust coating. PV of cost saving is VND 28,858,915,787.83 (USD 1,244,947).

Therefore, the PV of total benefit of using epoxy coating for the sluice gates is VND 108,335,540,289.07 or USD 4,673,296.

Table 13: The cost of coating the sluice gates in Cai Lon – Cai Be in one year

Item	Value (VND)
Unit price of normal surface coating (VND/liter)	109,437.44
Amount of paint used for surface coating (liter)	3,889
Unit price of normal anti-rust coating (VND/liter)	81,055.33
Amount of paint used for anti-rust coating (liter)	31,111
Total cost of normal coating (VND)	**2,947,311,543.21**
Unit price of epoxy surface coating paint (VND/liter)	163,190.22
Amount of epoxy paint used for surface coating (liter)	3,889
Unit price of epoxy anti-rust coating (VND/liter)	148,303.11
Amount of epoxy paint used for anti-rust coating (liter)	31,111
Total cost of epoxy coating (VND)	**5,248,503,209.88**

Economic cost of using epoxy coating for the sluice gates

The cost of using epoxy coating for the sluice gates is the incremental cost due to using more expensive paint. Two layers of anti-rust coating and one layer of surface coating are necessary for coating the sluice gates in CL-CB. Using epoxy coating required that the sluice gates must be repainted every 15 years. Then the cost of repainting would incur every 15 years in 100 years and in the year of replacement. This number will be discounted to present to calculate the cost of adaptation measure.

The prices of epoxy anti-rust coating and epoxy surface coating were collected from the quotations of different suppliers in the market. The amount of paint which would be used for CL-CB sluice gates is the same as estimation in the calculation of benefit, which is 3,889 liters for surface coating and 31,111 liters for anti-rust coating. PV of cost of using epoxy coating for the sluice gates is VND 11,588,202,424.05 (nearly USD 500,000).

Net benefit of using epoxy coating for the sluice gates

The investor's net benefit of using epoxy coating for the sluice gates or NPV is the difference between the PV of the total benefit and PV of the cost, which is VND 96,747,337,865.02 or USD 4,137,592. The BCR is 9.35, meaning that spending 1 dollar in this adaptation measure would bring 9.35 dollar of benefit to the investor. The NPV is a positive number and the BCR is larger than 1, showing that using epoxy coating for the sluice gates is a beneficial adaptation measure for the investor.

The society's net benefit can also be calculated by adding the benefit of the households in the project area. In this case, using WTP to measure the benefit is an appropriate method as coating the sluice gates with epoxy may not directly decrease the risk of failed operation of sluice gates, but it would enhance the efficiency of the sluice gates' operation. As calculated above, the PV of agricultural households' benefit is VND 1,536,189,278,020.45 or USD 66,269,083. Then the PV of total social benefit is VND 3,181 billion or USD137,2 million. The NPV would be VND 3,169 billion or USD 136.7 million (and the equivalent BCR is about 32.5). The NPV of society is much higher than NPV of the investor, which means that the adaptation measure is very beneficial for the whole society.

4. Conclusion

CL-CB sluice gates is still under construction and will be finalized in 2021 with the expectation of controlling the flood and salinity intrusion to create stable and sustainable production conditions in the Mekong River Delta, Vietnam. However, the climate risk assessment showed that sluice gate materials and components would be exposed and vulnerable to climate induced hazards such as high temperatures, heat waves, heavy rains, tropical storms, droughts, high winds, tornadoes, and thunderstorms/lightning. High water level, salinity combined with high temperature and high-water level combined with heavy rain would affect negatively on the lifetime and the operation of the structures. The results of the CBA of show that the two climate proofing measures: upgrading concrete for pillars and ship locks and using epoxy coating for the sluice gates are efficient both from the investor and the society's point of view as the Net Present Values are positive in all the cases. Thus, it is strongly recommended that the investor should invest in climate proofing measures at the beginning for long term benefit.

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