Economic Analysis supplementing the Climate Risk Assessment of the Cai Lon – Cai Be Sluice System

FINAL REPORT

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On behalf of:

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Registered offices
Bonn and Eschborn, Germany

Friedrich-Ebert-Allee 32 + 36
53113 Bonn, Germany
T +49 228 44 60-0
F +49 228 4460-17 66

E info@giz.de
I www.giz.de; www.adaptationcommunity.net

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Responsible/Contact:
Benjamin Hodick
benjamin.hodick@giz.de
Friedrich-Ebert-Allee 32
53113 Bonn

Authors:
Tran Minh Dien
Nguyen Duc Cong Hiep
Nguyen Thi Lien
Cao Van Chan
Ngo Thanh Toan

On behalf of:
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1. Introduction

Cai Lon – Cai Be sluice gate project is the largest sluice system being conducted in the Mekong River 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 controlling water sources (e.g. sea water, brackish water, and fresh water), creating stable and sustainable production conditions for production models. ecological (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; combine the west sea dyke to form a cluster of works proactively responding to climate change, sea level rise and natural disaster prevention; reducing inundation when the ground is low (due to land subsidence); reducing the damage of drought and salinity in the dry season for regional production models; contribute to fresh water supply; transport infrastructure development.

However, the Mekong River Delta of Vietnam is one of the world's most vulnerable delta 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 Cai Lon – Cai Be sluice gate project, might not hold up to its designed function for the lifespan of 100 years. Therefore, climate risk assessments (CRA) are necessary to develop capacities in the application of tools and processes for climate-proofing infrastructure. In addition, as CRAs often involve relevant stakeholders in the assessment, they can enhance the information exchange and especially information for the decision makers about the need to change planning and management approaches.

In order to support the climate-risk-informed decisions regarding the project, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), under the Mekong Delta Climate Resilience Programme (MCRP) (2019-2021) and the Vietnam component of global project Enhancing Climate Services for Infrastructure Investments (CSI) (2017 - 2022), conducted a case study of climate risk assessment (CRA), namely "Climate risk analysis (CRA) and assessment report for Cai Lon - Cai Be sluice gate project based on the PIEVC protocol" in 2017. Having examined the main climate and hydrological phenomenon in the project area, the CRA study provided plenty of improvement recommendations to make the finished sluice gate project more resilient towards climate change and climate variability.

With an aim to support in extensive application of climate risk assessment for such infrastructure in Kien Giang province, an extended and upscaled CRA is conducted with 3 work packages: Work Package 1. Follow-up check and update the results of the existing climate risk assessment developed for the Cai Lon – Cai Be sluice system, focus on the period comprised from after the detail design until construction completion; Work Package 2. Identify the most sensitive and vulnerable components of the complete Cai Lon – Cai Be case of sluice gate system and assess the potential climate risk that these components pose on the same type of infrastructure in the Kien Giang province; and Work Package 3. Economic analysis regarding the climate risk assessment of the Cai Lon – Cai Be sluice system and develop a standard methodology to analyse cost-benefit for climate risk assessment of the entire sluice system of Kien Giang province.

This report presents the preliminary results of Work Package 3, including Research objectives, Study area, Methodology and Economic Analysis of the climate proofing measures for Cai Lon – Cai Be Sluice Gates.

2. Research Objectives and Study area

2.1 Research objectives

The main objective of this Work Package 3 is to supplement the CRA by an economic analysis of the Cai Lon – Cai Be sluice gate project. Given that the CRA is still being updated in Work Package 1 and Work Package 2, the cost-benefit assessment team will work closely with the climate risk assessment team to get the most updated information for the analysis.

The detailed objectives are as follows.

1. To identify the according risk reduction for some CRA recommendations for Cai Lon – Cai Be sluice gate, which are feasible for the economic analysis;
2. To provide a comprehensive economic analysis to assess the desirability of some recommended climate proofing measures for Cai Lon – Cai Be sluice gate;
3. To provide a standard methodology of economic analysis for climate risk assessment that is suitable for extensive application on the entire sluice system of Kien Giang province.

2.2. Study area

Aligned with the CRA (GIZ, 2019) and the Work Package 1, 2, the scope of this study is the area of Cai Lon – Cai Be 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.

On **Figure 1**, 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 River Delta of including: Bac Lieu, Ca Mau, Kien Giang, Hau Giang, Soc Trang and Can Tho City.

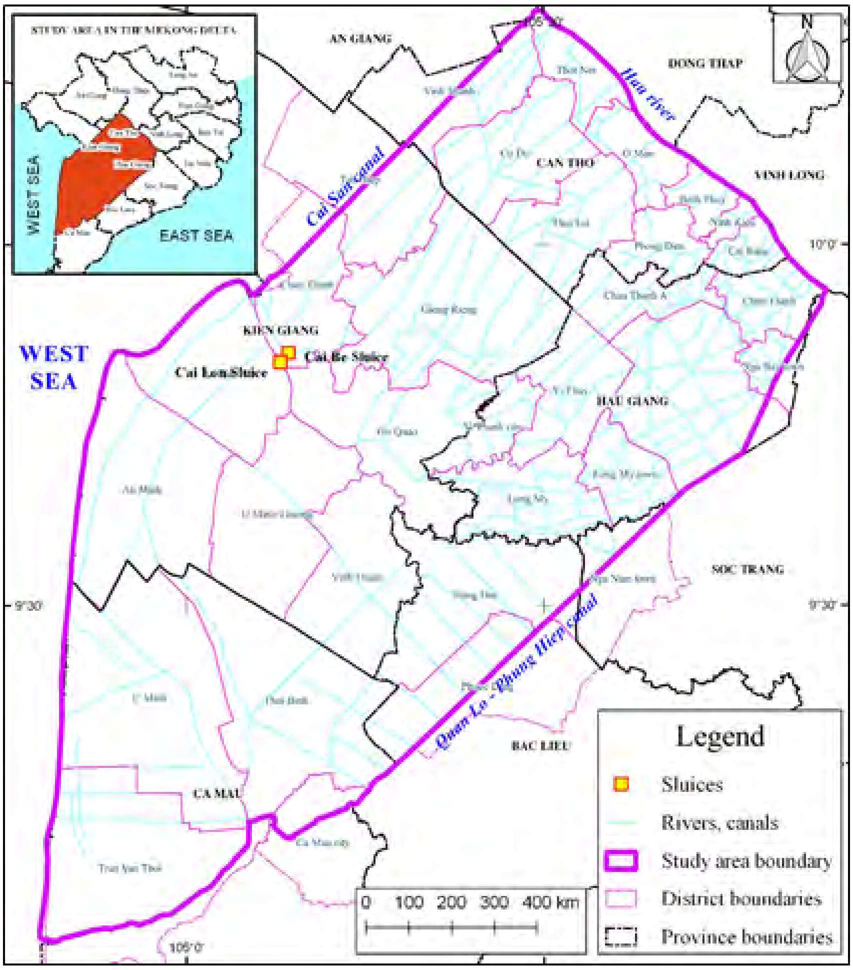


Figure 1. The study area

Source: Adapted from (GIZ, 2019)

3. The sluice gate system in Kien Giang Province

3.1. Overview of Kien Giang Province

Kien Giang is a coastal province located in the western of the Mekong river delta of Vietnam. The province has a coastline of more than 200 km and a relatively flat topography, with an average elevation from 0.8 to 1.2 meter above sea level in the Northeast and from 0.2 to 0.4 meter in the Southwest. Therefore, Kien Giang province is very vulnerable to salinity intrusion. In dealing with this issue, Kien Giang has a sea dyke of 212 km long and a coastal protection forest area of 5,578 ha. Along this sea dyke, 130 sluice gates have been completed, including 52 sluices in the Long Xuyen Quadrangle zone, 49 sluices in the western region of Bassac River, and 29 sluices in the U Minh Thuong zone. In the coming period, the remaining 27 sluice gates along the sea need to be invested in order to control salinity and regulate water for production and living.

The total natural area of Kien Giang province is 634,852.67 ha. It has 15 administrative units, including two provincial cities (Rach Gia city and Ha Tien city) and 13 districts (of which two island districts are Phu Quoc and Kien Hai) with a total of 145 communes, wards and towns. Kien Giang has a dense network of rivers and canals, taking advantage of agricultural development, flood drainage, and water traffic. In addition to the main rivers such as Cai Lon, Cai Be and Giang Thanh rivers, the canal system is distributed across the province with a total length of about 2,054 km. The hydrological characteristics of these rivers together with the tidal regime of the West Sea dominate the ability of water drainage in the rainy season and prevent salinity in the dry season.

Figure 2. The administrative map of Kien Giang Province

In the period 2016 - 2020, Kien Giang province maintains a stable economic growth rate and a fairly good economic scale throughout the country, with a positive economic structure shifting in accordance with local real conditions, better exploit the fields with potentials and advantages and mobilize more resources for development investment. Up to date, Kien Giang ranks second in the Mekong River Delta (Mekong Delta) in terms of budget revenue. Accordingly, the average economic growth (GRDP) in the 2016-2020 period reaches 7.22%/year. The size of the economy has increased sharply (in 2015 reaching 47,076 billion VND, in 2020 reaching 71,755 billion VND), per capita income increased from 1,630 USD in 2015, to 2,458 USD in 2020 (1.66 times higher than the year). 2015). The total budget revenue reached 49,807 billion VND, increased 24.3% compared to the beginning of the term; Particularly in 2020, it reaches VND 11,540 billion, 2.13 times higher than that of 2015.

3.2. Impacts of salinity intrusion

Salinity intrusion is the main concern in Kien Giang Province, which adversely affect local economic activities in the area, including agriculture and aquaculture. It happens during the dry season, from December to April.

Firstly, salinity intrusion often adversely impacts agriculture production, especially the winter-spring rice crop.

- The seasonal rice crop: This crop is planted from September to November, with the cultivated area of 62,610 hectares in 2019. Thus, there is often no damage due to saline intrusion (which occurs December-April);
- Winter-Spring rice crop: This crop is planted from September to December with the cultivated area of 289,837 hectares. Particularly, in Hon Dat District, 3,167.5 hectares of rice (out of 163,397 hectares of farming) were damaged by salinity (of which 1,882.2 hectares lost 30-70% of production, the rest lost over 70% of production).

Secondly, salinity intrusion also damages aquaculture production. The main aquaculture product of Kien Giang is brackish shrimp. Salinity intrusion can cause changes in environmental factors (especially water salinity) in the pond, negatively affecting the resistance of shrimp. Accordingly, the productivity is reduced significantly. In the dry season of 2019-2020, the whole province of Kien Giang had 6,949.6 ha of farmed shrimp damaged by severe drought and salinity intrusion. The interview in our first field trip recorded that some aquaculture farms lost 40 % of their productivity due to the change of environmental factors, mostly water quality, in 2019.

Third is the impacts on transportation. When salinity intrusion occurs during dry season, sluice gates are often closed. This also prevent the water transportation within inland and from inland to the sea. In addition, during the prolonged drought in 2019, the water levels of the canals in the buffer zone in An Minh Bac and Minh Thuan communes, U Minh Thuong district were lowered, causing the landslides of ring dykes and rural roads. The dyke of the provincial road 965 was eroded by the total length of 168m, in which the absolute landslide was 40m, the rest was eroded into 2-3m, affecting 4 houses. The rural traffic road in Minh Thuan and An Minh Bac communes was eroded 1,038m, affecting 1 house and making it difficult to travel and transport goods.

Fourthly, salinity intrusion affect the fresh water resource. In 2019, although the water supply for domestic use in the urban area was considered sufficient, some prevention cost had occurred. In fact, it is reported that during the dry season 2019-2020the Kien Giang’s Department of Agriculture and Rural Development had to construct 04 temporary dams with Larsen steel piles (01 dam in Kien Luong, 01 in Rach Gia, and 02 in Chau Thanh) in combination with effective operation of the sluice gate system in the area to prevent salinity and store freshwater.

3.3. Review of the sluice gate system in Kien Giang province

The sluice gate system in Kien Giang is managed following the 3 climate and hydrological zones, including Long Xuyen Quadangle zone, U Minh Thuong zone and Tay Song Hau zone (**Figure 2**). This study focuses on the Long Xuyen Quadangle zone, U Minh Thuong zone as the sluice gates in these zones are mostly to control the salinity intrusion.

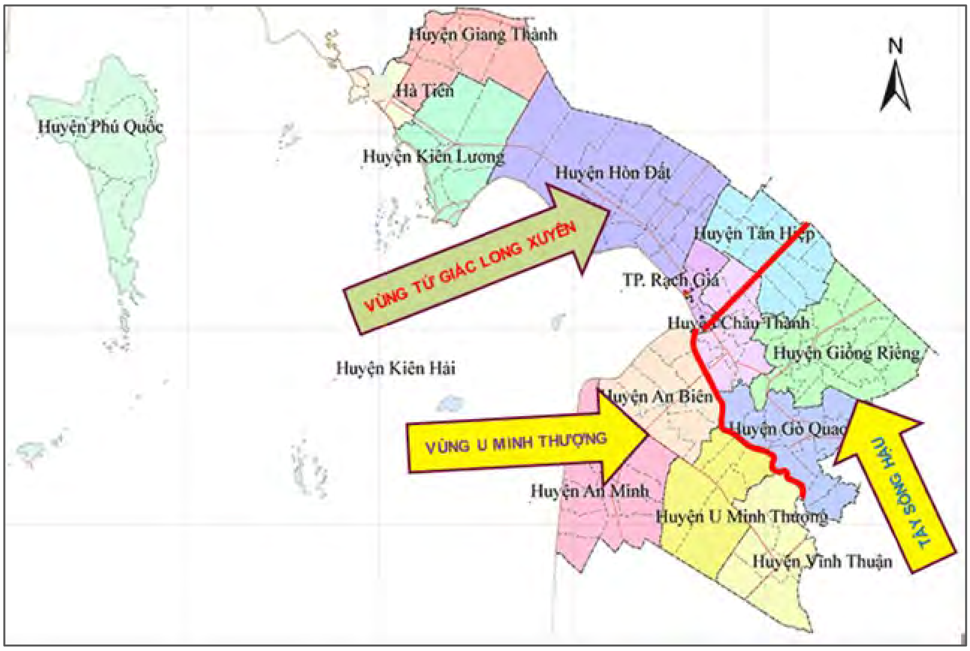


Figure 3: The three climate and hydrological zones in Kien Giang province

There are currently 130 sluice gates in Kien Giang province. In there, 84 sluice gates for managing salinity intrusion are located along the West Sea coastal lines (including Cai Lon and Cai Be sluice gates), of which 54 sluice gates are operating, 15 sluice gates are under construction and 15 sluices are at feasibility study stage (**Figure 3**). The 54 operating sluice gates include:

- 46 “automatic” sluice gates: operation based on the force of tidal regime (one-way and two-ways) and there are no mechanic engine;
- 04 “automatic” sluice gates, the valve gates of which were replaced by the type of flat valve gate. Thus, they are operated by hydraulic cylinder to slide vertically;
- 01 sluice gate was designed in the form of a pillar dam, bottom shutter gate, and operated by hydraulic cylinder;
- 01 sluice gate was designed in the form of a pillar dam, bottom shutter gate, and operated by winch;
- 02 sluice gates were designed in the form of a pillar dam, flat valve gate, and operated by hydraulic cylinder to slide vertically.

-

Figure 4: The sluice gate system in Kien Giang Province

It is noteworthy that the sluice gates are not for preventing seawater intrusion the entire year. They are, in fact, to “manage” the sea water intrusion – letting sea water in when needed (often for aquaculture production) and contain fresh water (often for agriculture production). Therefore, it is important to operate the sluice gates appropriately.

In terms of the operation, sluice gates are managed differently according to the zones:

- In Long Xuyen Quadrangle zone: The sluice gates are operated according to the "Operation regulation of irrigation system in the Long Xuyen Quadrangle" issued by the MARD under Decision No. 5313/QD-BNN-TCTL dated December 20, 2017. The Department of Agriculture and Rural Development of Kien Giang has commanded the Irrigation Department to regularly inspect and monitor the situation of the water sources as well as to operate the sluice gates in accordance with the regulations;
- In U Minh Thuong zone: The sluice gate system in U Minh Thuong region is operated flexibly to serve the production and living of local residents. The coastal sluice gates in An Minh and An Bien districts, that are automatically operated by the tide, are often sedimented, making it difficult for the operation. In addition, as this system has not been completed, the operation of the existing sluice gates is not synchronized. Thus, it is necessary to combine the temporary

dams to prevent salinity intrusion in the canals without sluice gates in order to improve the effectiveness of the system operation.

The operation of sluice gate system is scheduled according to the agriculture and aquaculture production in land. Therefore, Kien Giang province can be proactive in production with suitable seasonal calendars. Particularly during the period of drought and saline intrusion in 2019-2020, the Kien Giang Irrigation Department has operated efficiently and flexibly the coastal sluice gates in the LXQ region to mitigate the impacts in the province.

In terms of maintenance, the sluice gates in Kien Giang province is maintained periodically by the Kien Giang Department of Irrigation. Regularly inspection are conducted to promptly detect and repair unexpected problems during operation, in order to ensure the lifespan of infrastructures.

4. Review of Climate Risk Assessment (CRA) of Cai Lon – Cai Be Sluice Gates Project

4.1. Updates in climate – hydrological data analysis

The climate and hydrological data were updated to 2019 the by Southern Regional Hydro-meteorological Center. For local rainfall stations, there was lack of data from January to May in 2018. However, the data has been included in the climate data analysis in Phase 2 by CRA group.

High temperature

The historical data analysis showed that high temperature continues to tend to decrease at the study area. For projections, the RCP8.5 scenario in the Kien Giang province indicated that the number of days with temperature ≥35^{o}C has an average increase of 13.7 days per year at the early century (up to 2040), 36.3 days per year in the mid-century (2041 - 2070) and 88 days per year at the end of the century. The CCHIP tool also resulted that the average maximum temperature increase is 0.6 - 0.7^{o}C at the early century, 1.7^{o}C at the mid-century, and 3.0^{o}C the end of the century.

Heat wave

The historical data analysis resulted a sharp decrease of the heat waves in the past 32 years (1988-2019) in the Rach Gia station. However, the projections of this factor from Vietnam's climate change scenarios (MONRE, 2016) and the CCHIP tool showed that the maximum temperature will increase again in the 21st century, and even increase sharply at the end of the century. The number of days with the maximum temperature will be 100 and 88 days for Vietnam's climate change scenarios and results of the CCHIP tool, respectively. As a result, the heat waves more than 8 days will be forecasted to increase again in the 21st century.

Heavy rain

The average frequency of heavy rainfall for the meteorological stations in Kien Giang in the period of 1988-2019 was 0.57 (no change compared with the result in phase 1). However, the number of days with heavy rain in the stations of Xeo Ro, Rach Gia, and Vinh Hoa Hung increased slightly, while in the stations of Go Quao, Vinh Thuan, An Minh there was a slight decrease. The annual average rainfall at Rach Gia station has increased. The average number of rainy days per year at the stations ranges from 135 to 159 days. It can be seen that there was a little change in comparison with the corresponding values in Phase 1.

Tropical storm/depression

The collected data showed that every 6.4 years, there was a storm landed into the study area. Among 19 tropical storms and depressions in the East Sea every year, 10 storms directly landed in Vietnam and only storm came in the South of Vietnam. The total number of tropical storms and depressions in the East Sea in the period of 1988 – 2019 was 278, of which 188 storms directly landed in Vietnam, 13 storms landed in the South of Vietnam, and 5 storms and one depression directly came in the study area. Therefore, the number of storms affecting the study area was relatively small in comparison to the whole Vietnam. Most storms in the study area occurred from October to December. In recent years, the occurrence of strong storms of level 12 and above tended to increase, and the storm season ends later over the years.

The frequency of tropical storms and depressions affecting Vietnam are likely to decrease. The number of storms has an increasing trend at the end of the storm season, especially in the RCP8.5 scenario. Thus, the tropical storms and depressions tend to move towards the end of the storm season, when they mainly appear in the south. In terms of the storm levels, the number of weak and medium storms tends to decrease while the number of strong and very strong storms tends to increase considerably. On the other hand, the frequency of strong storms which directly affects the study site will be higher in the future.

Drought

Data collected by CRA group showed that the dry season has been getting more intense in the Mekong Delta in general and in Kien Giang in particular. For instance, the dry season of 2015-2016 is considered the most severe in the past 100 years, but in the dry season of 2019-2020, the drought situation in the Mekong Delta and Kien Giang was even more severe. The trend of temperature was predicted to increase in the 21st century. The number of days with high temperature will be much higher at the end of the century, and the dry season in Kien Giang is also expected to be more severe. The rainfall in April and May which is the dry season tends to decrease. The evaporation capacity will increase throughout the year. In short, drought events are anticipated to become more severe in the future in Kien Giang.

High wind

There was a total of 12 days (approximately 0.4 days/year) with the high wind at the Rach Gia station for the period of 1988-2017. During 2018-2019, there was no day with high wind more than 20 m/s in this area. As a result, the number of days with the high wind in the period of 1988-2019 slightly decreased to 0.375 days/year.

The distribution of days with the high wind at the Rach Gia station was mainly concentrated in the period of 1995-2006. The number of days with the high wind tended to decrease in this area. However, the statistical data showed that the number of days with gusts (≥ 20m/s) in Rach Gia in recent years tends to increase. There is no forecast for the frequency of high winds in the future in the study area.

Tornado

In this phase, the average number of tornadoes in a given year is based on the recorded damages from the tornadoes in the report of the Provincial Committee for Flood and Storm Control, and Search and Rescue of Kien Giang. According to the statistical data on the damages caused by tornadoes in the period of 2005 - 2015, tornadoes occurred almost every year in Kien Giang, at least 1-2 tornadoes recorded in a year. As the data of tornadoes have been collected too little, it is difficult to assess the trend of this phenomenon in the past. Under the impacts of climate change, the intensity of the tornadoes is expected to be stronger.

Thunderstorm/lightning

According to the report of the Provincial Committee for Flood and Storm Control and Search and Rescue of Kien Giang, there were about from 1 to 3 lightning events every year in the province. Thunderstorm/lightning mainly occurred in the rainy season and in the period of transition between the seasons. In the period from 1988 – 2019, there were about 98.5 days with thunderstorms per year in Kien Giang, increasing 2.5 days compared with the corresponding value in Phase 1 (96 days).

Water level

Data of water level was collected from the Xeo Ro hydrological station, which is the closest on Cai Lon – Cai Be Sluice Gate project site. In the period of 1988-2019, the maximum water level at this station was 1.05m, which was on July 13, 2018, and the average water level is 0.00m. These values are higher than corresponding values in Phase 1 which were 0.99m and -0.01m respectively. Every year the tidal water level was highest from September to December and was the lowest from April to July.

Saline intrusion

The analysis of updated saline data in the period of 1996-2019 showed that the maximum salinity value in Xeo Ro station was 31.0g/l, appeared on May 8, 2016, while the average salinity value was about 7.0g/l. In addition, the salinity values did not change much compared with the results of analysis of 1996-2017 saline data in Phase 1. The maximum salinity value was common in April, followed by February and March, and tended to decrease gradually in rainy season.

4.2. Updated climate probability scores for CRA for Cai Lon – Cai Be Sluice Gates

The following table shows the historical and future PIEVC probability scores of each climate and hydrological parameter for the CRA for the Cai Lon – Cai Be sluice gate system which were calculated by CRA group.

Table 1: The PIEVC probability scores for the Cai Lon – Cai Be sluice gates

Parameters	Threshold	Unit	Historical probability score	Future probability score
Climate				
High temperature	≥ 35^0C	Days/year	6	7
Heat wave	≥ 8 or more consecutive days with the maximum temperature ≥ 35ºC	Events/year	3	4
Heavy rain	≥ 100mm in a day	Days/year	4	5
Heavy 5-day total rainfall	≥250mm	Events/year	4	4
Tropical storms/depression	From level 8 (equivalent to the windy speed of 62 - 74km/h) or more	Events/year	3	4
Drought	K ≥ 4 in dry season	Drought events/32 years	5	6
High wind	≥ 20m/s	Days/year	4	4
Tornado	Fujita wind scale Based on the statistical data on the damages	Events/year	1	2
Thunderstorm/ Lightning	Based on the statistical data on the damages	Events/year	5	6
Hydrology				
Water level	0.9 m (design probability 5%)	Exceeding value/year	7	7
Salinity	3g/l	Exceeding value/year	7	7
Cumulative effects				
Salinity intrusion + high temperature	Salinity = 3g/l and high temperature ≥ 35^0C	Events/year	5	7
High water level + heavy rain	Water level ≥ 0.9m and heavy rain ≥ 100mm/day	Events/year	2	4

Source: CRA group (2020)

The comparison of the probability scores between Phase 1 and Phase 2 showed no change in climate and hydrological factors, except for the thunderstorms/lightning, and salinity intrusion combined with high temperature. While the future probability score for the thunderstorms/lightning increased by one (5 to 6), the probability scores for salinity intrusion combined with high temperature increased by one (4 to 5) and two (5 to 7) for historical and future probability scores, respectively.

4.3. Updated potential cumulative effects

The effect combinations of climate and hydrological elements on the CL-CB sluice gate project proposed in Phase 1 continued to be used in the CRA in Phase 2, including salinity intrusion combined with high temperature and high water level combined with heavy rain. These combinations are in line with the experience of the senior operation staff of sluices and the natural characteristics of the Mekong Delta. Particularly, the corrosion of reinforced concrete and metal of the infrastructure components was mainly impacted by high temperature, high rainfall, salinity and water level change (by tides, storm surges, sea level rise and land subsidence).

High water level combined with heavy rain

High water-level and heavy rain is defined as two occurrences of the water level greater than 0.9m and the heavy rain events more than 100mm/day occurred at the same time. The analysis of updated data (1988-2019) showed that the combination between high water level and heavy rain only occurred only once time in August 2006. The water levels greater than 0.9m will appear more frequently, especially at the end of the century. In addition, the intensity of rainfall and the number of days with heavy rain are also expected to increase in the future. As such, the frequency of high water-level combined with heavy rain is predicted to be higher in the past.

In 2020, heavy rains and rising sea levels made An Bien district suffer the biggest flood in recent years. The roads in An Bien, even the ones of 1.5 meter height were flooded. Travel activities of local people were severely affected. If heavy rain lasts for many days, the roads may be damaged. The elevation of approach roads to the Cai Lon - Cai Be sluice gates were designed in consistent with the historical hydro-meteorological data, that is, if compared with the recently updated climate risk, in the future, these roads have to face higher risk of damage, which may cause economic loss to society and increased costs for investors/ local government. The local government will have to pay additional costs to repair and maintain the damaged roads or build new ones. It is recommended that the approach roads should be elevated. The height of the approach roads will be determined based on the climate risk analysis for Cai Lon – Cai Be sluice gates.

When strong winds are combined with high water level, boats that are staying inside the sluice gates will drift. Some boats can be pushed by the wind and crashed the hydraulic cylinders which control the sluice gates. At Kenh Cut sluice gate, Rach Gia city, there are many scratches caused by the strong crash of the boát on the hydraulic cylinder controlling the sluice gate. If the crash is severe, the hydraulic cylinders are may be cracked or broken, affecting the operation of the sluice gates. The cost of replacing these hydraulic cylinders is relatively large. It is necessary to have some protective measures for hydraulic cylinders to avoid damage caused by such accidents; or the hydraulic cylinders should be made by better materials.

Salinity intrusion combined with high temperature

According to report by CRA group, the months with both high temperature and the maximum salinity intrusion were March, April and May. In this study, salinity intrusion combined with high temperature were determined if these two factors occurred at the same time, which means the high temperature were over 35°C and the salinity concentration was more than 3.0 g/l. The historical data shows that the number of days with average high temperature in the period of 1996-2019 was 7.1 days per year while the salinity of 3 g/l occurred during the dry season. Therefore it can be calculated that the combination of these two factors occurred 2.46 times per year. The historical probability score in this case has been estimated to be 5 in the Table 1.

It is predicted that in the future, the high temperature events will increase in Kien Giang, especially in the late 21st century, and the salinity intrusion will have the increase trend due to sea level rise. This means that the combination of high temperature and salinity intrusion is expected to occur more frequently. Therefore, the PIEVC future probability score of this combination in this case has been estimated to be 7, which is 2 point higher than the results of Phase 1.

Saline intrusion combined with high temperature has a negative effect on sluice gates. Field trips in some sluice gates in Kien Giang province showed that the most susceptible part to salinity and high temperature is the rubber bearings. The rubber bearings' roles are to reduce the friction between 2 layers of concrete, ensuring longevity of the bridge over the sluice gate. The closer to the sea the sluice gates, the more susceptible the rubber bearings to damage due to increased exposure to salt water and high temperature. At Kim Quy sluice gate, An Minh district, which is located 200 meters from the sea, some of the rubber bearings have been lost, the others became inelasticity. Thus they are no longer available for protecting the concrete layers of the sluice gates.

The recommended solution to this risk is to replace the bearings with another material that has a longer lifespan, better resistance to salinity and heat, e.g. stainless steel.

5. Literature review on economic analysis of climate-proofing measures for resilient infrastructure

Climate-proofing measures for infrastructure can yield a range of benefits relative to business-as-usual (OECD, 2018). These include:

- Increased reliability of service provision – reliable infrastructure has benefits ex-post, by reducing the frequency and severity of disruption. It also has benefits ex-ante, as it reduces the need for users to invest in backup measures (e.g. generators for businesses).

- Increased life of infrastructure, reduced repair and maintenance costs - preparing for climate change at the outset can avoid the need for costly retrofitting and reduce the risk of the asset becoming prematurely obsolete.
- Increased efficiency of service provision – in some cases, considering the impacts of climate change can reduce the unit costs of providing a service relative to business-as-usual approaches, for example through better management of hydropower resources.

However, measures for increasing the reliability of service provision may also increase costs: for example, adding redundancy, or designing assets to account for a wider range of potential climates (OECD, 2018). As well as the possibility of higher costs, there may be other trade-offs to make. For example, installing hard coastal defences have the potential to disrupt ecosystems, or increase the rate of erosion of other properties. Cost-benefit analysis should be undertaken to support decision-makers in making efficient choices. The ADB report (2015), Economic Analysis of Climate-Proofing Investment Projects, provides guidance on methodologies that can be used to assess such trade-offs.

5.1. Theoretical basis for economic analysis of climate-proofing measures

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*

The climate proofing of infrastructure projects (e.g. roads, bridges, etc.) seeks to reduce 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.

Figure 5 is useful to illustrate the basic relationship between cost of measure and effectiveness of infrastructure. The horizontal (x) axis represents effectiveness of climate proofing, ranging from 0 to 100 %; zero % effectiveness indicates immediate destruction of a project (e.g. a bridge) due to high vulnerability, while 100 % effectiveness indicates that construction of the bridge will withstand climate change impacts.

The curve represents the marginal cost (MC), that is, the additional cost of constructing the bridge to increase effectiveness. The increasing curve shows how improving the strength of the bridge becomes increasingly more costly. The total cost (TC), represented by the shaded area under the curve, is the total cost of constructing the bridge at Q value of climate proofing effectiveness (i.e. the sum of marginal costs for each unit of climate proofing up to Q).

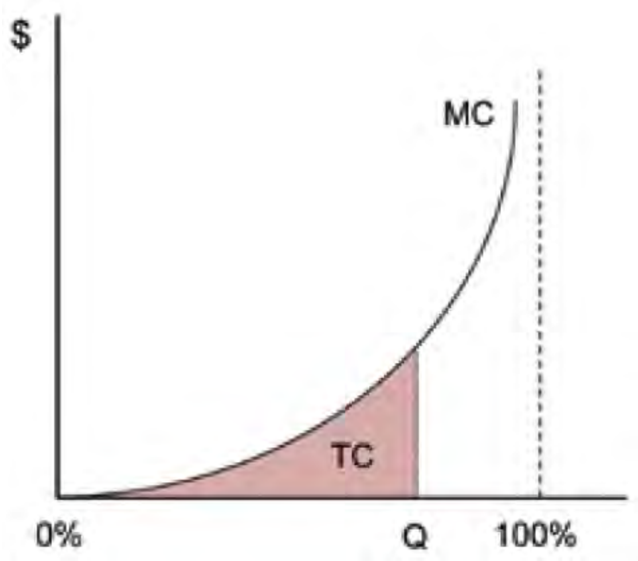


Figure 5. The costs of climate-proofing measure

Source: Kotchen (2011)

- *The benefits of climate proofing measures*

The benefits of climate proofing are avoided damages to property (e.g. destruction of buildings), 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 change). 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.

Recognizing the difference between the investor's perspective and the social perspective is important when it comes to thinking about the right benefits to include. From the investor's investment perspective, the benefits of climate proofing are financial returns. From the social perspective, the benefits often include the non-market values associated with things like avoiding loss of life, health benefits, diffuse economic activity, and environmental services. Here we consider the social perspective for purposes of public sector investments and policy.

Figure 6 show the relationship of the benefits with climate-proofing effectiveness. The curve represents the marginal social benefits (MSB), that is, the additional benefit to society of having one more unit of climate proofing effectiveness. These benefits are decreasing with increased fortification of infrastructure against climate risks. The total social benefit (TSB) of climate proofing to level Q, represented as the shaded region, is the sum of all marginal benefits to society for each unit of effectiveness up to Q.

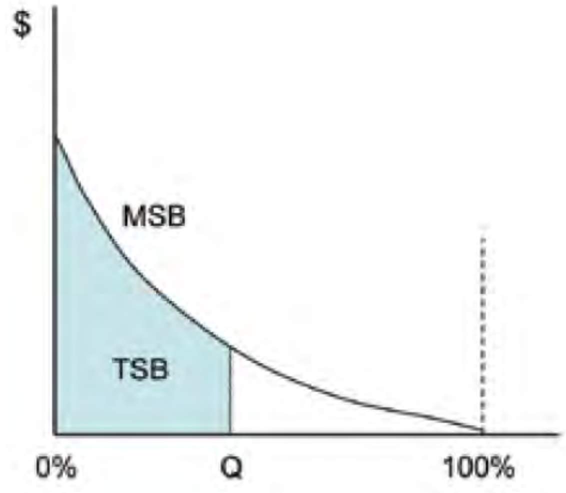


Figure 6. The benefits of climate-proofing measure

Source: Kotchen (2011)

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 7, given a scenario with climate change, the impact of climate proofing is estimated as the difference between the NPV of the project without climate proofing (noted NPVP(NoCP)—where CP stands for climate proofing) and the NPV of the project with climate proofing (NPVP[CP])—where NPVP(CP) includes the cost of climate proofing.

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 impacts along two scenarios:

- Scenario ***without adaptation***: What are the expected impacts 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 impacts of climate change on the project in the future if there were to be climate-proofing measures in place?

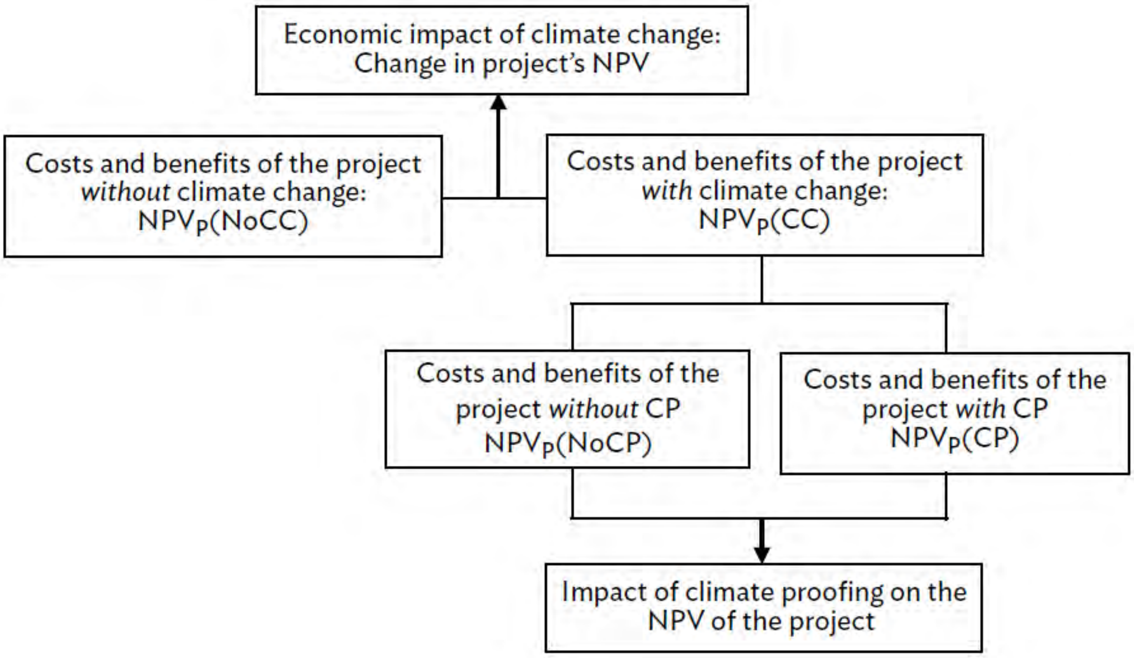


Figure 7. Impact of Climate Change and of Climate Proofing

Source: ADB (2015)

5.2. Case studies on economic analysis of climate proofing measures

ADB (2015) provided the following case studies:

- **Khulna Water Supply Project (Bangladesh)**. A study was conducted to assess the impacts of climate change on the urban water supply system in Khulna and to identify adaptation options to climate proof a proposed water supply investment project. The study found that projected decreases in river flows in the dry season and sea level rise would increase the salinity of the river, an important source of water supply. The adaptation measure were proposed: engineering measures including additional river dredging, re-excavation of drains with lining, sluice gate improvement and widening of drains. A cost-benefit analysis were conducted to find out if the measure is beneficial. The cost of the adaptation measure was increase in investment and annual O&M cost. The benefit was the damages avoided due to impact climate change to the economy, which include damages to households: loss of income; loss in terms of sickness and suffering and damages to assets and damages to other sectors: percent of lost output per year. The results showed that the benefit to cost ratio (BCR) for the period of 40 years at 10% social discount rate was 2.89, which is greater than 1. The internal rate of return (IRR) is 34,2%, which is larger than the social discount rate (10%). Therefore, the improvement of drainage system is economically efficient (ADB (2011).
- **Central Mekong Delta Region Connectivity Project (Viet Nam)**. The Central Mekong Delta Connectivity Project is an $860 million investment to enhance connectivity between agricultural and agro-processing provinces of southern Viet Nam with major national and regional markets. The project includes two major bridges (Cao Lanh and Van Cong) crossing the Mekong River, and a 15-kilometer road connecting the two bridges. A study was conducted to assess the vulnerability of the project to climate change (in particular sea level rise) and examine possible climate-proofing options. The study found that the embankments of the connecting road (between the two bridges) were vulnerable to the projected increase in frequency and intensity of flooding exacerbated by sea level rise. Projected impacts include (i) erosion of road embankments and scouring of road foundations, (ii) water logging of road foundations leading to road subsidence, (iii) reduced stability of infrastructure, and (iv) increased maintenance effort. Based on these findings, one of the climate-proofing options identified is to raise the current design height of the road embankment by 0.3 meters. The cost of this measure was estimated at $4.5 million, representing 0.5% of total project cost. The incremental cost included cost of additional embankment volume, additional area of ground treatment due to increased width of embankment, additional length of culverts due to increased width of embankment, and additional height of abutments and piers of six bridges However no attempt was made to estimate the expected benefits of such investment (ADB (2014).
- **The Road Network Sector Development Program** in Timor-Leste. The project covered the Dili–Mota Ain road (a coastal road with mountainous stretches) and the Ermera–Maliana

road (a forest road). The climate events that may occur in the project areas, flooding, heavy rains, and coastal erosion have the highest likelihood of being more intense in the future, thus causing direct damage to land and coastal infrastructure. In order to address sea level changes and increased storm surge wave height, the following activities will be included during construction on a project-wide basis: increasing vertical alignment to raise all areas of the road to above 2 m, constructing an earth levee bank with riprap protection against erosion, and increased maintenance. Cost – benefit analysis was conducted in three scenario: (i) without a climate event, (ii) with a climate event, without climate-proofing investment and (iii) with a climate event, with climate-proofing investment. Under status quo conditions, d Timor-Leste RNSDP (with their economic lives extended to 50 years) are viable as shown by their NPVs, IRRs and BCRs. The NPV values range from about $58.662 million (for Ermera – Maliana) to $96.79 million (for Dili–Mota Ain). In the case of climate change and no adaptation, NPVs became negative, which showed that no adaptation is economically infeasible. In the scenario of "with climate change, with adaptation", climate proofing of key road infrastructure may reduce benefit loss and improve economic efficiency with NPVs are $17.8 million and $36.17 million for two components (ADB, 2011). Thus CBA proved that it is necessary to apply climate proofing measures.

6. Research activities

6.1. Selection of climate proofing measures for Cai Lon – Cai Be sluice gates

6.1.1. The first field trip

The first field trip was conducted from 02-06 December 2020, with 2 main purposes: (i) Identifying the climate proofing measures for the CBA and (ii) Gathering some preliminary information for the CBA. The consultation team visited 12 sites along the 200-kilometre coastal line of Kien Giang Province, including Ba Hon sluice gate, Song Kien sluice gate, Kim Quy sluice gate, Cai Lon-Cai Be sluice gate, some agriculture farms, aquaculture farms and agri-aqua farms (**Figure 8**).

During the field trip, in-depth discussion was conducted with 13 officials, 6 farming households and the CRA team 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. In addition, some secondary data was collected including socio-economic reports of Hon Dat, An Bien, Kien Luong, Land use maps of Hon Dat, An Bien and Climate risk map of Hon Dat.

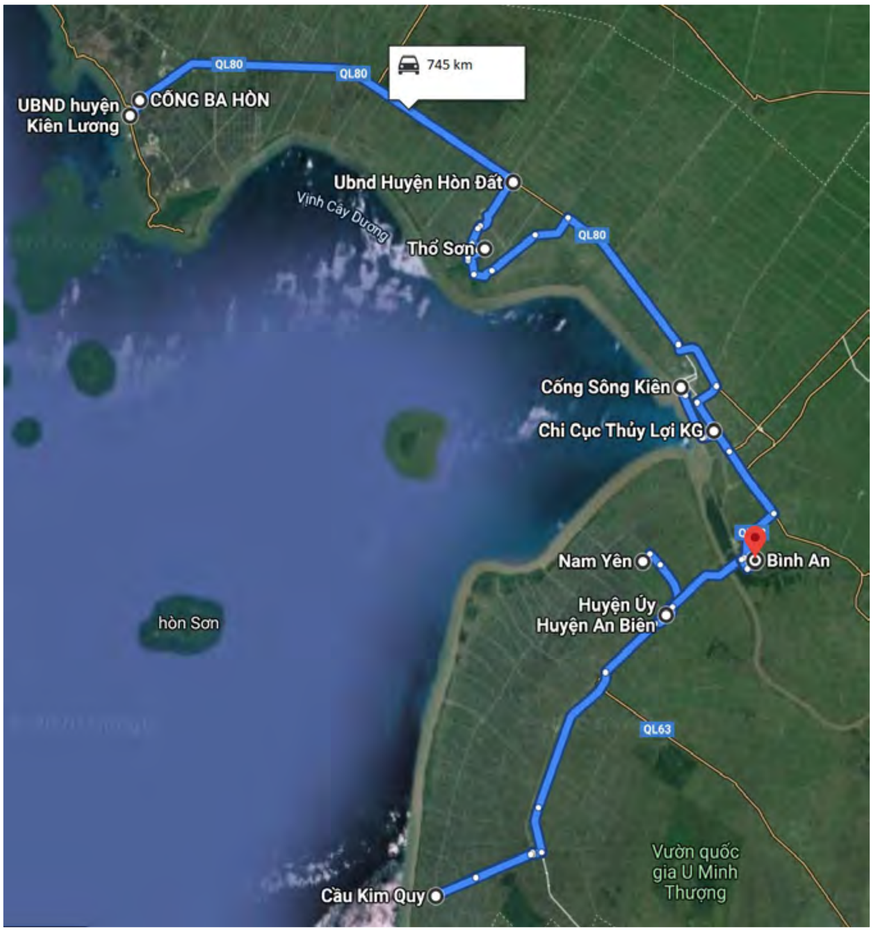


Figure 8. Visited sites in the first field trip (02-06 December 2020)

6.1.2. The second field trip

The second field trip was undertaken from 22-27 April 2021 to conduct a questionnaire survey on farming households for an extended economic analysis. Four main objectives of the survey includes (i) Identify some of the social benefits and costs of CL-CB sluice gates (apart from the operators benefits/costs); (ii) Identify the current private adaptation measures to salinity intrusion and the measures that can be no longer needed when CL-CB fully operate; (iii) Collecting information on the costs and benefits of the adaptation measures; (iv) Gathering the households' opinions on what can be improved.

The survey areas include both 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 Biên District) and also the farms outside of the protected area of CL-CB sluice gates (in Binh Giang Commune, Linh Huynh Commune and Son Binh Commune of Hon Dat District) (See **Figure 9** for more details).

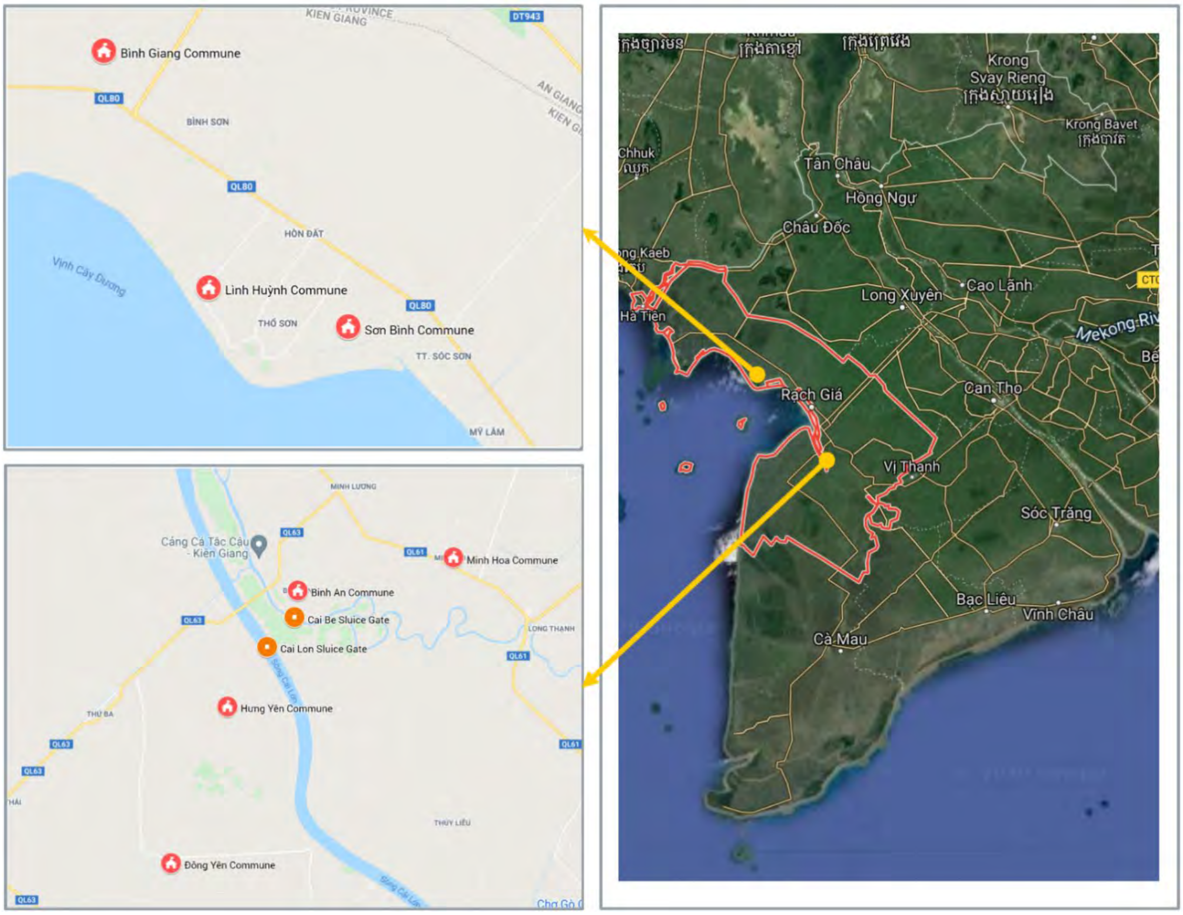


Figure 9. Survey area in the second field trip (22-27 April 2021)

The questionnaire is designed to be answered within 40 minutes (See Appendix 2 for more details). It includes 4 sections as follows:

- Section A: Salinity intrusion assessment
- Section B: Assessment of private adaptation to salinity intrusion
- Section C: Assessment of public adaptation to salinity intrusion
- Section D: Trust in public adaptation measures
- Section E: Household's production activities
- Section F: Expected impacts of CL-CB sluice gates
- Section G: General information of household

The survey had a total of 213 respondents, in consist 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. Direct interview method was used in the survey. The interviewers included the members of the CBA teams and the staffs of Chau Thanh and Hon Dat District's Agricultural Extension Centers. All the interviewers were trained by the CBA teams before the survey.

6.1.3. Proposed climate proofing measures

Table 2 summarizes the main recommendations from the PIEVC Protocol Step 1. The technical measures that can be put into economic analysis are change in the materials of pillar, ship locks and hydraulic cylinders gates, the underground wiring system, the lightning protection systems, automatic operation system and the regular maintenance. The non-technical measures include training courses for operational staff and climate services program. The measures selected in economic analysis will be chosen among the recommended measures by the climate experts and engineers from the results of climate risk analysis.

Table 2: Summary of main recommendations from climate risk analysis and assessment based on PIEVC protocol

Components	**Most relevant Climate Factors**	**Recommendations**
Concrete components: Pillars Ship Locks	High temperature Heat waves Water level Salinity	Use of sulphate resistant cement, anti-corrosion additive mixture, or high concrete grade (M500) and coating method by Epoxy for these components.
Hydraulic Cylinders Gates	Salinity intrusion combined with high temperature	Study of mechanisms and causes of metal corrosion in the Mekong Delta to have the suitable prevention measure such as using a stainless steel together with coating method by Epoxy;
Electric System	Thunderstorms/Lightning, Tornado, Storm and Heavy Rainfall	Consideration of underground wiring designs for both of Cai Lon and Cai Be sluice gates and incorporation of lightning protection systems in the design for the whole infrastructure.
Operational Staff	High temperature Heat wave Tropical storm/depression Thunderstorm/lightning	Support through additional training courses on coping with tropical storms and tornados; self-protection skills from high temperature, heavy rain, high wind in case of working outdoors; using the automatic operation mode or choose the proper time for maintenance
Control and Automatic Monitoring System	Tropical storm/depression Tornado Thunderstorm/ lightning	Select sensors with high tolerance to climatic factors. Project/Facility Management: The monitoring system needs regular maintenance to ensure its continuous functionality.
General: Climate Services		It is necessary to develop a climate service program(s) to enhance data

Components	Most relevant Climate Factors	Recommendations
		collection (e.g. tornados, sediment), sharing and to raise awareness about the need for climate services. This will make it easier to monitor and assess climate risks as a basis for effective climate risk management, not only for the Cai Lon – Cai Be project but also other infrastructures in the region

Source: GIZ (2019).

Technical measures

Step 1 in a CBA is to specify the climate proofing measures for Cai Lon – Cai Be sluice gates for analysis. In Phase 1 of the project, there was a list of measures that was recommended by the CRA group. The technical measures were the change in the materials of pillar, ship locks and hydraulic cylinders gates, the underground wiring system, the lightning protection systems, automatic operation system and the regular maintenance. The non-technical measures include training courses for operational staff and climate services program.

Non-technical measures

The field trip also showed that there were some issues relating to the operation of the sluice gates. The solutions for these issues can be considered as non-technical measures which can be put into economic analysis.

Development of operation manual for Cai Lon – Cai Be Sluice Gates

For the existing sluice gates, the decision to close/open the gate is made as follows: Communal People’s Committee surveyed the local farmers about their water demand and their need to close/open the sluice gates. Based on the results, the communal authority will propose to the District People's Committee. The District People's Committee will inform the Irrigation Sub-Department which is responsible for sluice gates management meet the needs of local people.

However, shrimp farmers and rice growers have different water demands. Rice farmers need freshwater to for the rice crops, while shrimp farmers want to get salt-water for shrimp farming. Although this issue has been largely resolved through the local land use planning and crop season calendar, there are still conflicts at some time of the year. For example, in the last month of the rice crop, the rice farmer wants the sluice gates keeping closed until harvest, but it is also the first month of the shrimp farming season, so the shrimp farmer wants to open the sluice gates for salt-water to come in. Such different demands for water use at the same time may embarrass the local government in making decisions in sluice gates management.

The CBA team recommends that it is necessary to develop an operation manual for Cai Lon – Cai Be Sluice Gates. The management agency of Cai Lon – Cai Be Sluice Gates will have a guided process to operate the sluice gates to avoid such conflicts between water users.

Better communication between stakeholders

Another problem with salinity control is information. In some cases, the people's need to close/open the sluice gate to prevent salt-water has been proposed to the Commune People's Committee, but the District People's Committee did not inform the Irrigation Sub-Department. The reason may be the District People's Committee found that the proposal was irrelevant at that time, but this decision was not communicated to local farmers. All they could do was waiting; and the cost may incur, or income would decrease due to unmet water demand. For example, because the sluice gate was not opened to get salt-water, some shrimp farmers had to reuse the salt-water. The reuse of salt-water required the shrimp farmers to pay for the recirculation system. Circulating salt-water led to water loss of 30-40% due to evaporation or sediment. As the amount of salt-water decreased, the shrimp farmers had to reduce the production in the following crops, resulting in a decrease in their revenue and profit.

Another issue to consider is information about salinity. According to the People's Committee of An Bien district, the district is equipped with a number of salinity meters, but over time, the data from these meters are no longer reliable. The information on salinity from the hydrometeorological center sometimes is not transferred to the People’s Committee. Therefore, the District People's Committee does not have accurate information on salinity to effectively operate the existing sluice gates system.

From these two findings, it can be seen that it is necessary to develop a smooth communication process from the people, the commune and district authorities to the provincial irrigation management agency. People's Committees at all levels need to know the water demand of the people, and if they cannot satisfy those needs, they need to notify the people so that they can take measures to adapt. The salinity monitoring system also needs to be upgraded to ensure the operation of the sluice gates system is based on complete and accurate information. Information about water salinity should also be communicated promptly to all stakeholders, which would be helpful for the development of hydrological databases and decision-making processes.

Cooperation in district’s land-use plan

The current land use in the locality is consistent with the existing sluice gates system. However, the Cai Lon – Cai Be Sluice Gates are still under construction and was not taken into consideration when the local government developed the current land use plan. Meanwhile, people do not fully comply with the government's land use. For example, there may be shrimp farms on the land planned for rice crops, which was supplied with freshwater only, then there was a lack of salt-water. And the shrimp farmers may have an irrelevant request to open the sluice gate for salinity. Thus, in the near future, when the Cai Lon – Cai Be Sluice Gates are finished, it is necessary to have better cooperation between District People’s Committees, Irrigation Sub-Department, Cai Lon – Cai Be management agency and local farmers in land-use plan.

Increasing income for operational staff

The last issue concerns the operational staff. With the existing sluice gates system, the operational staff often have other jobs beside their job at the sluice gates. Officers of the Irrigation Sub-Department have many responsibilities, one of which is managing the sluice gates system. The local staff responsible for closing/opening the sluice gates often has other livelihoods to generate additional income. The reason is the fact that the salary for sluice gates' operational staff is very low. This can affect their motivation and work performance. For example, in case of severe weather such as heavy rain, sluice gates' operational staffs have to operate the sluice gate under the direction of the Irrigation Sub-Department while taking care of their property, which will lead to ineffective public service jobs. In the future, it is necessary to increase the salary for sluice gates' operational staffs so that they can afford to live with this job. With large construction works as Cai Lon - Cai Be sluice gates, this issue is even more important because of the role of this work for the locality as well as for the wider area.

6.2. Consultation with relevant stakeholders

Consulting the CRA teams

Consulting meetings were organized, in which the CBA teams interviewed and consulted the CRA teams. Three semi-open questionnaires were designed for collecting opinions of CRA experts on the issues of selecting the climate proofing measures for cost – benefit analysis, the climate risks of components in Cai Lon – Cai Be sluice gates and the change in climate risk score when applying the climate proofing measures.

Consulting the PMU10

After identifying the climate proofing measures that would be put into economic analysis, it is important to get data on the financial cost of selected measures. Questionnaires were sent to PMU10 to collect data on the cost of components that needed climate proofing as well as the incremental cost of applying such climate proofing measures.

Consulting other experts in topics related to the adaptation measures

Direct interviews were conducted with some experts in the field of construction/engineering to get information of the impacts of climate proofing measures: the change in lifespan of components in normal condition and extreme weather events in the with adaptation and without adaptation scenarios. The prices of materials used for climate proofing measures were collected from the experts and some suppliers in the market.

Consulting the local authorities

During the first field trip, the team met the Irrigation Sub-Department and the People's Committees in Kien Luong, An Bien, An Minh, Chau Thanh and Hon Dat Districts, Kien Giang Province. In-depth interview and focus group discussion were conducted to collect information of the development of climate change over the years, the impacts of climate change on the production, the operation and the benefit of the sluice gates and the necessary of climate proofing measures in the sluice gates. Data on the current situation of agricultural production in the area were provided in the annual reports. This information was used for designing the questionnaire for household survey as well as synthesized in data analysis for cost-benefit analysis.

Information collected in the in-depth interview with local authorities showed some issues that may need to be addressed in this CBA as well as in the future when CBA is applied to other sluice gates in Kien Giang.

- Discussion in districts led to the understanding of affected area of Cai Lon – Cai Be Sluice Gates and the two models of farming in these districts. Thus, An Bien and Chau Thanh were selected for household survey and the questionnaires were designed for rice farmers and shrimp-rice farmers.
- The repair and maintenance cost of sluice gates is stipulated by the government. The CBA team would use this data source for estimating this cost in the next part (economic analysis).
- The relationship between level of salinity and the loss of production can be found for better estimation of benefit/cost of climate proofing the sluice gates. However, discussion with the district officers showed that the data on level of salinity is scattered. The farmers and the local officers can measure the level of salinity by using salinity meters and by their experiences, but the data from the meteorology agency should be officially provided on the regular basis in the dry season. More monitoring stations can be developed for better data collection.
- Another benefit of the climate proofing measures for the sluice gates is cost saving of building and dismantling the temporary dams, repairing the road and the dykes after heavy rain and floods… These data should be collected in all the area and should be easy to access for CBA in the future.

Consulting with GIZ and MPI

The implementation of economic analysis work package was periodically reported to GIZ and MPI. MPI were consulted in every step of CBA. The schedules of two field trips were consulted with and approved by MPI. With the introduction of MPI, in the first trip, the CBA team had the chance to work with the Project Management Board 10, the Sub-Department of Water Resources and the districts of An Bien, Chau Thanh, Hon Dat and Kien Luong in Kien Giang province. In the second trip, the CBA team conducted household survey in the two districts of An Bien and Chau Thanh.

The results of economic analysis were periodically reported in regular meetings with GIZ and MPI. During the meetings, GIZ and MPI gave feedback so that the CBA team could improve the economic analysis to meet the demand of the users.

- MPI expected that the results of economic analysis should be interpreted in more friendly way for non-economist readers and decision makers. Therefore, the criteria of assessing the investment in climate proofing measures in CBA included the Net Present Value (NPV), the Benefit/Cost Ratio (BCR) and the Internal Rate of Return (IRR) with the explanation. Although the NPV is the most important criteria, the readers found BCR easier to understand as it showed how much the investor and the society would benefit for one dong/dollar invested in climate proofing measure.

- MPI and GIZ suggested that the benefit of the public investor is not "private benefit" as in the case of Cai Lon – Cai Be sluice gates, the investor is the government. Thus, in this report, the analysis for the investor is referred as financial analysis and the benefit of the investor is the financial benefit from the investment. This would help to avoid the confusion that applying climate proofing measures would bring profit to the investor.

7. Economic Analysis of proposed climate proofing measures

7.1. 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 infrastructure projects (e.g. dams and roads) ranges from 50 to 70 years. Therefore, when assessing these options, the totality of costs, including investment and maintenance costs, benefits and expected impacts of climate change over the entire period should be taken into account. The lifespan of Cai Lon – Cai Be is expected to be 100 years, which is based on the design of the physical structures (cast-in-situ concrete composition).

Table 3: Time horizon for CRA of Cai Lon – Cai Be

System	Design life (year)	Material
Physical structure (cast-in-situ concrete composition)	70-100	Reinforced concrete of M300-400, Larsen IV
Mechanical system (gates, hydraulic cylinders)	30-50	Steel of Q345 or SUS304
Rip-rap sections	25-40	Precast concrete pile, gabions
Electric power supply	15-20	PVC, copper wires
Control and monitoring systems	10	Sensors and cables
Communication system	15-20	PVC, cables
Watertight gasket	5-10	Rubber

Source: GIZ (2019)

Social discount rate

Discount rates are commonly used to estimate the present values of the costs and benefits of the adaptation options under consideration because the costs of an option occur earlier in time than the benefits of such an option. Discounting implies that resources available in the future are worth less than the same amount available at present. This reflects the opportunity cost of resources: a given amount of resources today can be transformed into a greater amount in the future due to alternative investments to the project. Present values are very sensitive to the choice of the discount rate and to any assumption about the consistency of the discount rate over time.

There is ample debate about the choice of the appropriate social discount rate. Sensitivity analyses thus is necessary to test to what extent the result of the assessment is affected by changes in key variables such as the discount rate. Applying a range of discount rates allows planners to test the validity of results and ensure that the discount rate is not chosen close to a tipping point that reverses the decision, in which case further analysis is applied.

It is suggested by the economists that a declining discount rate should be used in long-time project. With a constant social discount rate, the social discount factors decline geometrically. Even using a modest SDR, costs and benefits that occur sufficiently far in the future have a negligible value. The use of a constant discount rate much in excess of 1.0 or 2.0% implies that it is not allocatively efficient for society to spend even a small amount today in order to avert a very costly environmental disaster far into the future. Boardman et al. (2014) 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.

7.2. Financial analysis of the measure of upgrading concrete for pillars and ship locks

As can be seen on Table 2, in order to adapt to the increasing risk of 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 adaptation measure has turned out as follows in the practice of CL-CB sluice gates:

- 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);

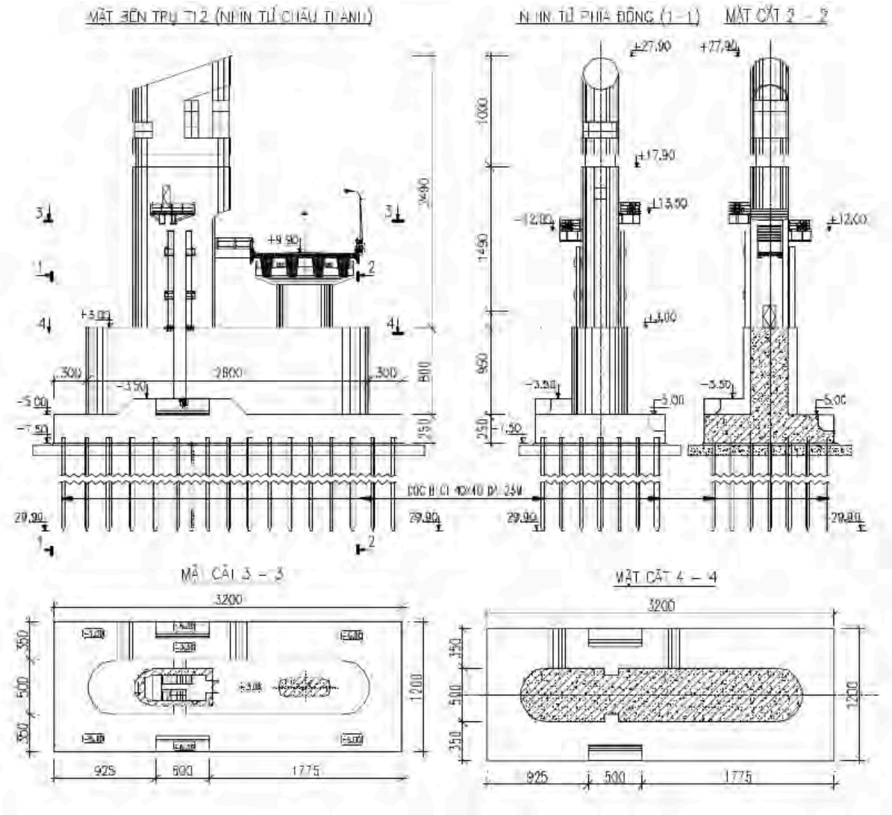
Our economic analysis then examines the according costs and benefits of the adaptation measure in reality of Cai Lon – Cai Be sluice gates.

Firstly, the according costs can be identified as follows:

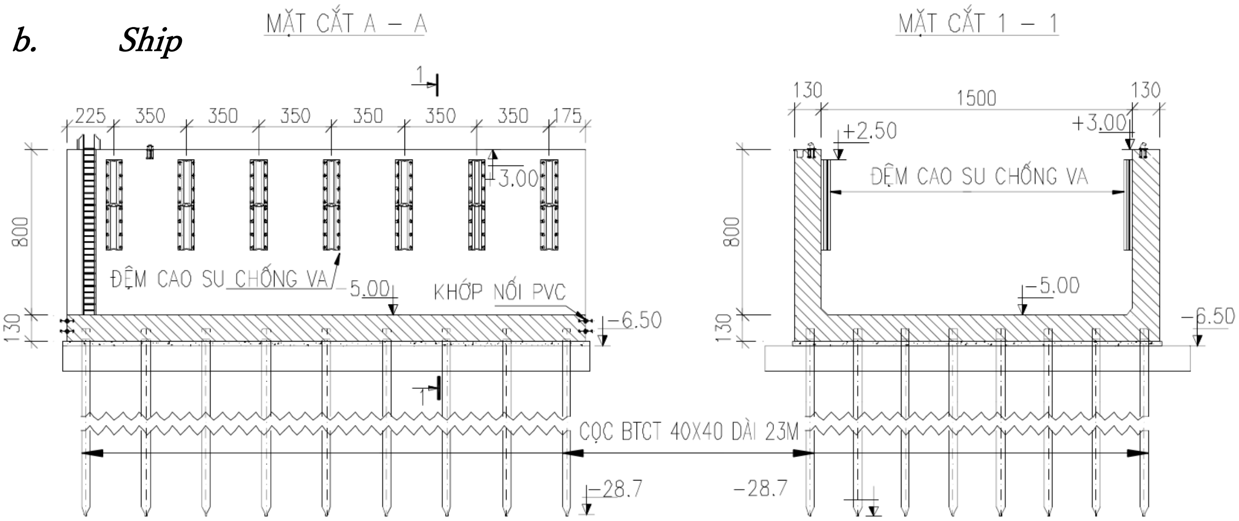
- Increased cost to upgrade from M300 concrete to M400 concrete;
- Increased cost to upgrade from M300 concrete to M400 concrete with sulphate resistant and anti-corrosion additive mixture (12 pillars of Cai Lon and Cai Lon ship lock and 3 pillars of Cai Be + Cai Be ship lock).

Figure 10: The design of pillars and ship locks of Cai Lon sluice gate

a. Pillar



b. Ship



Source: GIZ (2019).

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 4**).

Secondly, the investor's according benefits of the adaptation 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.

Table 4: Cost identification of upgrading concrete for pillars and ship locks

	Cai Lon Sluice Gate	**Cai Be Sluice Gate**
Amount of M300 concrete upgraded to M400 concrete (Ton)	11,000	2,200
Pillars - Amount of M300 concrete upgraded to M4000 concrete with sulphate resistant and anti-corrosion additive mixture (Ton)	66,000	13,500
Ship locks - Amount of M300 concrete upgraded to M4000 concrete with sulphate resistant and anti-corrosion additive mixture (Ton)	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**

Source: Calculation based on the data collected during the field trip 1.

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 CLCB 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 (dated 16 March 2017) 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 The risk scores (R) in PIEVC analysis, which reflects how vulnerable a component of CLCB 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 factors. 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 5: 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%
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%

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)	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%
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 ≥ 35°C)	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

The financial benefit of upgrading concrete for pillars and ship locks were calculated on an annual basis and discounted to present in a 100-year horizon. The present value (PV) of each benefit item is presented in Table 6. Using the formula of NPV, which is the difference between PV of the benefit and PV of the cost, the CL-CB sluice gate investor has the net present value of upgrading concrete for pillars and ship locks of VND26.3 billion (or USD 1.133 million). The BCR is 1.53 and IRR is 4.86%. NPV and BCR is larger than 0 and 1 respectively, showing that the adaptation measure is beneficial for the investor.

Table 6: 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**

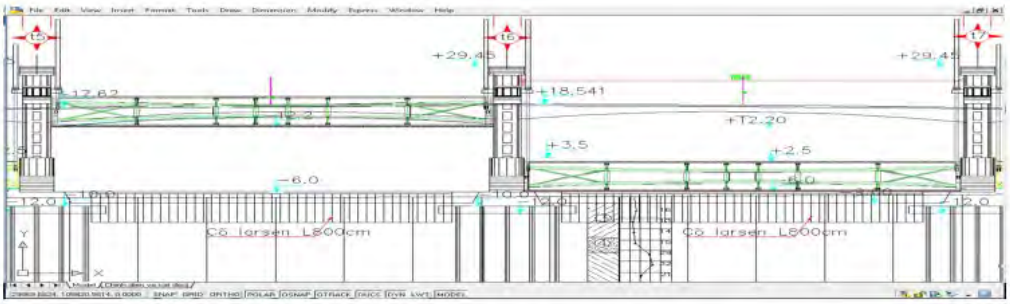
Residual value of adaptation scenario	261,327,549,295.775***
PV of residual value	**22,120,689,335.18**

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

7.3. Financial analysis of the measure of using epoxy coating for the sluice gates

The lift gate type is recommended for both of the 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, water level also indirectly causes physical and chemical corrosion. The recommended prevention measure is using a stainless steel together with coating method by Epoxy.

Figure 11: The gate design of Cai Lon sluice gate



Source: GIZ (2019).

Benefit of using epoxy coating for the sluice gates

Using coating method by Epoxy will increase the lifespan of the sluice gates. Discussion with experts in CRA teams showed that without the climate proofing measure (normal coating method), the duration of the sluice gates is 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 Cai Lon – Cai Be 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. Vietnamese experts and CRA team argued that with the special materials of the sluice gates (S355R which contains stainless steel, nickel and chromium) the sluice gates in Cai Lon – Cai Be 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 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 Cai Lon – Cai Be sluice gates was estimated by the PMU10 as 35,000 liter, of which 3,889 liter would be used for surface coating and the remaining 31,111 liter 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 7: 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**

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 Cai Lon – Cai Be. 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 Cai Lon – Cai Be sluice gates is the same as estimation in the calculation of benefit, which is 3,889 liter for surface coating and 31,111 liter 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

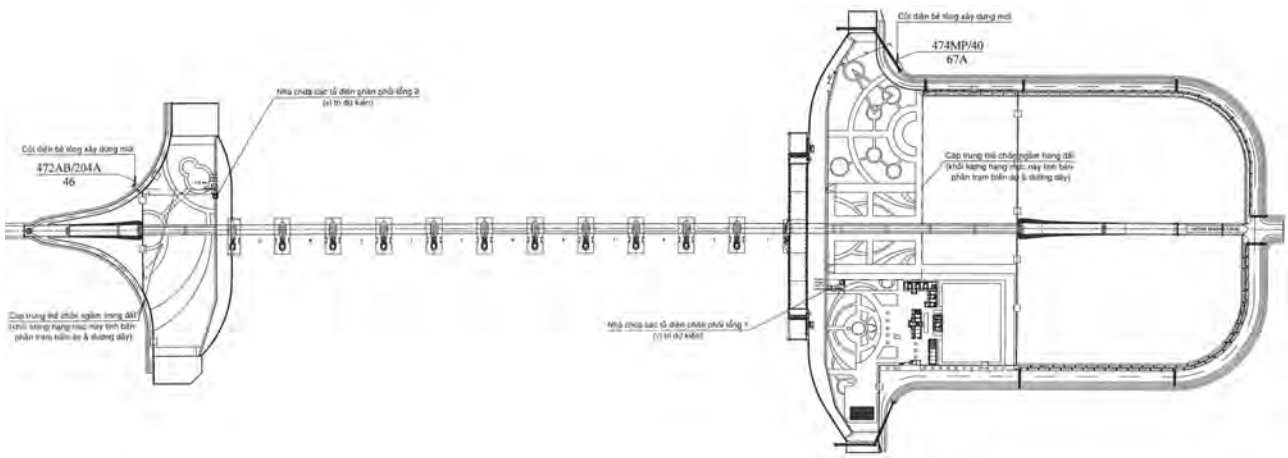
The investor's net benefit of using epoxy coating for the sluice gates or NPV is the difference between the PV of the total benefit and PV of the cost, which is VND 96.179 billion or USD 4.149 million. The BCR is 8.91, meaning that spending 1 dollar in this adaptation measure would bring 8.91 dollar 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 IRR is 36.78% which is much larger than the social discount rate, showing that this adaptation measure is very profitable for the investor.

7.4. Financial analysis of the measure of undergrounding the electrical wiring and upgrading the lightning protection system

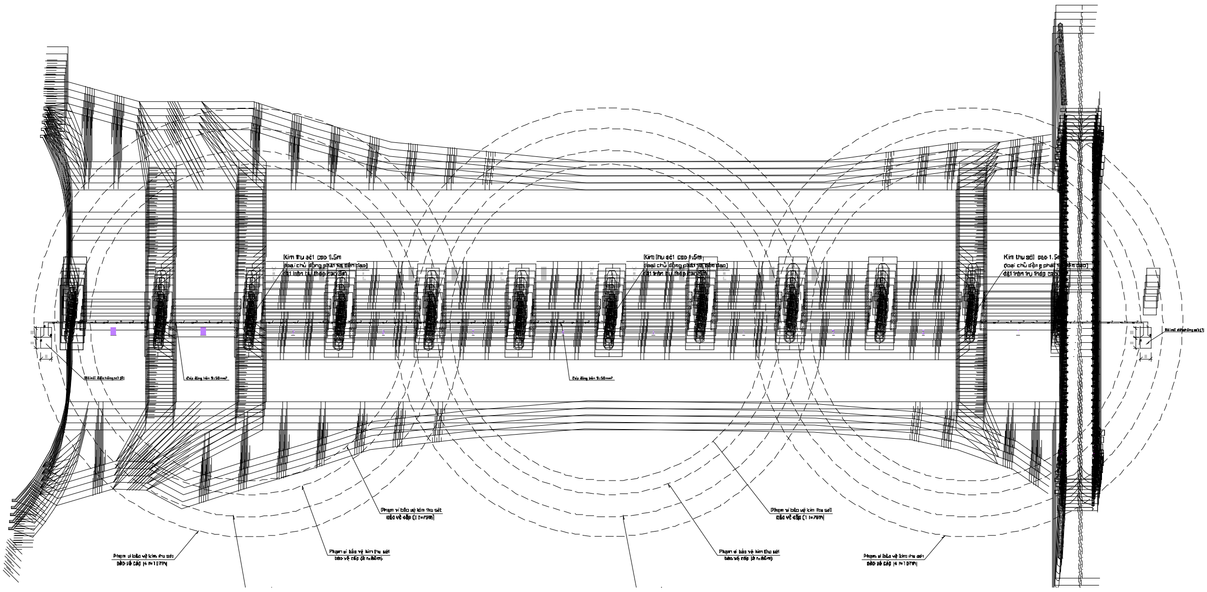
As can be seen on **Table 2**, in order to adapt to the increasing risk of thunderstorms/lightning, tornado, storm and heavy rainfall to the electric system, the CRA analysis suggested to apply underground wiring designs for both of Cai Lon and Cai Be sluice gates and incorporation of lightning protection systems in the design for the whole infrastructure.

Figure 12: The design of electric system of Cai Lon sluice gate

a. ***A part of the electrical wiring system***



b. A part of the lightning protection system



Source: GIZ (2019)

This suggestion was considered by the construction contractor, which turned out as follows in the practice of CL-CB sluice gates:

- Some parts of the electrical wiring were applied underground wiring designs*;*
- The lightning protection systems were upgraded.

In this section, we examine the costs and benefit of the change, namely adaptation measure 3 (undergrounding the electrical wiring and upgrading the lightning protection system).

Firstly, the according costs can be identified in Table 8

Table 8: Cost of undergrounding the electrical wiring and upgrading the lightning protection system

Cost	Cai Lon Sluice Gates	Cai Be sluice Gates
Total cost of electrical wiring system (VND) (excluding the electric equipment)	10,000,000,000	4,000,000,000
Cost of underground electrical wiring system (VND)	3,500,000,000	1,500,000,000
Cost increased due to the electrical undergrounding	35.00%	35.00%
Cost of the lightning protection system according to the construction contractor (real)	3,000,000,000	1,500,000,000
Estimated cost of the lightning protection system according to the preliminary design (1st design)	2,000,000,000	1,000,000,000

Source: Calculation based on the data collected during the field trip 1 and 2.

Secondly, the investor's benefits (financial benefits) from the adaptation measure are identified as follows:

- Benefit from higher endurance to climate risk: less annual maintenance costs for the electrical wiring system during a 100 years' time horizon.
- Benefit from increased expected lifespan: less replacement frequency is expected to reduce from once in a 20 years' time to once in a 50 years' time.

Similar to the previous adaptation measures, the increase expected lifespan of the electrical wiring system is identified according to our expert consultation using questionnaire, which results a 30-year increase. In addition, the benefit from higher endurance to climate risk is measured based on the saving of maintenance cost. This saving is estimated according to the maintenance cost and the probability of such cost occurs.

- The maintenance cost for electrical wiring system was not identified in the design of CLCB sluice gates. Moreover, the standard maintenance cost from 0.18 to 0.25 percent of the total investment set by Circular No. 03/2017/TT-BXD on Guideline for determination of costs of maintenance of construction works (dated 16 March 2017) cannot be used in this case, since investment for electrical wiring system is only 10 billion VND (accounted for 0.3 percent of the total investment for CL-CB sluice gates). In fact, an annual maintenance cost of 0.18 percent of total investment would be too much for the electrical wiring system, which cost only 0.3 percent of total investment. Thus, we identify the maintenance cost for electrical wiring system based on the 7 components of the system, which is clarified in the construction drawings of CL-CB sluice gates and in the expert consultation. In addition, the maintenance cost of the lightning protection system is negligible as it is not normally repaired in reality.
- The probability of occurring maintenance cost is equivalent to the the risk scores (R) in PIEVC analysis for the electric system. 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 ∆ R is estimated at 1.56%.

Table 9: The percentage change in risk scores (R) for electric system

Climate factor	Risk Baseline (R0)[a]	Risk Future (R1)[a]	Standardized[b] change in R: [(R1-R0)/R0]/49
Heavy rain	1	2	0.03
Tropical storm/depression	4	5	0.01
High wind	3	4	0.01
Tornado	6	7	0.03
Thunderstorm/ lightning	7	7	0.00
Average ∆R of electric system			**1.56%**

- [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.

The financial benefits of undergrounding the electrical wiring and upgrading the lightning protection system are calculated on an annual basis and discounted to present in a 100-year horizon. Accordingly, the Net present value (NPV) and Benefit-cost ratio (BCR) of adaptation measure 3 is presented in Table 10 below. The results show that the investor should invest in undergrounding the electrical wiring and upgrading the lightning protection system.

Table 10: NPV and BCR of undergrounding the electrical wiring and upgrading the lightning protection system

	Sum value of CL – CB sluice gates
PV of benefits	8,315,264,129
Maintenance cost saving due to adaptation (VND/year)	11,175,899
Replacement cost saving due to adaptation (VND)	3,250,000,000*
PV of costs	7,359,255,477
Cost of the measure (VND)	6,500,000,000**
Cost of replacement (VND)	5,000,000,000***
NPV (VND)	**1,104,141,547**
BCR (financial analysis)	**1.16**
IRR (financial analysis)	**2.58%**

*Note: * cost occurs in year 20th, 40th, 60th, 80th; ** cost occurs at the present; *** cost occurs in year 50th*

7.5. Examining social benefits of the adaptation measures

7.5.1. The survey results of farmers' damages and willingness-to-pay for improving sluice gate system

Farmers' damages

Increasing the climate-resilience of the sluice gates would also benefit the agricultural production households in the project area. Thanks to the adaptation measures to climate change, the Cai Lon - Cai Be sluice gates would work stably, creating favourable conditions for agricultural production households in the project area. Their benefit would be the avoided damages because of inadequate water availability for agricultural production when the sluice gates fail due to climate change. The avoided damage estimate is based on the average household income lost during salinity intrusion. This income is calculated from the household survey during the April 2021 survey trip.

The research team surveyed 213 households in Chau Thanh, An Bien and Hon Dat Districts, in which data of 108 households in Chau Thanh and An Bien are included in this analysis as they are directly affected by the Cai Lon – Cai Be Sluice Gates Project. There are 31 shrimp-rice farmers, 44 rice farmers with 1 or 2 crops per year and 33 rice farmers with 3 crops per year in the sample.

For 1-2 rice-crop farming households, the average revenue and cost per hectare per year are shown in the Table 11. The survey shows that the largest percentage of loss that the households have faced in recent years due to salinity intrusion is 38% 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 19%. Thus, thanks to the Cai Lon - Cai Be sluice, one hectare of production by rice growers will avoid losses of VND 11,230,629 or USD 484.48.

Table 11: Benefit of climate proofing measures for 1-2 rice-crop farming households

Items	Value (VND/hectare)
Annual revenue	59,430,564
Annual cost	25,127,543
The highest loss (in percentage) in recent years due to salinity intrusion	38%
Average loss (in percentage)	19%
Decrease in net income due to salinity intrusion or benefit of the Sluice Gates (VND)	11,230,629
Decrease in net income due to salinity intrusion or benefit of the Sluice Gates (USD)	484.48

The same method is applied for 3 rice-crop farming households. 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, which means the average loss is assumed as a half or 17.5%. Then the average avoided loss of 3 rice-crop farmers is VND 18.595.697/ha (USD 802.2).

Table 12: Benefit of climate proofing measures for 3 rice-crop farming households

Items	Value (VND/hectare)
Annual revenue	106,897,418
Annual cost	53,535,910
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 (VND)	18,595,697
Decrease in net income due to salinity intrusion or benefit of the Sluice Gates (USD)	802.2

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%. Note that the loss reported by the households is for the income from rice crop. Thus, the benefit of Cai Lon - Cai Be sluice is helping shrimp-rice farmers avoid loss of VND 7,170,961 per hectare per year or USD 309.35.

Table 13: Benefit of climate proofing measures for shrimp-rice farming households

Items	Value (VND/hectare)
Annual revenue	114,516,159
Annual cost	33,377,983

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 (VND)	7,170,961
Decrease in net income due to salinity intrusion or benefit of the Sluice Gates (USD)	309.35

Willingness-to-pay for improving the sluice gate system

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. In the survey, the respondents were asked how much they were willing to pay for improving the sluice gate system on an annual basis. They were explained that the money collected would be managed by a committee with representatives of local government and farmers and would be used for the operations as well as repair and maintenance of the sluice gates. Table 14 shows the average WTP of three groups of farmers.

Table 14: Average WTP of three groups of farmers

	WTP (VND per hectare per year)	WTP (USD per hectare per year)
1-2 rice-crop farmers	86,578	3.73
3 rice-crop farmers	116,617	5.03
Shrimp-rice farmers	100,198	4.32

Beneficial area

In order to estimate social benefit of the climate proofing measures, it is necessary to identify the area of each farming model in the project area. The CL-CB Sluice Gates' investor reported that the area of 3 rice-crop production, 2 rice-crop production and shrimp-rice production is 14,404 ha, 140,450 ha and 91,046 ha respectively (Environmental Impact Assessment Report). However, the ability of protection of CL-CB sluice gates is different across the provinces in the project area. Therefore, we will divide the project area into zones depending on their benefit from CL-CB sluice gates system.

According to the Feasibility Study of Cai Lon – Cai Be Sluice Gates, the total project area is 909,248 ha, in which Kien Giang's area is 330,803 ha, Hau Giang's area is 160,245 ha, Bac Lieu's area is 63,779 ha, Ca Mau's area is 204,351 ha, Soc Trang's area is 6,175 ha and Can Tho's area is 143,895 ha. Consulting with PMU10 showed that these provinces can be divided into three zones based on score of protection. Zone 1 includes Kien Giang and Hau Giang with the highest score of 19 and the weight based on the score is 1. Zone 2 consists of Bac Lieu and Ca Mau with the total score of 11, thus the weight is 0.55. Can Tho and Soc Trang are in zone 3 with the total score of 5, therefore the weight is 0.25. Based on the proportion of the area of each zone in the project area, we can calculate the beneficial area of each farming model with their weight as in Table 15.

Table 15: Beneficial area of the farming models

	Zone 1 (Kien Giang, Hau Giang)	Zone 2 (Bac Lieu, Ca Mau)	Zone 3 (Can Tho, Soc Trang)	Total area
Area (ha)	491,048	268,130	150,070	909,248
Proportion in total area	54%	29%	17%	100%
1-2 rice crop production (ha)	75,851	41,418	23,181	140,450
3 rice crop production (ha)	7,794	4,248	2,377	14,404
Shrimp-rice production (ha)	49,170	26,849	15,027	91,046
Weight	1	0.55	0.25	

The information of decrease in net income due to salinity intrusion and the WTP of each farming models and the beneficial areas will be used to estimate the social benefit of climate proofing measures in the next parts of this report.

7.5.2. Social economic analysis of the measure of upgrading concrete for pillars and ship locks

The social benefit of climate proofing measures in this report is the benefit of agricultural households in the project area. The first method to estimate this benefit is using avoided loss data. The avoided loss of each farming model was calculated in 7.5.1. Those values were the benefit of the households from the whole sluice gate system. To estimate the benefit of the measure of upgrading concrete for pillars and ship locks only, we multiply those values with the average reduction in risk score ΔR of the measure, which was estimated at 2.05%. Then the application upgrading concrete for pillars and ship locks of Cai Lon - Cai Be project will help the 1-2 rice-crop farmers avoid loss of VND 230,288/ha/year or USD 9.93/ha/year, avoided loss of 3 rice-crop farmers is VND 381,212/ha/year or USD 16.45/ha/year, and shrimp-rice farming households avoid the damage of VND147,005 /ha/year or USD 6.34/ha/year.

Multiplying the benefit of the climate proofing measure of each farming model with its corresponding area and weight in Table 15, we have the value of annual avoided loss in the whole project area as presented in Table 16. Applying NPV formula with the discount rate as discussed and the original year of 2020, the Present value of the households' benefit is estimated at VND 1,017,059,024,353.38. The PV of total benefit which includes investor's and social benefit of upgrading concrete for pillars and ship locks is VND1.093 billion or USD 47.147 million.

Table 16. Annual avoided loss of farmers due to upgrading the concrete for pillars and ship locks

Farming models	Annual avoided loss
Avoided loss of 1-2 rice crop farmers	24,041,844,294

Avoided loss of 3 rice crop farmers	4,082,606,660
Avoided loss of shrimp-rice farmers	9,951,308,236
Total	**38,075,759,190**

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 1.043 billion or USD 45.008 million 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 all the agricultural households in the project area is counted in this analysis. The benefit/cost ratio (BCR) also increases to 22.03, meaning that every dollar spent on climate proofing would bring 22.03 dollars benefit to the whole society. The social IRR is 76.8%, which is much larger than the social discount rate. This implies that such adaptation measure is economically beneficial from both investor and society's point of view.

The second approach to estimate the social benefit is using WTP of households. In the part 6.2.5.1, we calculated the average WTP per hectare per year for improving all the sluice gate system. To get the benefit of concrete upgradation for pillars and ship locks only, we use the weight of the percentage of cost of concrete of pillars and ship locks in total cost of the project, which is 13.35%. The WTP for concrete upgradation thus is presented in Table 17, with the total WTP is calculated from the beneficial area of each group of farmers.

Table 17: WTP for upgrading concrete for pillars and ship locks

	WTP for concrete upgrading (VND/ha/per year)	Total annual WTP
3 rice crop farmers	15,567	166,711,697
1-2 rice crop farmers	11,557	1,206,841,478
Shrimp-rice farmers	13,375	905,396,348
	Total	**2,278,949,523**

The PV of social benefit would be VND 60.874 billion (USD 2.26 million) and the total PV of investor's and social benefit is VND 136.735 billion (USD 5.898 million). With the cost stays the same at VND 49.6 billion, NPV of the adaptation measure (concrete upgradation for pillars and ship locks) is VND 87.135 billion, equivalent to USD 3.759 million. In this estimation, the BCR is lower, at 2.76, meaning that every dollar spent on climate proofing would bring 2.76 dollars benefit to the whole society. The IRR now is 6.59%, which is still larger than the social discount rate.

7.5.3. Social economic analysis of the measure of using epoxy coating for the sluice gates

The society's net benefit can also be calculated by adding the benefit of the households in the project area. Coating the sluice gates with epoxy may not directly decrease the risk of failed operation of sluice gates, thus using avoided loss approach to estimate the social benefit of the adaptation is not relevant. But the climate proofing measure would enhance the efficiency of the sluice gates' operation. In this case, using WTP for improving this component is the appropriate method. Applying the similar calculation of WTP as for the upgrading concrete measure, we have the WTP for using Epoxy coating for the sluice gates (Table 18). Then the PV of total social benefit is VND 839.810 million or USD 36.229. The social NPV would be VND 97.02 billion or USD 4,185,287. The social BCR is 8.98 and the IRR is 37.45%. The NPV of society is higher than NPV of the investor, which means that the adaptation measure is very beneficial for the whole society.

Table 18: WTP for epoxy coating of the sluice gates

	WTP for Epoxy coating of the sluice gates (VND/ha/per year)	Total annual WTP
3 rice crop farmers	185	19,312,830
1-2 rice crop farmers	137	1,470,459
Shrimp-rice farmers	159	10,756,722
	Total	**31,540,011**

7.5.4. Social economic analysis of the measure of undergrounding the electrical wiring

Similar to the measure of concrete upgradation, there are two methods to estimate the social benefit of the measure of undergrounding the electrical wiring. In the first method of using avoided loss, the average reduction in risk score ΔR of the measure is 1.56%. With the same steps of calculation, we have the PV of total social benefit is VND 583.128 or USD 25.156 million. The social NPV would be VND 576.192 or USD 24.856 million. The social BCR is 84.07 and the IRR is 891.87%. The NPV of society is higher than NPV of the investor, which means that the adaptation measure is very beneficial for the whole society.

Table 19. Annual avoided loss of farmers due to undergrounding the electrical wiring

Farming models	Annual avoided loss
Avoided loss of 1-2 rice crop farmers	18,295,257,121
Avoided loss of 3 rice crop farmers	3,106,764,092
Avoided loss of shrimp-rice farmers	7,572,702,853
Total	**28,974,724,066**

The second approach to estimate the social benefit is using WTP of households. The calculation is similar to using WTP for the two above measures. The percentage of cost of undergrounding the electrical wiring and upgrading the lightning protection system in total cost of the project is 0.2%.

The WTP for undergrounding electrical lines thus is presented in Table 20, with the total WTP is calculated from the beneficial area of each group of farmers.

Table 20: WTP for undergrounding the electrical wiring

	WTP for undergrounding the electrical wiring (VND/ha/per year)	**Total annual WTP**
3 rice crop farmers	229	2,452,930
1-2 rice crop farmers	170	17,756,989
Shrimp-rice farmers	197	13,321,645
	Total	**33,531,564**

The PV of social benefit would be VND 896 million (USD 38,639) and the sum of PV of social benefit and financial benefit is VND 9.21 billion, equivalent to USD397,352. The NPV of this climate proofing measure is VND 2.275 billion or USD 98.138. The IRR is 3.63%. In this estimation, the BCR is 1.33, meaning that every dollar spent on climate proofing would bring 1.33 dollars benefit to the whole society.

7.6. Sensitivity analysis

In sensitivity analysis, some values that depend on the assumptions will be changed to find out if the net benefits of the adaptation measures are positive or not. In other words, if the assumptions change, will the adaptation measures still financially and socially beneficial? In this study, the assumption of change in risk score and the cost of undergrounding the electricity wiring will be considered.

The changes in risk score were calculated with the assumption that the adaptation measures will reduce the risk score to the baseline level. Due to uncertainty in climate factors, the change in risk score can be lower. Now we assume that the adaptation measures will reduce the risk score by only a half of the base scenario, which means that the change in risk score for the pillars and ship locks is 1.025% and for the electricity system is 0.78%. This change will affect the results of CBA of two adaptation measures: (i) upgrading the concrete for the pillars and ship locks and (ii) undergrounding the electricity wiring and upgrading the lightning protection system. The financial and social NPV and BCR in this scenario is presented in Table 21. It can be seen that the financial and social NPVs in all cases are still positive and the BCRs are larger than 1. Therefore, the adaptation measures are still efficient.

Table 21: Sensitivity analysis when the change in risk score decreases by 50%

		Upgrading the concrete		**Changing the electricity system**	
		Avoided loss	***WTP***	***Avoided loss***	***WTP***
Social analysis	NPV (VND)	534,572,593,929	86,917,145,140	319,275,930,286	1,648,226,306
		(1,043,319,805,231)	(87,134,844,266)	(576,191,862,890)	(1,999,818,491)

	NPV (USD)	23,060,974	3,749,526	13,773,272	71,103
	BCR	11.78	2.75	47.03	1.22
		(22.03)	(2.76)	(84.07)	(1.29)
Financial analysis	NPV (VND)	26,043,081,753		900,682,257	
		(26,260,780,878)		(1,104,141,547)	
	NPV (USD)	1,123,475		38,855	
	BCR	1.53		1.13	
		(1.53)		(1.16)	

Notes: Values calculated in the base scenario are in parentheses

In the base scenario, the cost of undergrounding the electricity wiring and upgrading the lightning protection system is provided by the PMU10. Literature review shows that the cost of undergrounding the electricity wiring can be as high as 4 times of the cost of overhead wiring (Public Service Commission of Wisconsin, 2011). Using this assumption, we conducted the CBA for the investor and the society. Table 22 shows the results of this analysis. If the cost of undergrounding the electricity wiring is higher, the financial NPV will be negative, at VND -8.157 billion or USD -351.895. The BCR is 0.29 which is much lower than 1, which means that this adaptation measure is not profitable for the investor. However, if we add the social benefit estimated by avoided loss method, the social NPV will be positive at VND 770.364 billion or USD 33.232.795 and the BCR is very high of 112.07. Using WTP method still results in negative social NPV.

Table 22: Sensitivity analysis when the cost of undergrounding the electricity wiring can be as high as 4 times of the cost of overhead wiring

		Changing the electricity system	
		Avoided loss	***WTP***
Social analysis	NPV (VND)	424,878,416,252	-2,697,560,957
		(576,191,862,890)	(2,274,922,438)
	NPV (USD)	18,328,867	-116,370.32
	BCR	62.26	0.61
		(84.07)	(1.33)
Financial analysis	NPV (VND)	-8,360,678,556	
		(1,104,141,547)	
	NPV (USD)	-360,672	
	BCR	0.27	
		(1.16)	

Notes: Values calculated in the base scenario are in parentheses

8. Implementing CBA for sluice gates system in Mekong Delta

The steps of economic analysis for climate proofing measures of Cai Lon – Cai Be Sluice Gate Project can be expanded for other sluice gates in Mekong Delta. Climate factors may affect the operation of the sluice gates, and a climate risk assessment is conducted. The assessment more precisely identifies the potential impacts of climate change on the project and identifies possible option(s) (if any) to mitigate or alleviate these projected adverse impacts. These options are subjected to a technical feasibility and economic viability analysis. The economic analysis is to support decision making as it provides information on the economic efficiency of the climate proofing investment. Economic analysis will focus on the identification, valuation and comparison of social cost and benefit of climate proofing measure in following steps.

Step 1: Specify the climate proofing measures. In step 1, it is necessary to specify the climate proofing measures for the sluice gates to analyse. Economic analysis compares the net social benefits of investing resources in one or more particular potential measures with the net social benefits of the infrastructure that would be displaced if the climate proofing measures under evaluation were to proceed. The displaced project is often called the counterfactual. Usually, the counterfactual is the status quo, which means there is no climate proofing measures undertaken. Thus, one can interpret these benefits, costs, and net benefits as incremental amounts.

Data source: The climate proofing measures put into economic analysis must be the recommendations from climate risk assessment report. The measures recommended by CRA experts will ensure that they are technically feasible and climate proofing. Discussion with the sluice gate operators or the investors is necessary to recognize the measures that were being applied in the works or will be applied soon.

For economic analysis, the measures should be able to be described in detail: the technical specifications, the types of materials that would be used, the quantity of materials, the frequency of repair, maintenance and replacement, etc. This information can be collected from CRA experts and sluice gate operators/investors.

Step 2: Decide the scope of the analysis: In the second step, it is necessary to decide who has standing; that is, whose benefits and costs should be included. The analyst must decide the geographical area and the time horizon for analysis. The geographical area and time horizon will decide the impacts of the climate proofing measures of sluice gate system. For estimation of social benefit, it is important to know how many people as well as which production are protected by the sluice gates. Besides, infrastructure last a long time and the impacts may change over the years, thus we must determine the length of time for analysis.

Data source: Normally the geographical area is the beneficial area of the sluice gates, which can be decided based on the project documents of the sluice gates or consulting with water resource/agricultural experts. The time horizon for analysis is normally the lifetime of the sluice gates.

Large sluice gate works such as Cai Lon – Cai Be can last 100 years while smaller sluice gates have shorter lifetime.

Step 3: Predict the impacts quantitatively over the life of the project: The next task is to quantify all impacts in each period. The analyst must make predictions about the impacts for the with-climate-proofing-measures and without-climate-proofing-measures scenarios alternatives, for each year, and for each category of stakeholders. The cost of applying climate proofing measures for the sluice gates is the incremental cost for the investors, which includes the investment of climate proofing measures. The benefits of apply climate proofing measures for the sluice gates can be categorized as follows:

- For the investor/operator: Climate proofing measures would prolong the lifetime of components of the sluice gates, resulting in savings in repair and maintenance cost as well as replacement cost. The lifetime of the components in the with-climate-proofing-measures and without-climate-proofing-measures scenarios alternatives are different, thus it is important to identify the change in lifetime between the two mentioned scenarios.
- For the society: Climate proofing measures would reduce the risk of failure of sluice gates, which helps the farmers to avoid the loss of agricultural production, the cost of adaption to salinity intrusion, and loss of property if applicable.

Data source:

Cost of the investor/operator: The economic analysts should consult the investor/operator to find out how the climate proofing measures would change the structure or the operation of the sluice gate in the with-climate-proofing-measures scenario in comparison with the without-climate-proofing-measures scenario.

Benefit of the investor/operator: Consulting with CRA experts, sluice gate investor/operator, climate and civil experts is necessary to get the information on cost items of repair, maintenance and replacement and lifetime of the components in the with-climate-proofing-measures and without-climate-proofing-measures scenarios at the best estimation. Desk study and literature review is helpful when the local information is not available as some of the measures may have not applied in the area before.

Benefit of the society: Similar to identifying the cost/benefit of the investor/operator, the impacts on the society of climate proofing measures for sluice gate system should be found by consultation. In the Mekong Delta, the farmers have some types of adaptation measures to saline intrusion such as construction measures, adjusting planting calendar/techniques, crop and variety diversification, water management, diversifying income sources and other measures. Consultation with local government and local farmers would help the analyst understand the specific measures in the study area as well as the farming model and the loss due to sluice gates' failure that local farmers have to face. In-depth interview and focus group discussion are useful methods in this step so that a semi-structured questionnaire can be designed for next step.

Step 4: Monetize all impacts: The analysts next must monetize each of the impacts. To monetize means to value in Vietnam Dong (VND).

For the investor/operator: In this project, the analysts will monetize the additional cost of undertaking the climate proofing measures the sluice gates in Mekong Delta. With this information, market valuation can be used to evaluate the direct costs of climate proofing based on the additional costs necessary to increase effectiveness. The financial benefit is the avoided cost when the negative impacts of climate change on the Cai Lon – Cai Be sluice gates are minimized. This cost is evaluated based on the market price of the cost to fix, improve, or renovate the sluice gates when climate risks happen and damage the structure.

For the society: Benefits of the residents in the affected area are saved cost of self-adaptation measures and the avoided damages on production, properties and human health. In some cases, the benefits can be measured by market price while with some other cases, the avoided damages 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.

Data source:

Cost of the investor/operator: The investment cost in climate proofing measures can be collected from the sluice gates investor/operator and suppliers in the market. It is necessary obtain the best estimation of the cost for the materials, and at the same time to ensure that the applied solutions are modern and consistent with the provisions in Vietnamese standards.

Benefit of the investor/operator: It is similar to estimating the investment cost of climate proofing measures, but now the analysts have to collect the repair and maintenance cost in the with-climate-proofing-measures and without-climate-proofing-measures scenarios. It should be noted that these costs may not only different in values but also in the time of incurring. Longer lifetime of components because of climate proofing measures would lead to less repair and maintenance and replacement cost in all the duration of the sluice gates.

Benefit of the society: The benefit of the society can be measured by market price method or by non-market valuation method.

The analysts should collect data from reports on annual cost of adaptation and loss of production, properties and human health due to flood/ saline intrusion in the study areas. This kind of information can be found from reports of local governments (Provincial Department of Agriculture and Rural Development, Provincial and District People's Committees and the Office of Statistics), reports of related agencies and previous academic studies. The data can also be collected by household survey. Based on literature review, in-depth interview and focus group discussion with local officials and farmers, a semi-structured questionnaire should be designed with questions on cost of adaptation and loss of production, properties and human health due to flood/ saline intrusion. The respondents are the farmers, who should be selected in a sample that represented all the farmers in the study area.

If the analyst would like to use non-market valuation method, a household survey is also necessary to obtain the data on annual willingness-to-pay (WTP) for applying the climate proofing measures for the sluice gates. The contingent valuation method (CVM) is popular in this case.

Data analysis:

Cost and benefit of the investor/operator: The incremental cost of applying climate proofing measures, the cost of replacement and the repair and maintenance cost in the with-climate-proofing-measures and without-climate-proofing-measures scenarios should be allocated in their relevant time of incurring. The monetized value of benefits will be calculated based on the percentage of risks mitigated with the climate proofing measures. In principle, we can measure the effectiveness of climate proofing an infrastructure as ranging between 0 and 100 percent, where 100 percent means that with certainty floods, salinity intrusion or tropical storm will not damage or destroy the infrastructure. Change in climate risk score can be calculated from CRA report and is used to determine the financial benefit of applying a particular climate proofing measure by multiplying the change in climate risk score with the replacement cost of the investor.

Benefit of the society: Data collected from household survey should be analysed to find the average monetized value of adaptation cost and damages per hectare. Then the benefit of the society can be obtained by multiply these average values with the total production area of the study area. It should be noted that the change in climate risk score should be considered when calculate the social benefit because the data surveyed is the avoided cost of all the households when the whole sluice gate system operates effectively while we are estimating the benefit of climate proofing measures only. Similarly, data of WTP from CVM survey should be analysed to find out the average value per household or hectare, then the total benefit of applying a climate proofing measure can be obtained by multiplying the average WTP with the total number of household or total area in the study area. The results from benefit estimation are annual values, which will be used for discounting in the next step.

Step 5: Discount benefits and costs to obtain present values: For a project that has impacts that occur over years, we need a way to aggregate the benefits and costs that arise in different years. In economic analysis, future benefits and costs are discounted relative to present benefits and costs in order to obtain their present values (PV). The need to discount arises for two main reasons. First, there is an opportunity cost to the resources used in a project. Second, most people prefer to consume now rather than later. The social discount rate can be chosen based on previous study and economic analysis of public projects in Vietnam.

A spreadsheet is helpful for discounting. The economic analyst should create a table with rows and columns for year and the cost/benefit. Then the value of each cost/benefit item can be put in its corresponding year. Using the functions or formula in the spreadsheet, the PV of a stream of cost or benefit is calculated as follows:

$$PV(B_i) = \sum_{t=0}^{n} \frac{B_{it}}{(1+r)^t}$$

And

$$PV(C_i) = \sum_{t=0}^{n} \frac{C_{it}}{(1+r)^t}$$

In which: B_{it}: the benefit i in year t

C_{it}: the cost i in year t

r: the social discount rate

n: the lifetime of the project

Noted that the PV of financial benefit is calculated as the change in PV of replacement cost and change in PV of repair and maintenance cost. Then the PV of the total benefit/cost is the sum of PV of each benefit/cost item.

The net present value (NPV) of a particular climate proofing measure equals the difference between the PV of all the benefit and the PV of all the cost:

$$NPV = PV(B) - PV(C)$$

The basic decision rule for a single climate proofing measure (relative to the status quo) is that the climate proofing measure should be undertaken NPV is positive. In short, a climate proofing measure is recommended from the economic point of view if its benefits exceed its costs. When there is more than one alternative to the status quo and all the alternatives are mutually exclusive, then the rule is slightly more complicated: select measure with the largest and positive NPV. If no NPV is positive, then none of the specified alternatives are superior to the status quo, which should remain in place.

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:

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

The third criteria to evaluate the efficiency of the intervention is the internal rate of return. The internal rate of return (IRR) is the rate of discount that produces a net present value of zero (that is, it is the rate that equalises the discounted costs and the discounted benefits).

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

In general, when the estimated IRR exceeds the selected discount rate, NPV is positive, and the measure are efficient from economic point of view. When the estimated IRR is less than the selected discount rate, NPV is negative, and the measure is considered as inefficient. However, some options may not have IRR, for example in the case that if the net annual benefits over the lifetime of an option are all positive or negative.

Step 6: Perform sensitivity analysis: There may be considerable uncertainty about both the predicted impacts and the appropriate monetary valuation of the impact. For example, the analyst may be uncertain about the damages of production, properties, and human life and about the appropriate monetary value to place on each benefit. The social discount rate may also change over time due to change in macroeconomic context. The climate risks may change when there are updates on climate and hydrological factors. Sensitivity analysis attempts to deal with such uncertainties.

Step 7: Make a recommendation: Assuming that the analysed climate proofing measures are not mutually exclusive, the climate proofing measures with positive NPV will be recommended.

9. Conclusion

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 study undertakes a cost - benefit analysis of applying three climate proofing measures, which are (1) upgrading concrete for pillars and ship locks, and (2) using epoxy coating for the sluice gates, and (3) undergrounding electrical lines. 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, the sluice gates and the electrical lines. 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 those measures are all positive indicating high economic efficiency for the whole society. The results of key indicators for cost - benefit analysis of applying those climate proofing measures are summarised in Table 23.

Table 23: Key indicators for cost - benefit analysis of applying three climate proofing measures

		Upgrading the concrete		Epoxy coating	Changing the electricity system	
		Avoided loss	WTP	WTP	Avoided loss	WTP
Social analysis	NPV (VND)	1,043,319,805,231	87,134,844,266	97,018,442,042	576,191,862,890	1,999,818,491

		Upgrading the concrete		Epoxy coating	Changing the electricity system	
		Avoided loss	**WTP**	**WTP**	**Avoided loss**	**WTP**
	NPV (USD)	45,007,864	3,758,918	4,185,287	24,856,391	86,270
	BCR	22.03	2.76	8.98	84.07	1.29
	IRR	76.80%	6.59%	37.45%	891.87%	3.69%
Financial analysis	NPV (VND)	26,260,780,878		96,178,632,164	1,104,141,547	
	NPV (USD)	1,132,866		4,149,058	47,632	
	BCR	1.53		8.91	1.16	
	IRR	4.86%		36.78%	2.58%	

Our sensitivity analysis shows that the changes in risk score still result in positive values of both financial and social NPVs in all cases. However, if the cost of undergrounding the electricity wiring is as high as 4 times of the cost of overhead wiring higher, the financial NPV will be negative, and the social benefit will only positive when the avoided loss method is applied. Given the uncertainty about the cost level of the measure of undergrounding the electricity wiring, it should be careful to interpret the results of the CBA of undergrounding the electricity wiring.

Overall, the results of our CBA show that the three climate proofing measures are efficient both from the investor and the society's point of view. Thus, it is strongly recommended that the investor should invest in climate proofing measures at the beginning for long term benefits.

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Appendix 1: Contents discussed during field trips

Field trip 1: Secondary sources

Contents	Stakeholders
Natural and Socio-economic characteristics of study sites: area, population, economic structure, GDP, GDP growth, GDP per capita… in recent years	GSO, People's Committees at provincial, district and communal level.
Main economic activities at the study sites which can be affected by climate change: area, number of households, output of production (rice cultivation, shrimp farming, fruits…)	DARD, People's Committees at provincial, district and communal level
Infrastructure and public and private properties in the study sites which can be affected by climate change	
Development and trend of climate change over the years and forecast for the future	DARD, climate experts, People's Committees at provincial, district and communal level
Impacts of climate change at the study sites	
The role of climate proofing measures for Cai Lon – Cai Be sluice gates	

Field trip 2: Primary sources

Contents	Stakeholders
Interview with semi-structured questionnaires focusing on: (1) Loss of income/properties due to climate change/natural disasters when there is no climate proofing measures (2) Residents' assessment of to health/environmental benefits (if applicable) when the impact of climate change is mitigated.	Households at the study site: - Rice farmer - Shrimp farmer - Other households whose livelihoods are affected by climate change - Enterprises

Appendix 2: Questionnaires

QUESTIONNAIRE ON THE IMPROVEMENT OF SALINITY CONTROL SLUICE GATE SYSTEM

SECTION FOR INTERVIEWER:

Interviewer code: ....Numberical order of the respondent: ....

Date of survey:.............................**Place of survey (***District***)**: ....

SECTION A: SALINITY INTRUSION ASSESSMENT

A1. Would you tell us whether your farm has suffered damaged from salinity intrusion in the past 3 years?

1☐ Yes   If "Yes", please mark "X" on the year/years: ☐ 2018   ☐ 2019   ☐ 2020

0☐ No

A2. Overall, how would you say about the level of salinity intrustion in the past 3 years?

3☐ Increase   2☐ Decrease   1☐ No change   0☐ No idea

A3. Regarding the **reason** of salinity intrusion, please choose any number from 1 to 7 in the answer to best describe your opinion.

Very disagree			**Neutral**			**Very agree**
1	2	3	4	5	6	7

1)	Due to sea level rise	1	2	3	4	5	6	7
2)	Due to lack of fresh water coming from upstream	1	2	3	4	5	6	7
3)	Due to drough, less rain	1	2	3	4	5	6	7
4)	Due to the reduced water capacity of the region	1	2	3	4	5	6	7
5)	Due to the increasing demand for water of the region	1	2	3	4	5	6	7
6)	Other, please specify:	1	2	3	4	5	6	7

A4. If there is **no adaptation measure**, would you please tell us **the possibility** of your household **being affected** by saline intrusion in the following aspects. Please choose any number from 1 to 7 in the answer to best describe your opinion.

No possibility			**Medium possibility**			**Very high possibility**
1	2	3	4	5	6	7

1)	Reduce income	1	2	3	4	5	6	7
2)	Reduce the value of assets (e.g. price of estates, farm land)	1	2	3	4	5	6	7
3)	Impact on water for production	1	2	3	4	5	6	7
4)	Impact on drinking water	1	2	3	4	5	6	7
5)	Reduce crop production	1	2	3	4	5	6	7
6)	Reduce aquaculture production	1	2	3	4	5	6	7
7)	Impact on health	1	2	3	4	5	6	7
8)	Cause worry about possible damage	1	2	3	4	5	6	7
9)	Impact on the local living environment	1	2	3	4	5	6	7
10)	Other, please specify:	1	2	3	4	5	6	7

A5. Due to the **impacts of salinity intrusion** in the recent years, would you please tell us **your assessment of the following consequences** in your locality. Please choose any number from 1 to 7 in the answer to best describe your opinion.

Negligible			**Moderate**			**Very severe**
1	2	3	4	5	6	7

11)	Reduce income	1	2	3	4	5	6	7
12)	Reduce the value of assets (e.g. price of estates, farm land)	1	2	3	4	5	6	7
13)	Impact on water for production	1	2	3	4	5	6	7
14)	Impact on drinking water	1	2	3	4	5	6	7
15)	Reduce crop production	1	2	3	4	5	6	7
16)	Reduce aquaculture production	1	2	3	4	5	6	7
17)	Impact on health	1	2	3	4	5	6	7
18)	Cause worry about possible damage	1	2	3	4	5	6	7
19)	Impact on the local living environment	1	2	3	4	5	6	7
20)	Other, please specify:	1	2	3	4	5	6	7

A6. how would you say about the level of salinity intrustion in the **next** 3 years?

3☐ Increase 2☐ Decrease 1☐ No change 0☐ No idea

PART B: ASSESMENT OF PRIVATE ADAPTATION TO SALINITY INTRUSION

B1. Would you please tell us **which of the following measures you have done to adapt to salinity intrusion**?

#	Adaptation measures	Yes	No
Group 1 – Construction measures			
1.1	Building and repairing dykes/embankments for your own fields	☐	☐
1.2	Dredging canals and ditches in the field	☐	☐
1.3	New drilling/repair of underground water wells	☐	☐
Group 2 - Adjusting planting calendar/techniques			
2.1	Changing timing of planting and harvesting	☐	☐
2.2	Changing timing of pumping water to match the salinity levels	☐	☐
2.3	Changing timing of fertilizer/chemical use	☐	☐
2.4	Changing the amount of fertilizer/chemical use	☐	☐
Group 3 - Crop and variety diversification			
3.1	Using short-term varieties	☐	☐
3.2	Switching to salt-tolerant rice varieties	☐	☐
3.3	Crop rotation	☐	☐
3.4	Planting some other plants besides rice	☐	☐
Group 4 – Water management			
4.1	Investing in water storage	☐	☐
4.2	Changing water use practices to save water, recycling water	☐	☐
4.3	Filtering water	☐	☐
4.4	Buying water from other sources	☐	☐
Group 5 – Diversifying income sources			
5.1	Changing from farming to non-farming activities	☐	☐
5.2	Moving from crops to livestock (partly or totally)	☐	☐
5.3	Moving from crops to aquaculture (partly or totally)	☐	☐
Group 6 – Other measures			
6.1	Measuring the salinity of water	☐	☐
6.2	Following information on salinity intrusion on TV, radio, newspapers, internet, etc.	☐	☐
6.3	Following information on salinity intrusion announced by local authorities	☐	☐

6.4	Buying agricultural insurance	☐	☐
6.5	Migrating to another place	☐	☐
6.6	Other, please specify:	☐	☐

B2. Would you please tell us to what extent you perceive **your own ability to perform the following adaptive measures**? Please choose any number from 1 to 7 in the answer to best describe your opinion.

Extremely easy			**Medium**			**Extremely difficult**
1	2	3	4	5	6	7

	Group 1 – Construction measures							
1.1	Building and repairing dykes/embankments for your own fields	1	2	3	4	5	6	7
1.2	Dredging canals and ditches in the field	1	2	3	4	5	6	7
1.3	New drilling/repair of underground water wells	1	2	3	4	5	6	7
	Group 2 - Adjusting planting calendar/techniques							
2.1	Changing timing of planting and harvesting	1	2	3	4	5	6	7
2.2	Changing timing of pumping water to match the salinity levels	1	2	3	4	5	6	7
2.3	Changing timing of fertilizer/chemical use	1	2	3	4	5	6	7
2.4	Changing the amount of fertilizer/chemical use	1	2	3	4	5	6	7
	Group 3 - Crop and variety diversification							
3.1	Using short-term varieties	1	2	3	4	5	6	7
3.2	Switching to salt-tolerant rice varieties	1	2	3	4	5	6	7
3.3	Crop rotation	1	2	3	4	5	6	7
3.4	Planting some other plants besides rice	1	2	3	4	5	6	7
	Group 4 – Water management							
4.1	Investing in water storage	1	2	3	4	5	6	7
4.2	Changing water use practices to save water, recycling water	1	2	3	4	5	6	7
4.3	Filtering water	1	2	3	4	5	6	7
4.4	Buying water from other sources	1	2	3	4	5	6	7
	Group 5 – Diversifying income sources							
5.1	Changing from farming to non-farming activities	1	2	3	4	5	6	7
5.2	Moving from crops to livestock (partly or totally)	1	2	3	4	5	6	7
5.3	Moving from crops to aquaculture (partly or totally)	1	2	3	4	5	6	7
	Group 6 – Other measures							

6.1	Measuring the salinity of water	1	2	3	4	5	6	7
6.2	Following information on salinity intrusion on TV, radio, newspapers, internet, etc.	1	2	3	4	5	6	7
6.3	Following information on salinity intrusion announced by local authorities	1	2	3	4	5	6	7
6.4	Buying agricultural insurance	1	2	3	4	5	6	7
6.5	Migrating to another place	1	2	3	4	5	6	7
6.6	Other, please specify:	1	2	3	4	5	6	7

B3. Next, we would like to know to what extent you believe in **the effectiveness** of the following adaptive measures? Please choose any number from 1 to 7 in the answer to best describe your opinion.

Extremely ineffective			**Average**			**Extremely effective**
1	2	3	4	5	6	7

Group 1 – Construction measures								
1.1	Building and repairing dykes/embankments for your own fields	1	2	3	4	5	6	7
1.2	Dredging canals and ditches in the field	1	2	3	4	5	6	7
1.3	New drilling/repair of underground water wells	1	2	3	4	5	6	7
Group 2 - Adjusting planting calendar/techniques								
2.1	Changing timing of planting and harvesting	1	2	3	4	5	6	7
2.2	Changing timing of pumping water to match the salinity levels	1	2	3	4	5	6	7
2.3	Changing timing of fertilizer/chemical use	1	2	3	4	5	6	7
2.4	Changing the amount of fertilizer/chemical use	1	2	3	4	5	6	7
Group 3 - Crop and variety diversification								
3.1	Using short-term varieties	1	2	3	4	5	6	7
3.2	Switching to salt-tolerant rice varieties	1	2	3	4	5	6	7
3.3	Crop rotation	1	2	3	4	5	6	7
3.4	Planting some other plants besides rice	1	2	3	4	5	6	7
Group 4 – Water management								
4.1	Investing in water storage	1	2	3	4	5	6	7
4.2	Changing water use practices to save water, recycling water	1	2	3	4	5	6	7
4.3	Filtering water	1	2	3	4	5	6	7
4.4	Buying water from other sources	1	2	3	4	5	6	7
Group 5 – Diversifying income sources								

5.1	Changing from farming to non-farming activities	1	2	3	4	5	6	7
5.2	Moving from crops to livestock (partly or totally)	1	2	3	4	5	6	7
5.3	Moving from crops to aquaculture (partly or totally)	1	2	3	4	5	6	7
Group 6 – Other measures								
6.1	Measuring the salinity of water	1	2	3	4	5	6	7
6.2	Following information on salinity intrusion on TV, radio, newspapers, internet, etc.	1	2	3	4	5	6	7
6.3	Following information on salinity intrusion announced by local authorities	1	2	3	4	5	6	7
6.4	Buying agricultural insurance	1	2	3	4	5	6	7
6.5	Migrating to another place	1	2	3	4	5	6	7
6.6	Other, please specify:	1	2	3	4	5	6	7

B4. And we also would like to know to what extent you perceive **the cost consuming of the following adaptive measures (in terms of money, time, effort)**? Please choose any number from 1 to 7 in the answer to best describe your opinion.

Not costly at all			**Average**			**Extremely costly**
1	2	3	4	5	6	7

Group 1 – Construction measures								
1.1	Building and repairing dykes/embankments for your own fields	1	2	3	4	5	6	7
1.2	Dredging canals and ditches in the field	1	2	3	4	5	6	7
1.3	New drilling/repair of underground water wells	1	2	3	4	5	6	7
Group 2 - Adjusting planting calendar/techniques								
2.1	Changing timing of planting and harvesting	1	2	3	4	5	6	7
2.2	Changing timing of pumping water to match the salinity levels	1	2	3	4	5	6	7
2.3	Changing timing of fertilizer/chemical use	1	2	3	4	5	6	7
2.4	Changing the amount of fertilizer/chemical use	1	2	3	4	5	6	7
Group 3 - Crop and variety diversification								
3.1	Using short-term varieties	1	2	3	4	5	6	7
3.2	Switching to salt-tolerant rice varieties	1	2	3	4	5	6	7
3.3	Crop rotation	1	2	3	4	5	6	7
3.4	Planting some other plants besides rice	1	2	3	4	5	6	7
Group 4 – Water management								

4.1	Investing in water storage	1	2	3	4	5	6	7
4.2	Changing water use practices to save water, recycling water	1	2	3	4	5	6	7
4.3	Filtering water	1	2	3	4	5	6	7
4.4	Buying water from other sources	1	2	3	4	5	6	7
Group 5 – Diversifying income sources								
5.1	Changing from farming to non-farming activities	1	2	3	4	5	6	7
5.2	Moving from crops to livestock (partly or totally)	1	2	3	4	5	6	7
5.3	Moving from crops to aquaculture (partly or totally)	1	2	3	4	5	6	7
Group 6 – Other measures								
6.1	Measuring the salinity of water	1	2	3	4	5	6	7
6.2	Following information on salinity intrusion on TV, radio, newspapers, internet, etc.	1	2	3	4	5	6	7
6.3	Following information on salinity intrusion announced by local authorities	1	2	3	4	5	6	7
6.4	Buying agricultural insurance	1	2	3	4	5	6	7
6.5	Migrating to another place	1	2	3	4	5	6	7
6.6	Other, please specify:	1	2	3	4	5	6	7

B5. Please choose **3 biggest obstacles/difficulties** when conducting the above adaptation measures?

1)	Lack of money
2)	Lack of technique
3)	Labour shortage
4)	Lack of information on salinity intrusion and adaptation measures
5)	Lack of supportive policies from the authorities
6)	Other, please specify:

PHẦN C: ASSESSMENT OF PUBLIC ADAPTATION TO SALINE INTRUSION

C1. Would you please **assess the necessity o**f the public adaptation measures **conducted by the State and local authorities?** Please choose any number from 1 to 7 in the answer to best describe your opinion.

Extremely unnecessary			Average			Extremely necessary
1	2	3	4	5	6	7

	Group 1 – Construction measures							
1.1	Upgrading the existing saline control sluice gates	1	2	3	4	5	6	7
1.2	Constructing the Cai Lon – Cai Be sluice gates	1	2	3	4	5	6	7
1.3	Upgrading the existing sea dikes	1	2	3	4	5	6	7
	Group 2 – Non-construction measures							
2.1	Providing free training courses for people on adaptation measures to salinity intrusion	1	2	3	4	5	6	7
2.2	Improving communication system to make the opening and closing of sluices more reasonable with the farming activities	1	2	3	4	5	6	7
2.3	Improving water salinity information and warning system	1	2	3	4	5	6	7
2.4	Compensation for damage when salinity intrusion occurs	1	2	3	4	5	6	7
2.5	Mangrove rehabilitation	1	2	3	4	5	6	7
2.6	Providing better salt-tolerant varieties for farming	1	2	3	4	5	6	7
2.7	Providing water storage devices for farming households	1	2	3	4	5	6	7
2.8	Other, please specify:	1	2	3	4	5	6	7

C2. Now would you please tell us **to what extent you agree** with the following statements? Please choose any number from 1 to 7 in the answer to best describe your opinion.

Strongly disagree			Neutral			Strongly agree
1	2	3	4	5	6	7

1)	State and local authorities know what they have to do to response to salinity intrusion	1	2	3	4	5	6	7
2)	The government salinity warning system is reliable	1	2	3	4	5	6	7
3)	Public adaptation measures are very effective	1	2	3	4	5	6	7

PART D: TRUST IN PUBLIC ADAPTATION MEASURES

D1. Would you please tell us **to what extent you agree** with the following statements? Please choose any number from 1 to 7.

Strongly disagree						**Strongly agree**
1	2	3	4	5	6	7

1)	The sluice gate system **supplies sufficient water** to meet the demands of agricultural production	1	2	3	4	5	6	7
2)	The sluice gate system supplies water **at the right time** for each crop.	1	2	3	4	5	6	7
3)	The sluice gate system supplies water **of good quality** for each crop	1	2	3	4	5	6	7
4)	The sluice gate system is operated **strictly as scheduled** before.	1	2	3	4	5	6	7
5)	The sluice gate system is operated in the way that **ensures the balance between different water users** (i.e., rice farmers and shrimp farmers).	1	2	3	4	5	6	7

D2. Besides the state budget, it is necessary to mobilize the contribution of community for better sluice gates system in Kien Giang province. The collection of a water resource fee for the development and operation of sluice gates system is being considered on an annual basis. This fee will be collected through the Electricity Bill and managed by a communal committee which would include representatives of the local governments, communities and cooperatives.

Could you please tell us the **maximum amount you are willing to pay** for the development and operation of a better sluice gate system? ***Please carefully consider your expenditures for all your family***.

The maximum willingness to pay each year is: VND ....

If your answer is "0", please provide the most relevant reason in your opinion: (put an X in the appropriate box)

1☐	I support a better sluice gate system, but I CAN'T PAY because I have only enough money to spend for me and my family
2☐	I support a better sluice gate system, but I DO NOT BELIEVE my contribution will be USED ONLY for the sluice gate system.
3☐	I support a better sluice gate system, but the GOVERNMENT MUST BE RESPONSIBLE for the entire cost because they already got our taxes.
4☐	I support a better sluice gate system, but I do not agree to pay via ELECTRIC BILL.
5☐	A better sluice gate system is NOT USEFULL for me.
6☐	Others, please specify:

PART E: HOUSEHOLD'S PRODUCTION ACTIVITIES

E1. Profit from household's production activities (in VND million).

		Crop 1	Crop 2	Crop 3
1.1	**Types of rice/shrimp**			
1.2	**Area (ha or m^{2})**			
1.3	**From month…. to month…**			
1.4	**Profit (in one crop or per hectare)**			
1.5	**Revenue**			
1.5.1	Average price			
1.5.2	Average output			
1.6	**Cost of rice farming** *(for rice farmers)*			

		Crop 1	Crop 2	Crop 3
1.6.1	Cost of seed			
1.6.2	Cost of pesticides			
1.6.3	Cost of fertilizers			
1.6.4	Cost of hiring labours			
1.6.5	Number of family members participating in rice farming			
1.6.6	Contribution for water resource service			
1.6.7	Cost of hiring combined harvesting machine			
1.6.8	Cost after harvesting			
1.6.9	Other costs, please specify			
1.7	**Cost of shrimp farming** *(for shrimp farmers)*			
1.7.1	Land rent			
1.7.2	Cost of pond improvement			
1.7.3	Cost of shrimp seeds			
1.7.4	Cost of food			
1.7.5	Cost of medicine			
1.7.6	Cost of electricity, petrol…			
1.7.7	Loan repayment			
1.7.8	Cost of hiring labours			
1.7.9	Number of family members participating in shrimp farming			
1.7.10	Other costs, please specify			

E2. When the water supply does not meet the requirements of saline level, how many percent has the household's income from production been reduced in the past time? ....%

Please tell us the cost of self-defense against saline intrusion:

TT	Measures to adapt to saline intrusion	Cost	Year of spending
	Structural measures		
1.1	Installing and/or repairing dikes/embankments for our own fields		
1.2	Dredging inland canals		
1.3	Drilling and/or repairing water wells		
1.4	Others, please specify:		

Water management			
4.1	Increase water storage		
4.2	Saving and circulating water and		
4.3	Water purification treatments		
4.4	Buying more water		
4.5	Others, please specify:		

SECTION F: EXPECTED IMPACTS OF CL-CB SLUICE GATES
(Not applicable in Hon Dat District)

G1. When the Cai Lon – Cai Be sluice gates come into operation, would you please tell us how you may change your farming activities as follows.

Number of crops per year: ……………………………………………………………

Rice farming area is expected to increase by ……………………………………

Shrim farming area is expected to increase by ..………………………………

G2. **When the Cai Lon – Cai Be sluice gates come into operation**, would you please tell us **you will continue with which of the following adaptation measures?**

#	Adaptation measures	Yes	Maybe	No	No idea
Group 1 – Construction measures					
1.1	Building and repairing dykes/embankments for your own fields	☐	☐	☐	☐
1.2	Dredging canals and ditches in the field	☐	☐	☐	☐
1.3	New drilling/repair of underground water wells	☐	☐	☐	☐
Group 2 - Adjusting planting calendar/techniques					
2.1	Changing timing of planting and harvesting	☐	☐	☐	☐
2.2	Changing timing of pumping water to match the salinity levels	☐	☐	☐	☐
2.3	Changing timing of fertilizer/chemical use	☐	☐	☐	☐
2.4	Changing the amount of fertilizer/chemical use	☐	☐	☐	☐
Group 3 - Crop and variety diversification					
3.1	Using short-term varieties	☐	☐	☐	☐
3.2	Switching to salt-tolerant rice varieties	☐	☐	☐	☐
3.3	Crop rotation	☐	☐	☐	☐
3.4	Planting some other plants besides rice	☐	☐	☐	☐

#	Adaptation measures	Yes	Maybe	No	No idea
Group 4 – Water management					
4.1	Investing in water storage	☐	☐	☐	☐
4.2	Changing water use practices to save water, recycling water	☐	☐	☐	☐
4.3	Filtering water	☐	☐	☐	☐
4.4	Buying water from other sources	☐	☐	☐	☐
Group 5 – Diversifying income sources					
5.1	Changing from farming to non-farming activities	☐	☐	☐	☐
5.2	Moving from crops to livestock (partly or totally)	☐	☐	☐	☐
5.3	Moving from crops to aquaculture (partly or totally)	☐	☐	☐	☐
Group 6 – Other measures					
6.1	Measuring the salinity of water	☐	☐	☐	☐
6.2	Following information on salinity intrusion on TV, radio, newspapers, internet, etc.	☐	☐	☐	☐
6.3	Following information on salinity intrusion announced by local authorities	☐	☐	☐	☐
6.4	Buying agricultural insurance	☐	☐	☐	☐
6.5	Migrating to another place	☐	☐	☐	☐
6.6	Other, please specify:	☐	☐	☐	☐

SECTION G: GENERAL INFORMATION

In this part, we would like to ask you some questions to ensure a diversity of respondents in the survey.

H1. Please provide some information about the head of household (circle the appropriate number):

Name of head of household:

Year of birth	Gender	Ethnic group	Religion	Marital status	Education level
…………	1. Male 2. Female	1. Kinh 2. Khmer 3. Chinese 4. Cham 5. Others, please specify	1. Buddhism 2. Christian 3. Protestantism 4. Hoa Hao buddhism 5. Caodaiism 6. No religion	1. Single 2. Married 3. Others, please specify: ………………	0. No school 1. Primary school 2. Secondary school 3. High school 4. College/vocational school 5. Undergraduate

			7. Others, please specify		6. Postgraduate

Major job (circle the appropriate number)	1. Rice farming	2. Livestock	3. Shrimp farming
Year of start			
Second job			

H2. How many people are there in your household (those who live in your house in at least past 6 months): ……..

2.1. How many children (under 15 years old) are there in your farm household: ……….

2.2. How many members are doing off-farm jobs?.......................

H3. Now please tell us some information about your property.

3.1	How much land does your household have the right to use (hectare or m2)?	
3.2	Is your rice farming/shrimp farming on rented land or your own land? (please check on appropriate box)	
3.2.1	- Rented land	☐
3.2.2	- Owned land	☐
3.3	How far is it from your farm to the following places (in km):	
3.3.1	☐ Cai Lon (or Cai Be, or Xeo Ro) sluice gate?	
3.3.2	☐ Local sluice gates	
3.3.3	☐ Water resource (river, pond, reservoir…)	

H4. Are you a member of a local agricultural group or a cooperative?

1☐ Yes 0 ☐ No

H5. Has any member of your family ever participated in an agricultural training course?

1☐ Yes 0 ☐ No

H6. Please tell us your average monthly electricity bill: (Please tick in the appropriate box)

1 ☐ Less than VND 200,000

2 ☐ From VND200,000 to less than VND400,000

3 ☐ From VND400,000 to less than VND600,000

4 ☐ From VND600,000 to less than VND800,000

7 ☐ From VND1,200,000 to less than VND1,400,000

8 ☐ From VND1,400,000 to less than VND1,600,000

9 ☐ From VND1,600,000 to less than VND1,800,000

10 ☐ From VND1,800,000 to less than VND2,000,000

5 ☐ From VND800,000 to less than VND1,000,000

11 ☐ From VND2,000,000

6 ☐ From VND1,000,000 to less than VND1,200,000

12 ☐ I don’t know

H7. Would you please tell us about the average monthly income of the whole household (Please tick in the appropriate box)

1☐ Less than VND5mil.

2☐ From VND5mil to VND10mil.

3☐ From VND10mil to VND15mil.

4☐ From VND15mil to VND20mil.

5☐ From VND20mil to VND25mil.

6☐ From VND25mil to VND30mil.

7☐ From VND30mil to VND35mil.

8 ☐ From VND35mil to VND40mil.

9 ☐ From VND40mil to VND45mil.

10☐ From VND45mil to VND50mil.

11☐ From VND50mil.

12☐ No income

13☐ I don’t know

Thank you for answering our questions.
We wish you healthy, happy and having promising harvests!

Appendix 3: List of interviewee in the 1st Field trip (02-06 December 2020)

#	Name	Organization/Address	Tel
1	Ông Nhung	Đội trưởng vận hành Cống thuỷ lợi Ba Hòn, Huyện Kiên Lương	0919722220
2	Ông Trọng	Trưởng Phòng Kinh tế, UBND Huyện Kiên Lương	0978339737
3	Ông Bình	Phó Phòng NN&PTNT, UBND Huyện Hòn Đất	02973706778
4	Ông Bình	Cán bộ Khuyến Nông, Xã Thổ Sơn, Huyện Hòn Đất	0369074769
5	Ông Hưng	Chủ đầm nuôi tôm thâm canh, Ấp Vạn Thanh, Xã Thổ Sơn, Huyện Hòn Đất (Cống Hòn Me 2)	0332532521
6	Ông Khai	Phòng Quản lý đê, Chi Cục Thuỷ Lợi Kiên Giang	0378284706
7	Ông Toàn	Phòng Quản lý đê, Chi Cục Thuỷ Lợi Kiên Giang	0794274599
8	Ông Trương Quang Lưu	Trưởng Phòng Kinh tế hạ tầng, UBND Huyện An Biên	0913864609
9	Ông Lê Văn Liền	Phó Phòng Nông nghiệp, UBND Huyện An Biên	0913102827
10	Ông Trương Minh Bền	Phó Phòng Tài nguyên môi trường, UBND Huyện An Biên	0919828265
11	Ông Hân	Nông dân Xã Nam Yên, Huyện An Biên	0919929396
12	Ông	Cán bộ Quản lý cống Kim Quy	
13	Ông	Cán bộ Quản lý cống Kim Quy	
14	Ông Thống	Quản lý cống Sông Kiên, TP Kiên Giang	0945429272
15	Ông Lê Quốc Việt	Trưởng Phòng Nông nghiệp Huyện Châu Thành	0918659154
16	Ông Cao Văn Tư	Nông dân ấp Vĩnh Quới, Xã Bình An, Huyện Châu Thành	0818427428
17	Ông Nguyễn Văn Ngộ	Nông dân ấp An Thành, Xã Bình An, Huyện Châu Thành	0374999052
18	Ông Trác Chí Thành	Nông dân ấp An Thành, Xã Bình An, Huyện Châu Thành	0769747123
19	Ông Nguyễn Văn Sơ	Nông dân ấp An Thành, Xã Bình An, Huyện Châu Thành	0977303571
20	Nhóm chuyên gia CRA (5 người)		

Appendix 4: Data collection activities in the 1st Field trip (02-06 December 2020)

a. Meetings with local authorities, managers and sluice operators




b. Meetings with local farmers


Appendix 5: Survey in the 2st Field trip (22-27 April 2021)

a. In Chau Thanh and An Bien district



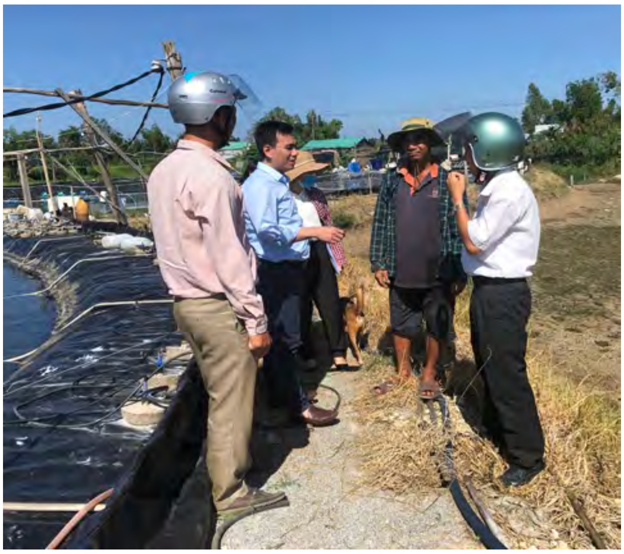


a. In Hon Dat district


Appendix 6: Some farming models in Kien Giang province

b. Agriculture and extensive aquaculture model

c. Intensive aquaculture



Appendix 7: Climate-related concerns in sluice gates

a. Hydraulic cylinders in Kenh Cut sluice gate (Rach Gia city) were crashed by boats due to strong wind and high tide, causing scratches.

b. Rubber bearings were lost or inelastic due to salinity and high temperature in Kim Quy sluice gate, An Minh district.

Appendix 8: Presentation on the economic analysis of climate proofing measures in Cai Lon – Cai Be Sluice Gates

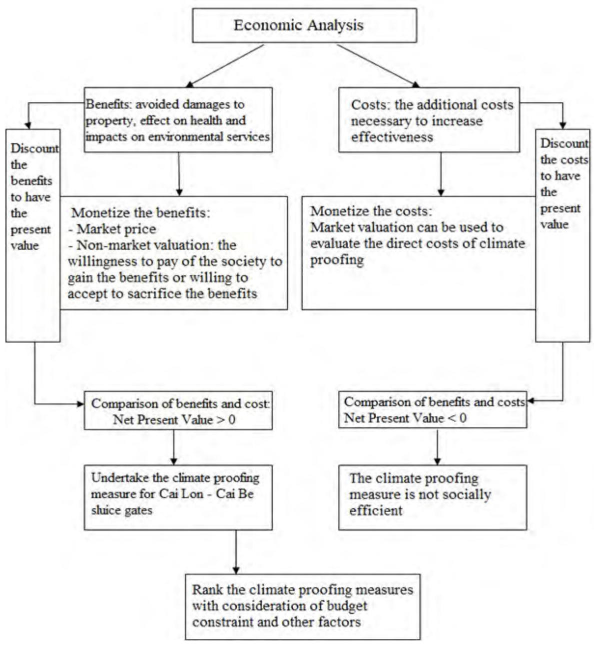
ECONOMIC ANALYSIS SUPPLEMENTING THE CLIMATE RISK ASSESSMENT OF THE CAI LON –CAI BE SLUICE SYSTEM

COST-BENEFIT ANALYSIS FOR THE PERIOD AFTER FEASIBILITY STUDY

CBA TEAM: NGUYEN CONG THANH
NGUYEN DIEU HANG
NGUYEN HOANG NAM

1

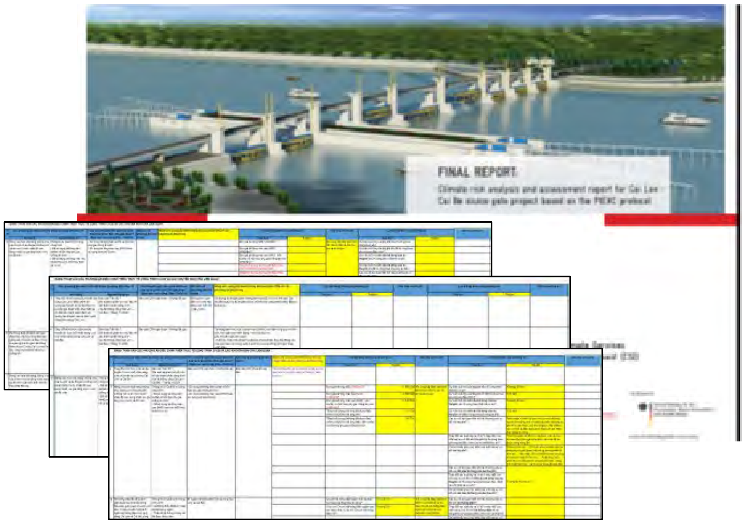
FRAMEWORK FOR ECONOMIC ANALYSIS



2

PRIVATE COST-BENEFIT ANALYSIS FOR THE ADAPTATION MEASURES

- **Specify the suggested and implemented adaptation measures:**
  - CRA Final reports;
  - Data collection Updated during the field trip 1 (02-06 December 2020) and field trip 2 (22 -27 April 2021);
  - Questionnaires to collect experts' opinions (e.g. CRA team and others) and additional secondary data (e.g. construction drawings, price lists)



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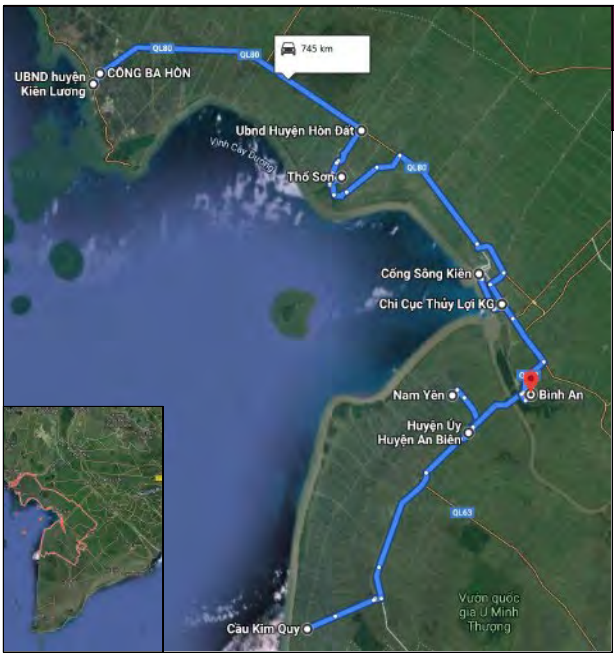


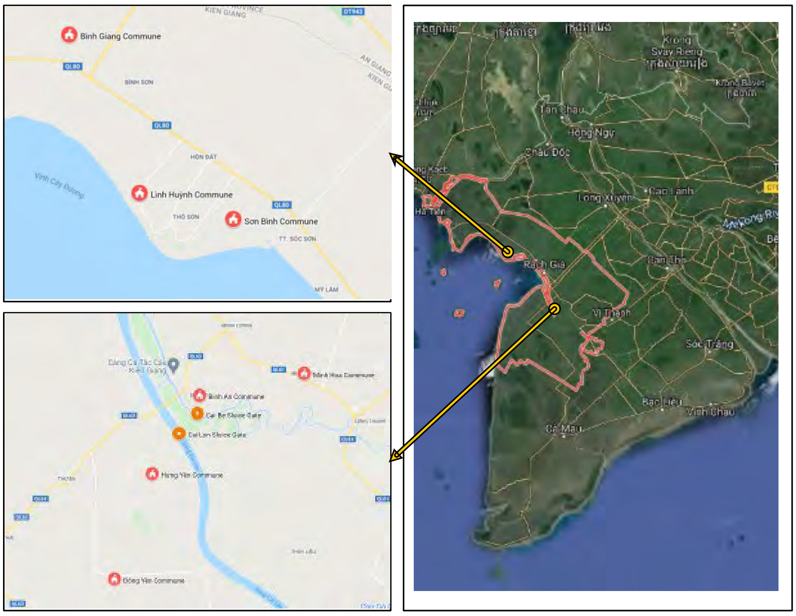
FIELD TRIP I

- Field trip in Kien Giang Province (02-06 Dec 2020)
  - Roughly 745 km traveling to 12 sites along the 200 km coastal line of the province, including Cai Lon and Cai Be sluice gate;
  - In-depth discussion with 13 officials, 6 farming households and the CRA team;
  - Secondary data collection (continuing) ;

4

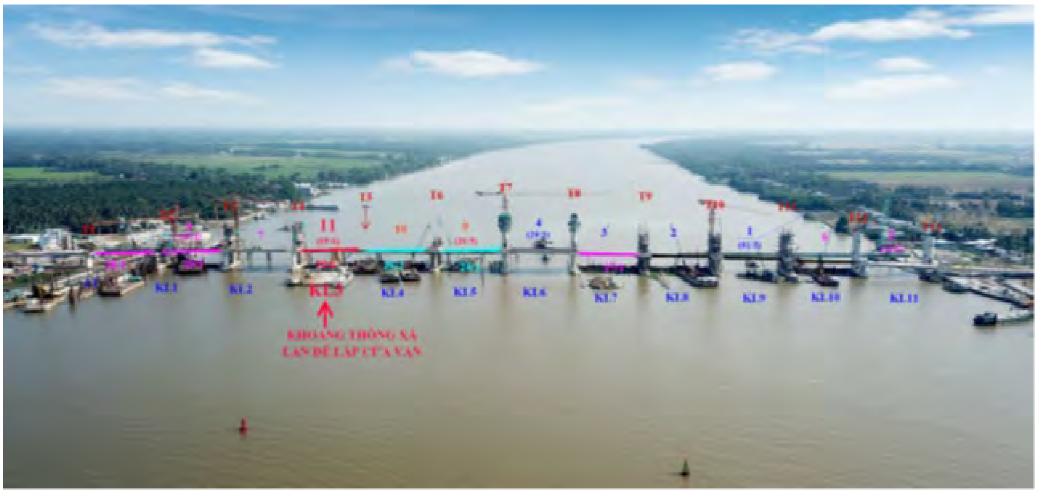
FIELD TRIP 2

- In the protected area of CL-CB sluice gates:
  - o Chau Thanh District: Binh An Commune and Minh Hoa Commune;
  - o An Bien District: Hung Yen Commune and Dong Yen Commune;
- Not in the protected area of CL-CB sluice gates:
  - o Hon Dat District: Binh Giang Commune, Lình Huỳnh Commune and Son Binh Commune;



5

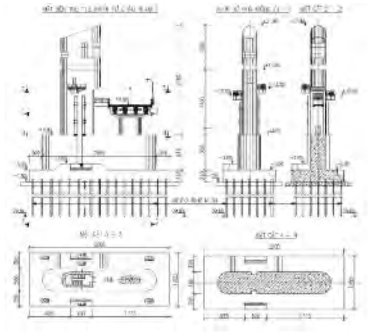
MEASURE 1: USE OF SULPHATE RESISTANT CEMENT, ANTI-CORROSION ADDITIVE MIXTURE AND HIGH CONCRETE GRADE FOR PILLARS AND SHIP LOCKS



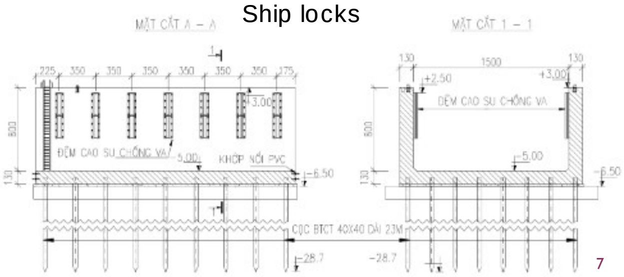
6

- Measure implemented - changes comparing to the 1st preliminary design:
  - M3000 concrete was upgraded to M4000 concrete (for the pile parts deep below the ground);
  - M3000 concrete was upgraded to M4000 concrete with sulphate resistant and anti-corrosion additive mixture (for the parts in contact with sea water/at risk of corrosion);

Pillars



Ship locks



7

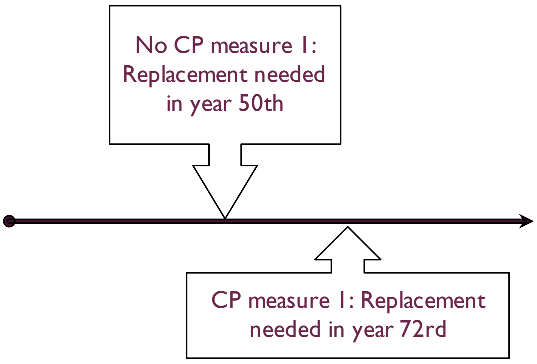
- **Identification of Costs**
  1. Increased cost to upgrade from M3000 concrete to M4000 concrete;
  2. Increased cost to upgrade from M3000 concrete to M4000 concrete with sulphate resistant and anti-corrosion additive mixture (12 pillars of CL + CL ship lock and 3 pillars of CB + CB ship lock);

	Cai Lon Sluice Gate	Cai Be Sluice Gate
Amount of M300 concrete upgraded to M400 concrete (Ton)	11,000	2,200
Pillars - Amount of M300 concrete upgraded to M4000 concrete with sulphate resistant and anti-corrosion additive mixture (Ton)	66,000	13,500
Ship locks - Amount of M300 concrete upgraded to M4000 concrete with sulphate resistant and anti-corrosion additive mixture (Ton)	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**

8

Identification of Benefits

1. Benefit from increased expected lifespan – less cost of replacement for pillars and ship locks during a 100 years time horizon:
   - ▶ Expert consultation: The average expected lifespan is increased from 50 years to 72 years.



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

- B_t: total benefit in year t
- C_t: total cost in year t
- r: the social discount rate
- n: the lifetime of the project

A climate proofing measure is recommended from the economic point of view if NPV > 0 and IRR > r

9

Identification of Benefits

2. Benefit from higher endurance to climate risk - less maintenance cost for pillars and ship locks during a 100 years time horizon:
   - ▶ The maintenance cost was not identified in the design of CLCB. This cost is often estimated by the management board when needed (after the construction finished);
     - o Circular No. 03/2017/TT-BXD on Guideline for determination of costs of maintenance of construction works (dated 16 March 2017) set the standard maintenance cost from 0.18 to 0.25% of the total investment;
   - ▶ Calculation of the probability of maintenance cost occurs?
     - o The risk scores (R) in PIEVC analysis reflects the probability of maintenance needed;

       R = P*S
     - o The CP measure 1 is to avoid the increase of Severity scores (S) (of pillars and ship locks). Meanwhile, the probability scores of climate and hydrological factors (P) are objective existence;

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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%
High water level + heavy rain (Water level ≥ 0.9m and heavy rain ≥ 100mm/day)	4	8	2.04%
Average ΔR of Pillars			**1.90%**

Note:

- [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.

Climate factor	Risk Baseline (R0)[a]	Risk Future (R1)[a]	Standardized[b] change in R: [(R1-R0)/R0]/49
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%
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 ≥ 35°C)	12	20	1.36%
Average ΔR of Ship lock			**2.19%**
Average ΔR of Pillars and Ship lock			**2.05%**

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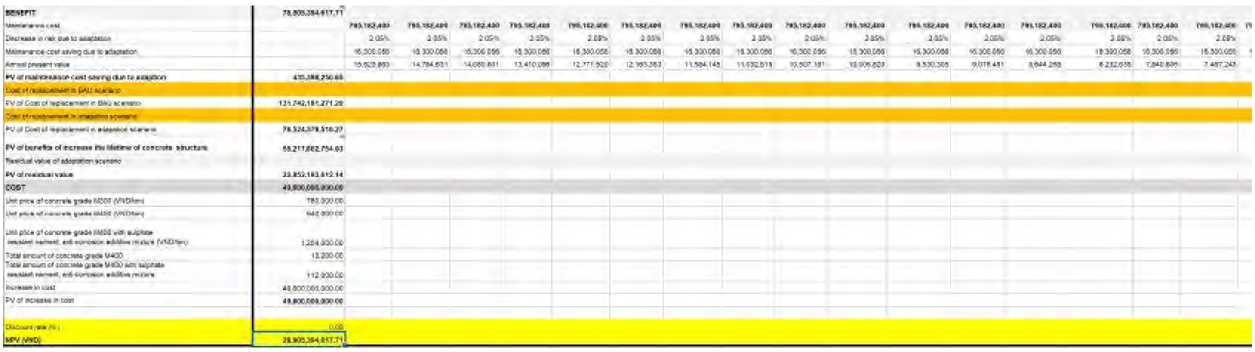
- CBA result:



BENEFIT	28,905,384,817.71
PV of maintenance cost saving due to adaptation	435,288,250.65
PV of Cost of replacement in BAU scenario	131,742,181,271.28
PV of Cost of replacement in adaptation scenario	78,524,378,516.27
PV of benefits of increase the lifetime of concrete structure	53,217,802,754.03
PV of residual value	23,852,183,812.14
COST	49,800,000,000.00
Unit price of concrete grade M300 (VND/m)	780,000.00
Unit price of concrete grade M400 (VND/m)	840,000.00
Unit price of concrete grade M400 with sulphate resistant cement, anti-corrosion additive mixture (VND/m)	1,284,000.00
Total amount of concrete grade M400	13,200.00
Total amount of concrete grade M400 with sulphate resistant cement, anti-corrosion additive mixture	112,000.00
Increase in cost	49,800,000,000.00
PV of increase in cost	49,800,000,000.00
Discount rate (%)	0.08
NPV (VND)	28,905,384,817.71

NPV AM1: 22.1 billion VND (USD 0.96 million)
BCR AM1: 1.53

► **Adaptation measure 1 is beneficial for the investor**

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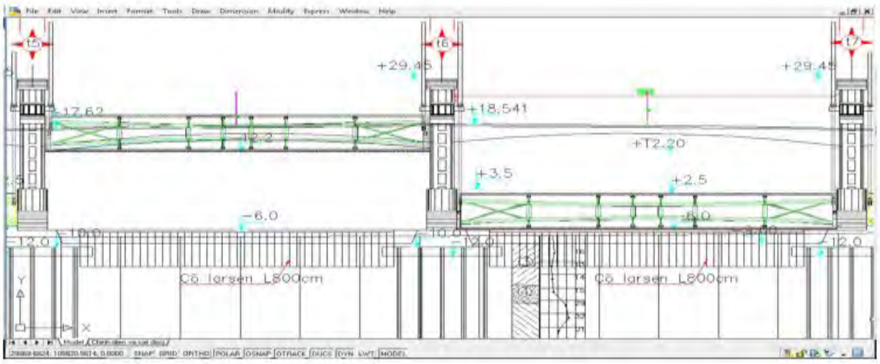
CP MEASURE 2: USING COATING METHOD BY EPOXY FOR THE SLUICE GATES



13

CP MEASURE 2: USING COATING METHOD BY EPOXY FOR THE SLUICE GATES

Identification of cost:

- Cost: Using coating method by epoxy will increase the cost of coating
- The price of epoxy and normal paint is collected from quotations from some suppliers in the market
- The amount of paint used is collected from consultation with CRA group

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**

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ADAPTATION MEASURE 2: USING COATING METHOD BY EPOXY FOR THE SLUICE GATES

Identification of benefit:

- Benefit: Using coating method by epoxy will increase the lifetime of the sluice gates
- Due to adaption measure, the risk score for the sluice gates decreases by 1.66%

→The lifetime of the sluice gates is expected to increase from 15 years to 16 years

- Discussion with CRA group resulted that the lifetime of the sluice gates would increase from 15 years to 30 years

→ We use the average value: (16+30)/2 = 23 years

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CP MEASURE 2: USING COATING METHOD BY EPOXY FOR THE SLUICE GATES

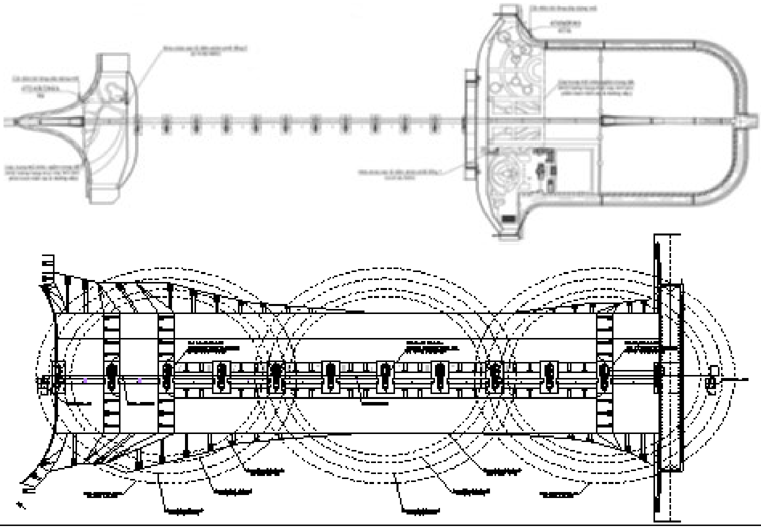
Using a stainless steel together with coating method by Epoxy for the gates															
BENEFIT	156,089,793,937														
Cost of replacement in BAU scenario						250,000,000,000									
PV of Cost of replacement in BAU scenario	342,440,186,246					1.26267E+11								0	0
Cost of replacement in adaptation scenario														250,000,000,000	
PV of Cost of replacement in adaptation scenario	186,350,392,309													85,462,467,772	-
PV of benefits of increase the lifetime of concrete structure	156,089,793,937														
COST	12,030,611,515														
Unit price of epoxy coating paint	183,150														
Unit price of normal coating paint	109,437														
Amount of paint used for the sluice gates	35,000														
Increase in cost of epoxy coating paint	1,088,347,222						########					1,088,347,222		1,088,347,222	
NPV of increase in cost	12,030,611,515				0	0	[illegible]	0	0	0	0	[illegible]		643,130,305	
Discount rate (%)	5%														
NPV (VND)	144,059,182,422														
Year	0	1	2	3	13	14	15	16	17	18	19	20	21	22	23

NPV AM2: 96.2 billion VND (USD 4.1 million)
BCR AM2: 8.91

► **Adaptation measure 2 is beneficial for the investors**

16

MEASURE 3: UNDERGROUNDING THE ELECTRICAL WIRING AND UPGRADING THE LIGHTNING PROTECTION SYSTEM



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MEASURE 3: UNDERGROUNDING THE ELECTRICAL WIRING AND UPGRADING THE LIGHTNING PROTECTION SYSTEM

Identification of cost:

Cost	Cai Lon Sluice Gates	Cai Be sluice Gates
Total cost of electrical wiring system (VND) (excluding the electric equipment)	10,000,000,000	4,000,000,000
Cost of underground electrical wiring system (VND)	3,500,000,000	1,500,000,000
Cost increased due to the electrical undergrounding	35.00%	35.00%
Cost of the lightning protection system according to the construction contractor (real)	3,000,000,000	1,500,000,000
Estimated cost of the lightning protection system according to the preliminary design (1st design)	2,000,000,000	1,000,000,000

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MEASURE 3: UNDERGROUNDING THE ELECTRICAL WIRING AND UPGRADING THE LIGHTNING PROTECTION SYSTEM

Identification of benefit:

- Benefit from higher endurance to climate risk: less annual maintenance costs for the electrical wiring system during a 100 years' time horizon.
- Benefit from increased expected lifespan: less replacement frequency is expected to reduce from once in a 20 years' time to once in a 50 years' time.

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MEASURE 3: UNDERGROUNDING THE ELECTRICAL WIRING AND UPGRADING THE LIGHTNING PROTECTION SYSTEM

Climate factor	Risk Baseline (R0)[a]	Risk Future (R1)[a]	Standardized[b] change in R: [(R1-R0)/R0]/49
Heavy rain	1	2	0.03
Tropical storm/depression	4	5	0.01
High wind	3	4	0.01
Tornado	6	7	0.03
Thunderstorm/ lightning	7	7	0.00
		Average ΔR of electric syste	1.56%

- [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.

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MEASURE 3: UNDERGROUNDING THE ELECTRICAL WIRING AND UPGRADING THE LIGHTNING PROTECTION SYSTEM

	Sum value of CL– CB sluice gates
PV of benefits	8,315,264,129
Maintenance cost saving due to adaptation (VND/year)	11,175,899
Replacement cost saving due to adaptation (VND)	3,250,000,000*
PV of costs	7,359,255,477
Cost of the measure (VND)	6,500,000,000**
Cost of replacement (VND)	5,000,000,000***
NPV (VND)	**1,104,141,547**

Note:

** cost occurs in year 20th, 40th, 60th, 80th;*

*** cost occurs at the present;*

**** cost occurs in year 50th*

NPV AM3: 1.1 billion VND (USD 47,665)
BCR AM3: 1.16

► **Adaptation measure 3 is beneficial for the investors**

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SOCIAL BENEFIT OF THE ADAPTATION MEASURES

- Field survey in Chau Thanh, An Bien and Hon Dat districts
- Data collection:
  - Loss of income due to salinity intrusion
  - Willingness to pay for improving the sluice gates

Farming models	No. of households
1-2 rice-crop farming	44
3 rice-crop farming	33
Shrimp-rice farming	31
Total	**108**

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SURVEY RESULTS

- Benefit of climate proofing measures for 1-2 rice-crop farming households

Items	Value (VND/hectare)
Annual revenue	59,430,564
Annual cost	25,127,543
The highest loss (in percentage) in recent years due to salinity intrusion	38%
Average loss (in percentage)	19%
Decrease in net income due to salinity intrusion or benefit of the Sluice Gates (VND)	11,230,629
Decrease in net income due to salinity intrusion or benefit of the Sluice Gates (USD)	484.48

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SURVEY RESULTS

- Benefit of climate proofing measures for 3 rice-crop farming households

Items	Value (VND/hectare)
Annual revenue	106,897,418
Annual cost	53,535,910
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 (VND)	18,595,697
Decrease in net income due to salinity intrusion or benefit of the Sluice Gates (USD)	802.2

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SURVEY RESULTS

- Benefit of climate proofing measures for shrimp-rice farming households

Items	Value (VND/hectare)
Annual revenue	114,516,159
Annual cost	33,377,983
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 (VND)	7,170,961
Decrease in net income due to salinity intrusion or benefit of the Sluice Gates (USD)	309.35

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SURVEY RESULTS

- WTP for upgrading concrete for pillars and ship locks

	WTP (VND per hectare per year)	WTP (USD per hectare per year)
1-2 rice-crop farmers	86,578	3.73
3 rice-crop farmers	116,617	5.03
Shrimp-rice farmers	100,198	4.32

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SOCIAL BENEFIT OF THE ADAPTATION MEASURES

- Beneficial area

	Zone 1 (Kien Giang, Hau Giang)	Zone 2 (Bac Lieu, Ca Mau)	Zone 3 (Can Tho, Soc Trang)	Total area
Area (ha)	491,048	268,130	150,070	909,248
Proportion in total area	54%	29%	17%	100%
1-2 rice crop production (ha)	75,851	41,418	23,181	140,450
3 rice crop production (ha)	7,794	4,248	2,377	14,404
Shrimp-rice production (ha)	49,170	26,849	15,027	91,046
Weight	1	0.55	0.25	

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COST-BENEFIT ANALYSIS OF UPGRADING CONCRETE FOR PILLARS AND SHIP LOCKS

- Using avoided loss method

Annual avoided loss of the adaptation measure = benefit of the sluice gate x the average reduction in risk score ΔR of the measure 2.05% x beneficial area

Farming models	Avoided loss (VND)	Avoided loss (USD)	Total avoided loss (VND)
1-2 rice-crop farming	230,288	9.93	24,041,844,294
3 rice-crop farming	381,212	16.45	4,082,606,660
Shrimp-rice farming	147,005	6.43	9,951,308,236
Total			38,075,759,190

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COST-BENEFIT ANALYSIS OF UPGRADING CONCRETE FOR PILLARS AND SHIP LOCKS

- Using WTP:

Social benefit = WTP/hectare/year x percentage of the components in total value of CL-CB 13.35% x beneficial area

Farming models	WTP/ha/year(VND)	Total WTP
3 rice crop farmers	15,567	166,711,697
1-2 rice crop farmers	11,557	1,206,841,478
Shrimp-rice farmers	13,375	905,396,348
	Total	**2,278,949,523**

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COST-BENEFIT ANALYSIS OF UPGRADING CONCRETE FOR PILLARS AND SHIP LOCKS

	Upgrading the concrete	
	Avoided loss	WTP
NPV (VND)	1,043,319,805,231	87,134,844,266
NPV (USD)	45,007,864	3,758,918
BCR	22.03	2.76
IRR	76.80%	6.59%

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COST-BENEFIT ANALYSIS OF USING EPOXY COATING FOR THE SLUICE GATES

- Using WTP:

Social benefit = WTP/hectare/year x percentage of the components in total value of CL-CB (0.16%) x beneficial area

Farming models	WTP/ha/year(VND)	Total WTP
3 rice crop farmers	185	19,312,830
1-2 rice crop farmers	137	1,470,459
Shrimp-rice farmers	159	10,756,722
	Total	**31,540,011**

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COST-BENEFIT ANALYSIS OF USING EPOXY COATING FOR THE SLUICE GATES

	Value
NPV (VND)	97,018,442,042
NPV (USD)	4,185,287
BCR	8.98
IRR	37.45%

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COST-BENEFIT ANALYSIS OF UNDERGROUNDING THE ELECTRIC WRING AND UPGRADING THE LIGHTNING PROTECTION SYSTEM

- Using avoided loss method

Annual avoided loss of the adaptation measure = benefit of the sluice gate x the average reduction in risk score ΔR of the measure 1.65% x beneficial area

Farming models	Avoided loss (VND)	Avoided loss (USD)	Total avoided loss (VND)
1-2 rice-crop farming	175,198	7.558	18,295,257,121
3 rice-crop farming	290.093	12.51	3,106,764,092
Shrimp-rice farming	111.867	4.826	7,572,702,853
Total			28,974,724,066

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COST-BENEFIT ANALYSIS OF UNDERGROUNDING THE ELECTRIC WRING AND UPGRADING THE LIGHTNING PROTECTION SYSTEM

- Using WTP:

Social benefit = WTP/hectare/year x percentage of the components in total value of CL-CB 0.2% x beneficial area

Farming models	WTP/ha/year(VND)	Total WTP
3 rice crop farmers	229	2,452,930
1-2 rice crop farmers	170	17,756,989
Shrimp-rice farmers	197	13,321,645
	Total	33,531,564

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COST-BENEFIT ANALYSIS OF UNDERGROUNDING THE ELECTRIC WRING AND UPGRADING THE LIGHTNING PROTECTION SYSTEM

	Avoided loss	WTP
NPV (VND)	576,191,862,890	1,999,818,491
NPV (USD)	24,856,391	86,270
BCR	84.07	1.29
IRR	891.87%	3.69%

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SENSITIVITY ANALYSIS:THE CHANGE IN RISK SCORE DECREASES BY 50%

		Upgrading the concrete		Changing the electricity system	
		Avoided loss	WTP	Avoided loss	WTP
Social	NPV (VND)	534,572,593,929	86,917,145,140	319,275,930,286	1,648,226,306
		(1,043,319,805,231)	(87,134,844,266)	(576,191,862,890)	(1,999,818,491)
	NPV (USD)	23,060,974	3,749,526	13,773,272	71,103
	BCR	11.78	2.75	47.03	1.22
		(22.03)	(2.76)	(84.07)	(1.29)
Private	NPV (VND)	26,043,081,753		900,682,257	
		(26,260,780,878)		(1,104,141,547)	
	NPV (USD)	1,123,475		38,855	
	BCR	1.53		1.13	
		(1.53)		(1.16)	

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SENSITIVITY ANALYSIS: COST OF UNDERGROUNDING THE ELECTRICITY WIRING CAN BE AS HIGH AS 4 TIMES OF THE COST OF OVERHEAD WIRING

		Changing the electricity system	
		Avoided loss	WTP
Social	NPV (VND)	424,878,416,252	-2,697,560,957
		(576,191,862,890)	(2,274,922,438)
	NPV (USD)	18,328,867	-116,370.32
	BCR	62.26	0.61
		(84.07)	(1.33)
Private	NPV (VND)	-8,360,678,556	
		(1,104,141,547)	
	NPV (USD)	-360,672	
	BCR	0.27	
		(1.16)	

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CONCLUSION

- Overall, the results of our CBA show that the three climate proofing measures are efficient both from the investor and the society's point of view

→ It is strongly recommended that the investor should invest in climate proofing measures at the beginning for long term benefits

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THANK YOU

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Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

Friedrich-Ebert-Allee 32 + 36
Germany
T +49 228 44 60-0
F +49 228 44 60-17 66

Dag-Hammarskjöld-Weg 1 - 5
Germany
T +49 61 96 79-0
F +49 61 96 79-11 15

E info@giz.de
I www.giz.de