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Success Factors and Challenges: Implications of Real Options Valuation of Constructed Wetlands as Nature-Based Solutions for Wastewater Treatment

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Abstract: Constructed wetlands (CWs) are engineered water treatment systems that mimic the features and functions of natural wetlands. As a nature-based solution (NBS) for wastewater treatment, CWs are sustainable and cost-effective while providing various ecosystem services. However, their widespread application faces several uncertainties, particularly in developing countries. This study aims to analyze the success factors and challenges in implementing CW projects. Using the case of successful CWs in Bayawan City in the Philippines, this study surveyed 270 household heads from the community benefiting from the CWs and interviewed various CW stakeholders, including the project planner, management, community leader, social workers, and CW workers. The results showed that 89% of the respondents were aware of the existence of CWs in the community and 73% believed in their long-term sustainability. Among the identified factors for the successful implementation of the CW project were government support (43%), good governance (32%), and public support (14%). On the other hand, the implementation was challenged by improper maintenance (63%), overcrowding in the community (11%), foul smells (4%), funding (4%), and climate-related uncertainties, including natural calamities (4%), flooding (7%), earthquakes (4%), and sea level rise (11%). The implications of these success factors and challenges were discussed in the application of real options valuation to CW projects by incorporating the identified uncertainties into flexible decision making in the scaling up and widespread implementation of a more sustainable NBS to water resources management.

Keywords: constructed wetlands; challenges; nature-based solutions; real options; success factors

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1. Introduction

Wastewater management is one of the global problems impacting human health, as well as terrestrial and aquatic ecosystems. Billions of people around the world have no effective sanitation systems, so unsafe containment or disposal of feces results in the contamination of food and water sources with deadly pathogens [1]. However, the expansion of metropolitan cities and increasing water consumption have concomitantly resulted in a huge generation of gray and wastewater, which flows back into the ecosystem without being treated or reused, polluting aquifers and waterways [1,2]. Effluents from domestic, agricultural, and industrial wastewaters contain organic carbon, nitrogenous organics, inorganics, suspended/dissolved solids, and heavy metals [3]. There is increasing attention to developing innovative solutions to ensure the safe discharge of wastewater into ecosystems.

Wastewater treatments have become an important technology that is utilized to manage various quantities and concentrations of domestic, industrial, and agricultural wastewater. The target is to enhance water quality up to permissible limits, as recommended by different regulatory agencies, such as the World Health Organization (WHO), as well as national and international environmental agencies [4]. Wastewater treatment can be categorized into four fundamental stages: preliminary, primary, secondary, and tertiary technologies [5]. Recent advancements in wastewater treatment technologies utilize nanomaterials, microalgae, photocatalysts, microgels, boron nitride, and carbon felt/polyvinyl alcohol to treat domestic wastewater and other types of pollutants, including heavy metals, emulsions, soluble organic sewage, oily seawater, and acid/alkali corrosive oily sewage [6–12]. Nonetheless, conventional wastewater treatments are high-cost and energy-intensive, and form large amounts of sludge [13]. Additionally, maintenance, monitoring, emerging contaminants, low-efficiency sludge treatment, and disposal are major limitations that increase the total cost of treatment technologies [14].

Another promising option is the utilization of constructed wetlands as a nature-based solution (NBS) for wastewater treatment. Constructed wetlands (CWs) or treatment wetlands have emerged as one such sustainable, environmentally friendly, efficient real-world treatment technique for pollutant removal from wastewater [15]. As NBSs, they are engineered treatment systems that mimic the functions of natural wetlands by utilizing natural vegetation, soils, and microbes to capture stormwater, reduce nutrient loads, and create diverse wildlife habitats [16]. Compared to conventional wastewater treatments, CWs are characterized by low operational and maintenance requirements and are stable in terms of performance, with less vulnerability to inflow variation [17]. Additionally, they provide several ecosystem services, including provisioning (biomass and water supply), regulating (wastewater treatment and purification, climate regulation, flood prevention, and erosion control), cultural (recreation and aesthetic, biodiversity, education, and research), and supporting (habitat formation, nutrient cycling, and hydrological cycling) services [16].

Despite these benefits, the replication and upscaling of CW projects remain challenging for several reasons. According to Vymazal et al. [18], the major challenges for CWs are the scaling-up of laboratory and small-scale CWs because of issues in operation and maintenance costs, as well as the evaluation of the long-term performance of constructed wetlands. In another study, Makopodo et al. [19] found potential challenges in adopting CWs, including inadequate expertise and technical support, low volume of discharge during off-seasons, limited space or land, and the attitude of managers towards CWs. Moreover, Tan et al. [20] found that the absence of a standard or guideline for the CW system, the large land area requirement, and the feasibility of the CW system in treating either domestic wastewater or septage must be convincing to the State Planning Authority before applying for the use of the land. On the other hand, Graversgaard et al. [21] identified key success factors for CW implementation, such as sufficient compensation levels, flexible scheme designs, and information-based strategies documenting relevant benefits and sustainability issues.

For traditional project valuation methods, the above-mentioned challenges and success factors are not reflected. For instance, the "now-or-never" decision using the net present value (NPV) does not consider the uncertainties in CWs and the flexibility of managing decisions regarding the adoption of CW projects. Nevertheless, real options valuation (ROV) addresses these issues by incorporating risks and uncertainties, as well as management flexibility in making irreversible investment decisions [22]. Using ROV, a project planner has the option to postpone a CW project to a later period if the investment environment is not favorable at the moment. There are also other management decision options, such as the timing of scaling up existing CWs, the temporary shutdown of CW operation if the conditions are unfavorable, continuing operation when the condition gets better, switching CW components and operations (vegetation, substrates, water reuse, and energy utility), and the timing of decommissioning the CW facility. To the best of our knowledge, ROV has not been applied in the valuation of any CW project. However, the identification and analysis of investment uncertainties in the ROVs of CWs must first be carried out.

This research aims to bridge this gap by identifying the success factors and challenges in implementing a CW project and discovering how they can be incorporated in the application of ROV to the adoption of CWs as NBSs for wastewater treatment. Specifically, this study answers the following research questions: (1) What are the success factors in implementing a CW project? (2) What are the challenges in implementing a CW project?

(3) How can these success factors and challenges be utilized to apply ROV to CWs as NBSs for wastewater treatment? Taking the case of a CW project in Bayawan City, Philippines, this study conducts key informant interviews and surveys of the project's stakeholders, including planners, implementers, and beneficiaries, to elicit their lived experiences in implementing the project. The findings of this study provide recommendations for replicating and upscaling existing CWs as a sustainable solution to water resources management in the case country and other developing economies.

2. Methodology

2.1. Case Study of Constructed Wetlands

The constructed wetlands, the first ever in the Philippines, were created by Bayawan City with the assistance of German technical cooperation, as detailed in a signed memorandum of agreement in compliance with Republic Act 9275 or the Philippine Clean Water Act. The CWs, as shown in Figure 1, have been operational since 2006. The CW project is located in the Fishermen's Gawad Kalinga Village, a 7.4-hectare relocation site for fisherfolk and informal settlers in the coastal area of Bayawan City, Negros Oriental, as shown in Figure 2.

Figure 1. Vertical flow (left side) and horizontal flow (right side) constructed wetlands in the City of Bayawan. Photo taken by the authors.

The constructed wetlands treat the effluents from the village. The houses have pour-flush toilets, and the wastewater undergoes partial treatment in septic tanks. There are 67 septic tanks, with each serving between six and 10 houses. The liquid portion of the wastewater is transported through a small-bore sewer system to a main sump for storage and solids removal. From there, the wastewater is pumped into header tanks and then flows through the CWs, as shown in Figure 3.

The CW facility was designed for a flow rate of 50 L/person/day for a population of 3000 people (600 households, with an average of 5 people/household). The facility is composed of two CWs: an 1800 m^2 vertical soil filter and an 880 m^2 horizontal soil filter. The treated wastewater is stored and used for irrigation in farming projects. A combination of septic tanks, small-bore sewers, and constructed wetlands was chosen as an affordable and reliable treatment solution that could easily be implemented and maintained. The recommendation to use a vertical soil filter and a horizontal vegetated soil filter was based on treatment efficiency and space availability at the relocation site.

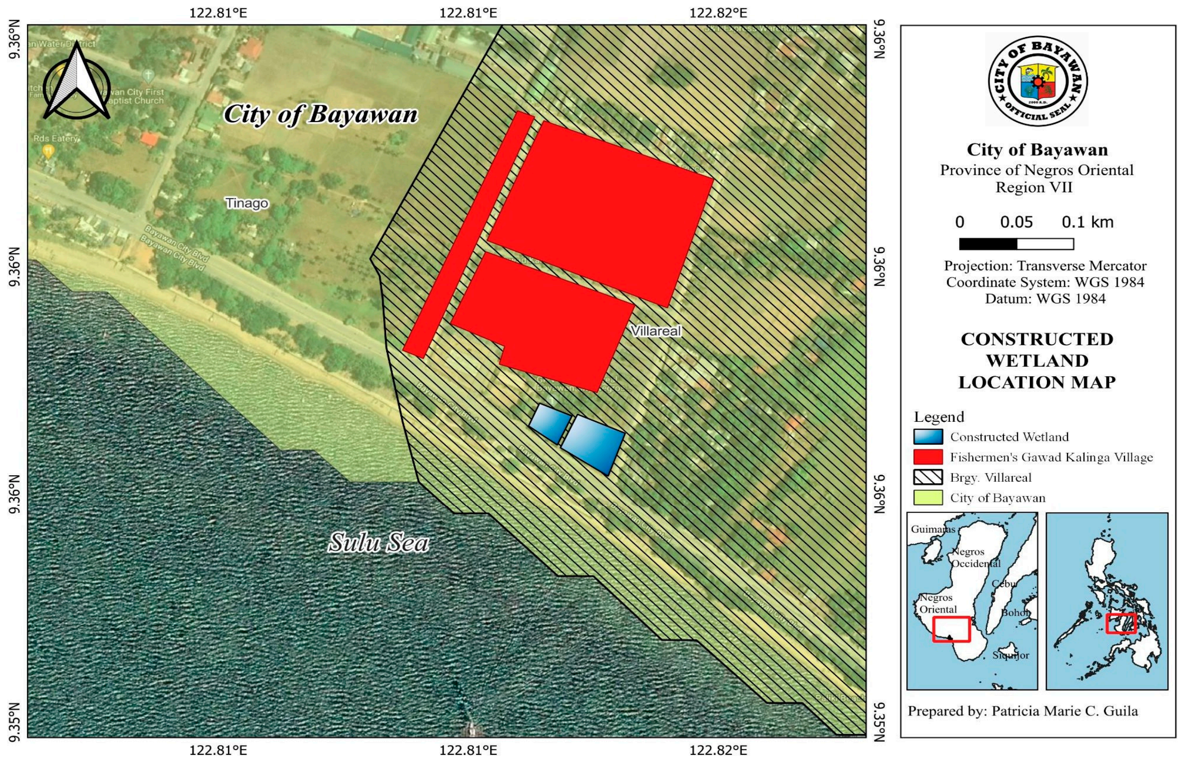

Figure 2. Location map of the constructed wetlands in Fishermen's Gawad Kalinga Village in the City of Bayawan. Reproduced from Guila [23] under CC-BY-4.0 from publisher University of the Philippines Los Baños, 2023.

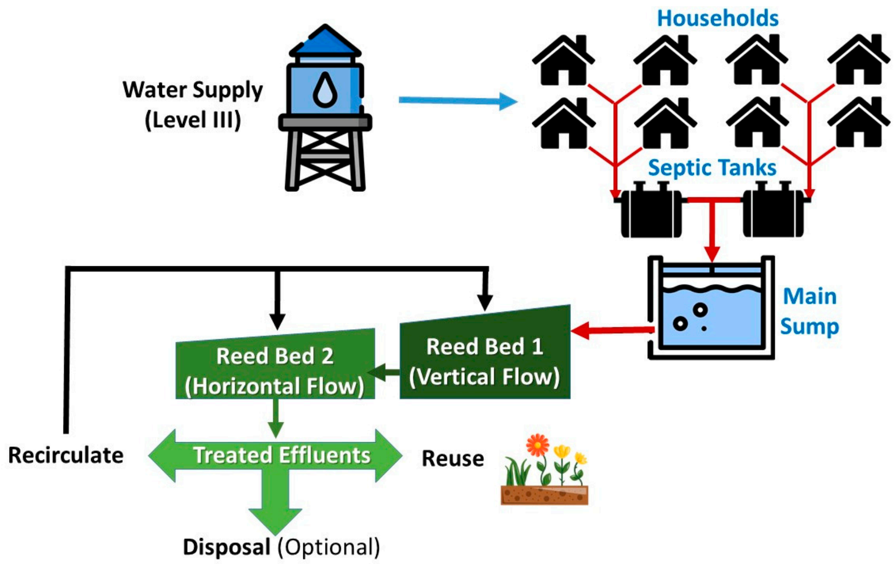

Figure 3. Flowchart of a wastewater treatment system using constructed wetlands in the City of Bayawan, Negros Oriental.

2.2. Research Instrument and Data Collection

This study explored various uncertainties in the implementation of CW projects as a prelude to real options valuations of CWs by looking at the challenges and success factors. It utilized a survey questionnaire and key informant interviews (KIIs) of various stakeholders involved in planning through implementation, as well as the beneficiaries of the CW project. First, a survey questionnaire was utilized to explore the success factors and challenges of the project from the perspective of household heads from Fishermen's

Gawad Kalinga Village. It was composed of three sections (see Supplementary Materials for the survey questionnaire). The first section provided the background and purpose of the study. It also included informed consent to participate in the study and other ethical considerations, such as anonymity of respondents, confidentiality of the data, and a clause to exclude their participation at any time as requested. The second section asked about the respondents' awareness of the existence of CWs and the sustainability of their operations in the community. The third section elicited the perceived success factors and challenges in implementing the CW project in the community.

The data were collected at the Multipurpose Hall of the Fishermen's Gawad Kalinga Village in February 2023. A purposive sampling method was used to select who would participate in the study from the village's 750 households with the following criteria: (1) household head of a family, (2) living in the village, (3) in the last five years. The inclusion of the number of years ensured that the household head was fully aware of the existence of the CWs to treat the wastewater in the village. While the survey questionnaire was written predominantly in English, this study utilized 10 enumerators who spoke the local language to address the language barrier. The survey received responses from 270 household heads. The demographics of the respondents are summarized in Table 1.

Table 1. Demographics of respondents.

Sex	Age	Civil Status	Educational Attainment	Monthly Income
Male, 20% Female, 80%	15 to 35 years, 20%	Single, 11%	Primary Level, 26%	Below USD 100, 61%
	36 to 55 years, 45%	Married/Common-law, 70%	Primary Education, 38%	USD 100-200, 32%
	55 and above, 35%	Separated/Widowed, 19%	Secondary Education, 29%	Above USD 200, 7%
			Post-secondary Education and above, 7%	

As shown in Table 1, most of the respondents (80%) were females, as their husbands or common-law partners were working during the time of data gathering. Of the respondents' ages, 20% ranged from 15 to 35 years, 45% between 36 and 55 years, and 35% from 55 years and above. Of the household heads, 70% were married or with a common-law partner, 11% were single, and 19% were separated, widowed, or widowers. It can be noted that the majority of households (61%) earned an income below USD 100 per month and only 7% above USD 200 per month. This explains the economic status of the households in the Fishermen's Gawad Kalinga Village, which were given the socialized housing facility by the city government.

To support the results of the survey, a key informant interview (KII) was also utilized. KII is a qualitative research technique used to gather in-depth information from key informants who have firsthand experience, specialized knowledge or expertise, or significant involvement in the area being studied. It aims to gain insights, perspectives, and detailed information that might not be easily accessible through other means, such as surveys, questionnaires, and secondary sources [24]. This provided an in-depth discussion on the successes and challenges in the implementation of CWs in the village from the perspectives of other stakeholders in CW planning and operation, including the project planner, engineering, management, community leader, social workers, and CW workers. Open-ended questions asked in the KII are presented in the Supplementary Materials.

To analyze the data collected from both surveys and KIIs, a qualitative content analysis was applied. Content analysis is a method for analyzing the content of a variety of data, such as visual and verbal data. It enables the reduction of phenomena or events into defined categories or themes to better analyze and interpret them [25]. Compared with thematic analysis, which emphasizes subjective interpretation and identification of underlying themes or meanings, content analysis is a more structured, objective, and systematic approach that can also provide both qualitative and numerical results [26]. The numbers and percentages of subthemes of the codes generated from the survey are presented in Section 3. The main themes generated from both surveys and KIIs are discussed from the perspective of real options valuation (ROV) in Section 4. To provide a better understanding of ROV, its levers, and its application in various environmental projects, an ROV background is presented in the next subsection.

2.3. Real Options Analysis Background

Real options valuation (ROV), or real options analysis, is a financial tool used to value investment opportunities that have embedded real or non-financial variables and uncertainties. From financial analysis, "options" are derivative contracts that give the holder the right, but not the obligation, to buy or sell a financial asset at a predetermined price within a specified timeframe. On the other hand, a "real option" is the right, but not the obligation, to undertake real (tangible) project initiatives, such as postponing, expanding/contracting, or shutting down/restarting capital investment based on market, technological, and/or economic conditions [27]. While it is more commonly associated with financial assets, it can also be applied to projects in various industries and sectors [22,28–31], including environmental projects such as CWs that provide nature-based wastewater treatment.

The ROV is a more useful project valuation tool when investment conditions are highly volatile and uncertain. Otherwise, traditional valuation methods, such as net present value (NPV), are more appropriate if investment and market conditions are stable or less flexible [27]. As shown in Figure 4, the NPV only recognized two: the present value of expected cash flows and the present value of fixed costs, while the ROV has six levers, including the uncertainty in future cash flows, a period when a decision should be made, risk-free interest rate, and opportunity cost, in addition to the two in the NPV results.

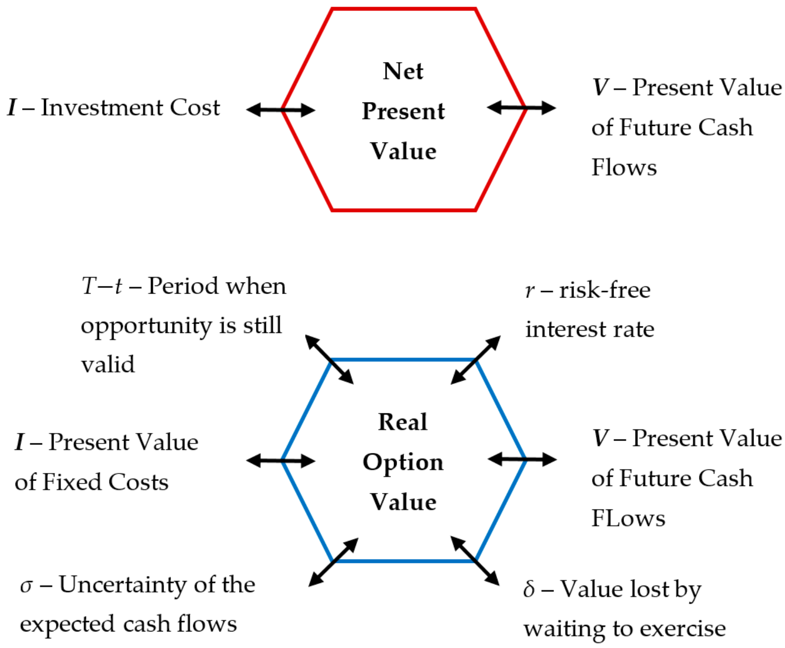

Figure 4. Comparison of levers in net present value and real options value. Reproduced from Agaton [27] under CC-BY-4.0 from publisher MDPI, 2021.

For environmental projects, such as CWs, uncertainties that affect the investment decision-making process include market, policy, technology, social acceptance, and environmental uncertainty [29]. Incorporating ROV into the assessment of CWs acknowledges the dynamic and uncertain nature of environmental projects because it provides decision makers with a more comprehensive understanding of the value associated with the flexibility to adapt and respond to changing conditions over the CW project's lifecycle. Hence, this study evaluates the uncertainties of a real and successful CW project by identifying the factors affecting its implementation.

3. Results and Discussion

Before identifying the success factors and challenges in the implementation of CWs, this study identified the community's awareness of the presence of CWs in the village. Out of the 270 respondents, 240 households (88.89%) were aware of constructed wetlands and their existence in Fishermen's Gawad Kalinga Village. This indicated a high level of awareness among the respondents regarding the CWs. However, there were 14 individuals not aware of constructed wetlands and their purpose but aware of their existence in the village. Also, 5 respondents answered that they knew what CWs were but did not know about their existence in their village. A total of 11 respondents were unaware of both CWs and their existence in their village. The awareness of stakeholders plays a crucial role in fostering a sense of shared responsibility and promoting collective action toward the protection and sustainable management of CWs. Moreover, a heightened awareness of the environmental impact of a project, combined with its effects on the socioeconomic status of communities, calls for broader involvement in decision-making [32].

In terms of project sustainability, 72.59% (196 households) believed that the project was sustainable. This indicated that the majority of the respondents had a positive perception of the project's ability to maintain its operations and to have a lasting positive impact on the community. On the other hand, 17.04% (46 households) expressed a negative view, indicating skepticism about the project's sustainability. Moreover, 10.37% (28 households) were not certain about the project's sustainability. The high percentage of respondents who believed the project to be sustainable reflected a positive perception of the project's overall viability and potential to continue delivering its intended outcomes and benefits in the long term. On the other hand, the householders who expressed skepticism or uncertainty about the project's sustainability highlighted the need for further examination and engagement with stakeholders. It is important to address their concerns, clarify any misconceptions, and provide additional information to foster a shared understanding of the project's sustainability. These uncertainties are discussed in detail in the next subsections, which focus on the factors affecting successful implementation as well as the challenges to making the CW project implementable and sustainable.

3.1. Success Factors of Constructed Wetlands Project Implementation

The success factors of the CW project in Bayawan City are crucial because they influence the project's ability to be replicated and scaled up. By identifying and understanding these factors, the project can serve as a model for similar initiatives. The replication and scalability of successful CW projects can lead to the widespread adoption of this nature-based solution, benefiting multiple communities and contributing to sustainable development.

Table 2 provides insights into the reasons for the successful implementation of the project, as reported by the respondents. Out of the total 270 participants, the most frequently mentioned reason for successful implementation was government support, cited by 42.96% (116 individuals), followed by good governance by 31.85% (86 individuals). As commonly mentioned, "The project was successfully implemented by the government because of the great effort they give to the project", "good governance", "the government is visionary and already looking at the future of its citizens", and "constant monitoring and communication of government employees". This highlights the significance of government backing in terms of policy support, resource allocation, and institutional commitment, which are crucial for the successful execution of projects. This supports the previous claim that government support through better policies and regulations significantly impacts the success of environment-related projects, particularly in developing countries [4]. Additionally, good governance encompasses transparent and accountable decision making, effective regulations, and the involvement of stakeholders. These factors contribute to the overall management and effectiveness of the project, fostering a conducive environment for the implementation of CW projects.

Table 2. Success factors in the implementation of CWs.

Success Factors	N *	Percentage **
Government Support	116	42.96%
Good Governance	86	31.85%
Public Support and Acceptance	39	14.44%
Promised Benefits	28	10.37%
Consistent Monitoring and Evaluation	15	5.56%
Information and Communication with Residents	13	4.81%
Strong International Partnership	1	0.37%

* Number of responses; ** the sum of percentages exceeds 100% as respondents answered one or more challenges.

Public support and acceptance were mentioned by 14.44% of the respondents (39 individuals) as key factors in the project's successful implementation. Respondents mentioned, "The project was successfully implemented because of the unity of the people in the community and their cooperation towards achieving the objectives of the project" and "We are happy to have the CWs for us to sustain the cleanliness of our environment because if we don't have the CW, I think we are so polluted today". This indicates the importance of engaging and gaining the support of the local community, as their active involvement and acceptance can facilitate the smooth execution of the project and promote its long-term sustainability. Decision-making influenced by active community and stakeholder participatory planning eventually triggers a more holistic and ecologically sound intervention toward addressing various environmental problems [33]. On the other hand, a lack of local social acceptance can increase the risk of failures, cost escalation, and project delays [34].

Other reasons cited for the project's successful implementation included promised benefits (10.37%), consistent monitoring and evaluation (5.56%), proper information and communication with residents (4.81%), and strong international partnerships (0.37%). Among the responses were "It is very useful for the community in terms of treating the wastewater of the community and it will attract tourists from other countries", "consistent monitoring of the officers and workers of CWs", and "proper information and communication with the residents". These factors emphasize the importance of delivering tangible benefits to the community, monitoring progress, maintaining effective communication channels, and leveraging international collaborations for knowledge sharing and capacity building. For instance, monitoring and evaluation activities, such as the assessment of inputs, outputs, outcomes, and impacts shared with stakeholders at different stages of the project implementation, not only strengthen the relationship among stakeholders but also assist in evidence-based decision-making to improve the impacts of the project on the community [35].

It is crucial to recognize and leverage these factors for successful project implementation. Government support, good governance practices, and public acceptance are foundational pillars that contribute to the overall success and sustainability of projects. Continued monitoring and evaluation ensure that the project remains on track and adapts to evolving needs. Additionally, effective information dissemination and international partnerships can further enhance project outcomes and resilience. The high level of awareness observed in this study aligns with previous research on community awareness of environmental initiatives.

3.2. Challenges in Constructed Wetlands Project Implementation

Identifying the challenges associated with constructed wetland projects necessitates a multisectoral approach that involves collaboration and coordination among various stakeholders, including government agencies, local communities, and environmental organizations. Taking a holistic perspective means considering not only the technical aspects but also the social, economic, and environmental dimensions to ensure the long-term sustainability and effectiveness of the projects.

Table 3 presents the challenges encountered on the CWs that make them unsustainable. Among the 46 participants who indicated the project was not sustainable, the most frequently mentioned reason was improper maintenance, which was reported by 63.04% (29 individuals). They mentioned that “toilets are always clogged when the septic tanks are full”. This suggests that the lack of effective and regular maintenance practices is perceived as a significant barrier to the project’s long-term sustainability. However, the comments were not solely about the CWs, but also about the sewage system of the village to which the CWs are connected. In addition, these perceptions were contrary to the results of KIIs with other stakeholders, particularly those working on the operations and maintenance of the CWs. According to the KIIs, operations and maintenance are delegated to different teams, including field operations (management of the facility, daily operations, site security, and record-keeping), engineering and maintenance (inspection and repair, monitoring of operations, cleaning, and emergency engineering work), and water quality monitoring. It should be noted that, while CWs are exclusively eco-friendly wastewater treatment strategies, they gradually leave the environment significantly vulnerable to the accumulated adverse environmental impacts due to a lack of strategic sustainability assessment protocols, operational failures, poor maintenance, and the effect of CW–ecosystem interactions [36]. This is also explained in another study, which found that improper maintenance causes more damage than benefit, so maintenance operations need careful planning and controls to minimize these negative impacts [37].

Table 3. Challenges encountered in the implementation of CWs.

Challenges	N *	Percentage **
Improper Maintenance	29	63.04%
Overcrowding	5	10.87%
Sea Level Rise	5	10.87%
Flood	3	6.52%
Foul Smell	2	4.35%
Natural Calamities	2	4.35%
Lack of Funding	2	4.35%
Miscoordination in the Community	1	2.17%
Public Refusal	1	2.17%
Change in Policy	1	2.17%

* Number of responses; ** the sum of percentages exceeds 100% because respondents answered one or more challenges.

Other reasons cited for the project’s perceived lack of sustainability included overcrowding and sea level rise, each mentioned by 10.87%, and flooding (6.52%). These factors indicate concerns related to the capacity and resilience of the project to accommodate population growth and adapt to the impacts of climate change, respectively. Workers in CWs mentioned that “during heavy rainfall or strong typhoons, the CWs were flooded with water, the some of the wastewater went directly to the ocean”. Additionally, the engineer mentioned that “when an earthquake hit the province, there were some cracks in the CWs but we immediately fixed them and improved the system to make it more resilient to quakes”. Initially, the CW project was designed to accommodate 600 households in the village. However, the current users of the facility are now over 750 households. This increased the wastewater volume per day, nutrient overload, changes in regular operations, and maintenance challenges. Such problems were exacerbated by natural disasters, including the threat of sea level rise, as the CWs were situated around 50 m from the seashore. This is also explained in a previous study [38], which found that planning the financing of wastewater treatment should consider the lifecycle of such a facility, as to do otherwise would lead to underperformance and overloaded facilities with poorly operated and maintained treatment plants.

Meanwhile, a smaller percentage of respondents mentioned other reasons, such as foul smells (4.35%), natural calamities (4.35%), lack of funds (4.35%), lack of coordination in the community (2.17%), public refusal (2.17%), and policy change (2.17%). They mentioned that "households near the wetland are complaining about the foul smell whenever the operation is ongoing", "it was smelly but depends on the wind direction", and "sometimes it was flooded when clogged". This supports the previous claim that one of the challenges in public perception of the CWs is the foul odor, especially at night, leading to individuals perceiving an unequal distribution of the polluting nature and nuisances of the CWs [39]. The foul smell was caused by the ammonia present in the sewage water, which could be extracted by the vegetation present in the CWs [40]. Additionally, the lack of funds and technical expertise to manage and operate the facility often makes CW projects economically infeasible, particularly in low-income regions [41]. Furthermore, the lack of widespread public support, combined with community rejection and technical and economical implementation issues, as well as ensuring quality standards and energy efficiency at low cost, are some of the main barriers identified by treated wastewater promoters [42]. These reasons highlight various challenges and issues that can hinder the project's sustainability, including financial constraints, community coordination, public acceptance, and changes in external policies or regulations.

It is crucial to address the reasons identified by the respondents to ensure the project's sustainability. Effective maintenance strategies should be developed and implemented to ensure the ongoing functionality and performance of the project. Additionally, considering factors such as population growth, climate change, and potential environmental impacts can inform adaptive management strategies to enhance the project's resilience and long-term sustainability.

4. Implications for Real Options Valuation

Identifying uncertainties is an important step in real options valuation (ROV), as it allows decision-makers to understand the factors that can impact the value of a project or investment with the flexibility needed to adapt to changing conditions over time. In this study, we identified the sources of uncertainties in the implementation of CWs by evaluating the challenges and success factors in the case of CWs in Fishermen Gawad Kalinga Village in Bayawan City. The results of the analysis can be categorized into political and policy support, technical, social acceptance, financial, and environmental uncertainties.

For any project, political and policy support is one of the major factors affecting investment decisions. Unexpected events, such as natural catastrophes and legal decisions, as well as scientific and popular reports, may affect public opinion, alter policies, and lead to political actions. For instance, the accident in Fukushima resulted in the phasing out of nuclear energy generation in Germany and Switzerland [43]. In the case of the CWs in Fishermen Gawad Kalinga Village, strong political support and good governance paved the way for the success of the project. On the other hand, uncertainties in policy changes, such as the relocation of settlers, changes in land use, and land conversion, impact the replicability as well as the upscaling and sustainability of existing CWs.

Another type of uncertainty is the technical aspect, which includes the planning, preparation, operations, maintenance, and monitoring of CWs. The study's respondents were skeptical of the sustainability of the project due to improper maintenance, such as the foul smell. During the initial years of CW operations in Bayawan City, numerous complaints of foul smells were received from both the village and the surrounding neighborhood. However, these were carefully addressed by the project's technical team. Another challenge is overcrowding in the village, as the original CW plan aimed to accommodate 600 households with five members on average. However, the village now has 750 households, with some units having 10 residents, resulting in the CWs operating beyond their capacity. If this trend continues, then the efficiency and sustainability of the CWs will be at stake.

Both political support and technical issues affected the social acceptance of the project. As shown in the results, technical problems like the foul smell affected public support and acceptance of the project. However, this case is not isolated, as public trust and support are always among the factors for a successful project. For NBS projects, the key factors affecting social acceptance are procedural and distributive fairness, trust, perceived risks, competing societal interests, costs and benefits, knowledge, experience, ecosystem services, and personal norms [44,45]. To increase social acceptance, efforts should focus on transparent communication, collaboration, and stakeholder consultations to provide and promote awareness of the project's design, benefits, and expectations [45,46].

Financing is another uncertainty that challenges the implementation of CWs. In the case of Bayawan City, the CW project is one of the social services provided by the local government, along with the relocation of informal settlers to Fishermen Gawad Kalinga Village. Besides the overwhelming construction cost, the project is non-income generating, and therefore the operations and maintenance costs are shouldered by the local government. Toxopeus and Polzin [47] also identified two main underlying barriers to NBS finance: the balancing and coordinating of public and private finance for a particular NBS and the challenge of valuing and accounting for the multiple benefits delivered by the NBS. In such cases, other ecosystem services from a CW project should also be accounted for, including the provision of water (in the case of Bayawan City) for gardening, fire hydrant, and road cleaning purposes; regulating services, such as treating wastewater and nutrient recycling; supporting biodiversity and wildlife; and cultural services, such as educational and eco-tourism sites [16]. Additionally, financing strategies may include the coordination of public and private finance by enabling the sharing of costs (and risks) with various stakeholders [47]. However, this may also result in another financing challenge in the case of Bayawan, as the main beneficiaries of the CWs are relocated informal settlers and among the poorest of the poor in the city, who can barely contribute to financing the costs of operating the CWs.

Lastly, environmental factors, particularly climate change uncertainty, affect the sustainability of CW projects. Extreme weather and climatic hazards, such as severe storms, strong hurricanes, flooding, droughts, wildfires, heat waves, pests, infectious diseases, and the pandemic, which have been increasing in the past years, continuously pose threats to human lives and communities, biodiversity, and ecosystems [48]. In the case of Bayawan, the CW project is affected by typhoons, sea level rise, and flooding. Indeed, climate change is identified as a major threat to wetlands because the altered hydrology and rising temperature can change the biogeochemistry and function of a wetland to the degree that some important services might be turned into disservices, such as water purification to releasing nutrients to the surface water, a higher rate of decomposition than primary production, and from being a carbon sink to being a carbon source [49]. To address these issues, CWs should be more resilient to the impacts of climate change and natural hazards. Moreover, constant monitoring of technical parameters as well as external factors is needed to ensure the sustainability of CW projects.

Considering these uncertainties in the real options valuation of constructed wetlands involves incorporating them into option pricing models and scenario analyses. Decision makers should assess the flexibility needed to adapt the project based on changing conditions, regulatory developments, and ecological dynamics over time.

5. Conclusions

Constructed wetlands are cost-effective, nature-based solutions for treating domestic, agricultural, and industrial wastewater. As ecosystems, they provide various ecosystem services that benefit humans and the environment. However, this solution's widespread application, particularly in developing countries, is hampered by several factors. The main contribution of this paper is to look at the real options perspective of the economic feasibility on CW projects by considering various uncertainties in their implementation. This study analyzed these uncertainties as the success factors and challenges in project implementation by taking the case of an existing CW facility in Bayawan City, Negros Oriental, Philippines.

Using a survey of household heads in the village connected to the constructed wetlands and other stakeholders, the study found that government support (43%), good governance (32%), and public support (14%) were the most identified factors for the successful implementation of the CW project. On the other hand, the implementation was challenged by improper maintenance (63%), overcrowding in the community (11%), foul smells (4%), funding (4%), and climate-related uncertainties, including natural calamities (4%), flooding (7%), earthquakes (4%), and sea level rise (11%). The identified factors were utilized to analyze their implications for the real options valuation of CW projects. These factors were categorized as various decision-making uncertainties, including political and policy support, technical, social acceptability, financial, and environmental uncertainties. Identifying uncertainties is an important step in real options valuation, as it allows decision-makers to understand the factors that can impact the value of CW projects with the flexibility needed to adapt to changing conditions over time.

This study had several limitations that could be bases for future research. First, this study applied a qualitative analysis to explore the success factors and challenges of implementing CWs based on the lived experiences of various stakeholders and beneficiaries of the project. Quantitative research is needed to complement this study, for instance, by correlating the identified success factors and challenges with demographic characteristics of the respondents, such as gender, education, economic status, size of household, and others. Moreover, both qualitative and quantitative analyses should be applied to other CW uses, including the treatment of agricultural, industrial, and municipal wastewater. Lastly, the results of this research serve as bases for future studies that will consider various uncertainties in making investment decisions regarding the implementation, upscaling, or replication of CW projects to provide a more sustainable and environmentally friendly solution to water resources management.

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