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Flood mitigation through circular economy

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Abstract
Flood mitigation through a circular economy involves integrating sustainable and regenerative practices to reduce the impact of flooding while promoting resource efficiency and minimizing waste. Ensuring the enduring sustainability of flood mitigation projects is crucial to address the escalating flood risks linked to swift urbanization and the impacts of climate change in flood-prone areas. While several sustainability assessment methods are accessible, they are primarily suited for national or catchment-level plans, with none specifically tailored for individual flood mitigation initiatives .This research paper proposes a new innovative decision support framework for sustainability assessment (SA) of flood mitigation projects throughout the project life cycle, focusing on two main aspects: how the project can provide sustained flood risk reduction and how flexible it can be for compliance with sustainable development of the floodplain. The sustainability assessment framework is structured to align with five critical stages, mirroring the project management cycle. These stages include:
a) Contextualizing the project concerning regional sustainable development;
b) Assessing during planning and implementation to ensure the incorporation of sustainability considerations;
c) Evaluating performance and identifying additional sustainability issues during a flood event;
d) Conducting periodic assessments to verify the achievement and compliance with regional sustainable development plans; and
e) Assessing modifications or upgrades to the project.

This research paper also outlines the implementation process of the framework, encompassing methods for data collection, qualitative and quantitative analyses of sustainability indicators, and multi-criteria analysis to produce conclusive outputs for decision-making. The utilization of this framework aims to enhance decision-making processes, ensuring the sustainability of flood mitigation projects and fostering flood-resilient sustainable development in floodplain areas.

KEYWORDS: flood mitigation, circular economy, sustainability assessment, decision support framework, project life cycle, sustainable development, flood risk reduction, climate change, urbanization, resource efficiency, waste minimization, flood-resilient development, multi-criteria analysis, sustainability indicators

I. Introduction

Flood risk mitigation projects are typically initiated in response to significant flooding incidents, often in an ad-hoc manner and with financial backing from the national government or international donors, lacking adequate pre-planning. Efficient planning and execution of flood risk reduction measures that align with sustainability principles are vital for the enduring development of floodplains. The current procedures for planning flood mitigation projects involve conducting feasibility studies with various options across different flood scenarios, choosing and implementing the most viable option, and monitoring the project's progress over time. The feasibility study takes into consideration environmental, social, and economic factors within the project area, influencing the selection of the optimal option. In certain instances, management measures are implemented to mitigate adverse environmental and social impacts. However, there lacks a mechanism within the project planning and execution processes to evaluate the potential for sustained reduction in flood risk by the flood mitigation project, as well as its significant contribution to the sustainable development of the floodplain.This research paper introduces a suggested framework designed for the sustainability assessment of flood mitigation projects and outlines the procedures for its implementation. The framework serves as a valuable decision-making tool for planners, contributing to the assurance of sustainability in such projects.

II. Literature Review

Sustainability can be defined as the quality of the development process that can be perpetuated indefinitely for present and future generations. Sustainability assessment, on the other hand, involves evaluating the significance or status of a specific development activity, encompassing economic, environmental, and social effects, and it employs an integrated approach. The determinants of sustainability for a development proposal are approximated based on achievements toward pre-selected aims or criteria grounded in accepted principles of sustainable development (Sadler et al., 2008; Sadler, 2010).

The assessment of sustainability in development programs has intrigued planners and scientists, aiming to gauge progress toward sustainable development. Sadler (2004) advocates for an integrated decision-making process at different levels of policymaking, including micro-level integration for individual projects, meso-level integration for policies and programs, and macro-level integration at the national level. Recently, various methods have been developed for macro or national-level sustainability assessment, such as accounting-based approaches (e.g., Genuine Progress Index (GPI)), narrative assessments (e.g., World Bank’s World Development Report), and indicator-based assessments (e.g., Dashboard of Sustainability) (Dalal-Clayton and Sadler, 2014). Sustainability assessment tools for the meso-level, like a 'sustainability test' for appraising policies, plans, and programs (Nelson, 2003), and capital stock-based 'Telos' sustainability assessment tools used for provinces in the Netherlands (Knippenberg et al., 2007), have also been developed. The UK government has taken a pioneering step by adopting meso-level sustainability appraisal guidance for regional and local authorities (ODPM, 2005). However, none of these macro- and meso-level sustainability assessment tools have been linked to projects at the local level, which have a significant impact on the outcomes of such assessments.

Some researchers have recently proposed sustainability assessment methods for individual projects. For instance, Varey (2004) introduced an integrated sustainability assessment (ISA) model for appraising development proposals by local government council managers. The ISA model incorporates a simple one-page 'Thinking Tool' that generates a collective score of net benefits and impacts to determine project acceptance or rejection. In the case of large infrastructure projects like bridges, Ugwu et al. (2006) proposed an analytical decision model for sustainability appraisal in infrastructure projects (SUSAIP). This sustainability assessment process includes a 'weighted sum model' technique in multi-criteria decision analysis (MCDA) and the 'additive utility model' in an analytical hierarchical process (AHP) for multi-criteria decision-making, producing a 'sustainability index' and ranking of alternative design options based on various sustainability indicators.

Similar to infrastructure projects such as roads and bridges, most structural flood mitigation projects involve significant infrastructure elements such as levees and dams (Kundzewicz and Takeuchi, 1999). The goals of flood mitigation project planning differ significantly from those of other projects, requiring an integrated assessment that considers present and future environmental, social, and economic issues in the floodplain. Therefore, there is a need for sustainability assessment tools explicit to flood mitigation projects. Some initiatives have been taken to develop sustainability assessment tools for regional flood mitigation projects. Kumar et al. (2012) describe a sustainability assessment process for an urban river corridor re-development project in Sheffield, UK, using a Bayesian belief network (BN)-based integrated model to determine the best sustainable scenario. The UK government has recently developed sustainability appraisal guidance for evaluating flood and coastal erosion management-related policies, plans, and schemes (DEFRA, 2007a). In this approach, the sustainability tool and several performance indicators, such as environmental impact, operation and maintenance, health and safety, and cost risk evaluation, have been used to evaluate alternative options for flood mitigation projects in the planning stage only. No further assessment in the post-implementation stages is reported (DEFRA, 2007b).

Overall, current sustainability assessment approaches for projects focus on selecting the best alternative option, but there is no mechanism to verify whether the selected option will be genuinely sustainable in the long term. It is imperative that sustainability assessment becomes an integral part of the project planning, implementation, and monitoring process (DEFRA, 2007a). The discussed assessment methods do not link the contribution of the individual project’s outcome to the sustainable development goals of the region or country. Moreover, the current sustainability assessment approaches (Ugwu et al., 2006; DEFRA, 2007a; Dalal-Clayton and Sadler, 2014) do not assess whether the project can fulfill its objectives (sustained outcome) over the project life as well as the effect of any modification in the project.

Approaches to Assessing Sustainability: Theories and Application

Sustainability assessment involves the examination of the value, importance, or condition of a comprehensive or specific development activity. It encompasses a wide-ranging field of professional analysis that considers the economic, environmental, and social impacts of development. The assessment explores sustainability implications through an integrated approach, applicable at micro, meso, and macro levels of policy-making. Sustainability refers to the ability of a development process to continue indefinitely, benefiting both present and future generations. Sustainability assessment, on the other hand, involves evaluating the value, significance, or progress of a task, action, or specific development activity. This analysis considers the economic, environmental, and social impacts of development, taking an integrated approach to ensure sustainability. To determine the sustainability of a development proposal, one must assess progress towards pre-established goals or criteria based on accepted principles of sustainable development.

Numerous sustainability appraisal methods have been developed for macro and meso-level policies and plans, including the Genuine Progress Index (GPI), Dashboard of Sustainability, Integrated Sustainability Assessment (ISA) from the MATISSE project (Jager et al., 2008), and sustainability appraisal (SA) guidance for regional and local authorities in the United Kingdom (ODPM, 2005). However, to ensure the effective attainment of sustainability goals, it is essential to implement the sustainability appraisal process at the project level and link it to meso- and macro-level planning. Varey (2004) introduced a conceptual model for an Integrated Sustainability Assessment (ISA), which presents a straightforward one-page 'Thinking Tool' that municipal executives and local government council managers can use to evaluate development proposals. In the case of significant infrastructure development, such as a bridge project, Ugwu et al. (2006) have proposed an analytical decision model and structured methodology for sustainability appraisal in infrastructure projects (SUSAIP). The model establishes a 'sustainability index' and ranks various alternative design options based on critical sustainability indicators.Although the physical infrastructure of flood control projects, such as levees, dams, and flood walls, may have similarities with other infrastructure such as roads and bridges, the goals and Planning considerations of flood control vary significantly. Therefore, a separate sustainability assessment approach, specific to flood control projects, is essential. In the field of flood risk management, there have been few efforts to integrate sustainability assessment processes into development planning. Notably, the UK Government has recently adopted sustainability assessment methods for managing flood and coastal erosion risks (DEFRA, 2007a), based on SA guidance for regional and local in the UK (ODPM 2005). This sustainability assessment approach has been applied to the Forres Project as part of the Moray Flood Mitigation Scheme, which serves as a case study. Sustainability tools, incorporating various assessments of performance indicators such as environmental impact, operations and maintenance, health and safety as well as risk and cost assessments, were used to evaluate alternatives (DEFRA 2007a, b).Another example, as demonstrated. by Kumar et al. (2012), illustrates the sustainability assessment process of an urban river corridor redevelopment project in Sheffield, UK. In this project, an integrated model based on a Bayesian Belief Network (BN) was developed to unify sustainability indicators, thereby facilitating the comparison of alternative development scenarios. different potentials and selecting the most sustainable option.In general, sustainability assessment methods have been implemented at the project level, aiming to select the best option by evaluating the options. replacement based on sustainability indicators. However, there is still a lack of mechanism to verify whether a top-rated project is truly sustainable. These approaches do not link the contribution of each project's overall outcomes to sustainable development goals at the regional and national levels. Furthermore, current sustainability assessment methods do not assess whether a project produces sustainable results or meets its objectives throughout the project's life cycle. The evolution of a project's goals and outcomes throughout its life cycle can be another aspect to consider when assessing sustainability in a long-term context.

III. Methodology

This study involves a systematic review of the current project planning processes and sustainability assessment approaches used across different sectors. It also includes a survey and consultation with experts. Two projects from two regional councils in the country were analyzed using a wide range of methodologies, including case studies. The case study projects were investigated to determine their planning and implementation processes and sustainability aspects. A series of consultations were conducted with experts involved in the projects to consider the positive and negative aspects of the planning process and the integration of sustainability aspects into the projects. A set of sustainability indicators was developed through an extensive literature review and case studies. These sustainability indicators were further validated using a structured questionnaire with 15 experts working on flood management issues in Australian local governments and consultancy firms. Based on the project life cycle of flood protection projects and current practices, a proposed sustainability assessment framework was developed. Additionally, detailed instructions are provided for implementing the various phases of the framework.

Proposed Framework for Assessing the Sustainability of Flood Mitigation Projects

Comprehending the entire life cycle of a project is crucial for recognizing sustainability issues associated with the project and determining the integration of sustainability assessments into the existing planning procedures. Taking various factors into account, the complete life cycle of a standard flood mitigation levee project has been outlined (Figure 1) based on pertinent literature and case studies. Critical concerns at each stage of the project life cycle are highlighted here

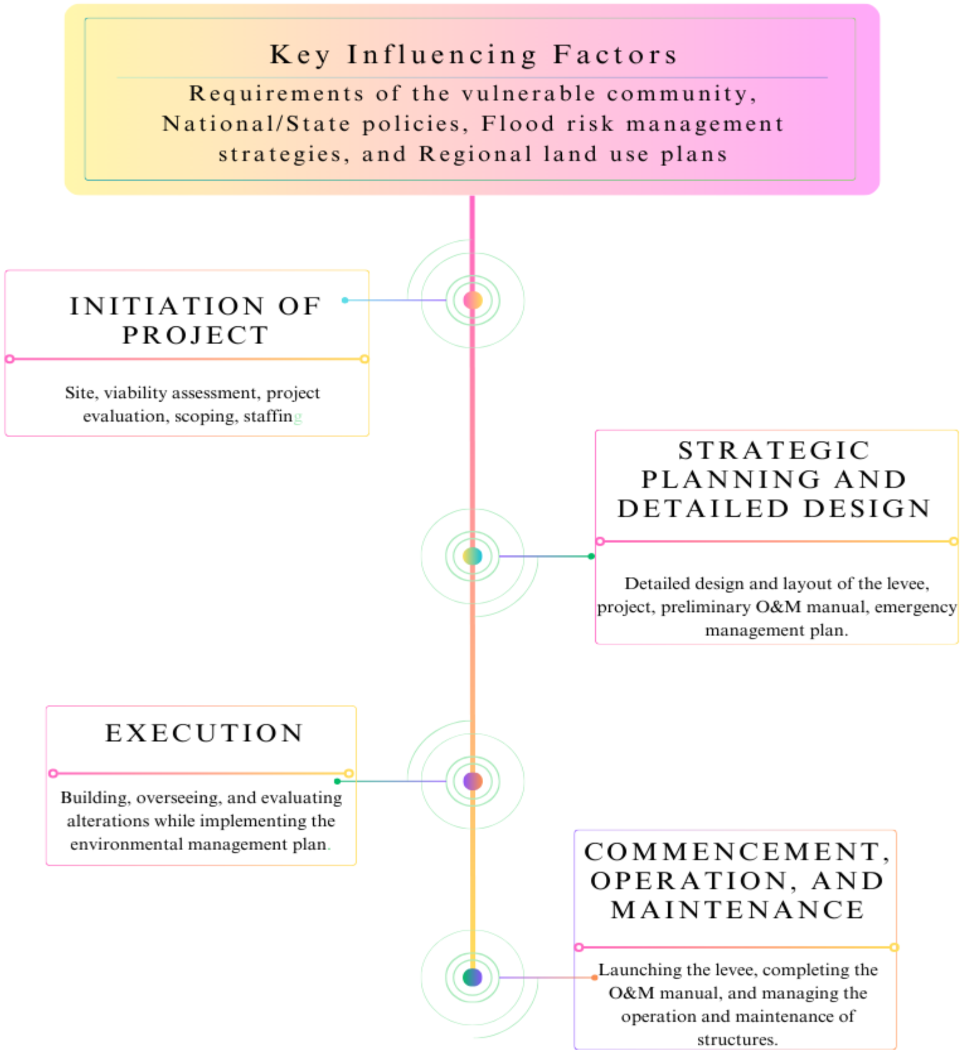

Figure 1: T he entire life cycle of a standard flood mitigation levee project.

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Implementation Procedures

Grasping the complete project life cycle is crucial for recognizing sustainability issues linked to a project and establishing the incorporation of sustainability assessments into existing planning procedures. Examining diverse aspects, the comprehensive life cycle of a standard flood protection embankment project is elucidated based on relevant literature and case studies (Figure 1). The following are key considerations at each phase of the project life cycle.

Initiation of project

Floodmitigation levee projectsaretypicallyinitiatedbyflood-pronecommunitiesandgovernmentsbasedonthehistoricallegacyoffloodcontrolactivitiesinfloodplains. Theinitiationphaseofaprojectcanlastanywherefromoneyeartoseveralyears(evendecades),dependingonthefloodexposure,theneedsofthe4,444people,thescopeoftheproject,detailedfloodriskinformation,andfundingrequirements.

Privatelyand/orcommunity-fundedsmallprojectscanstartquickly. However,complicationsarisewhenfundingandresourcesarerequiredfromlocalandnationalgovernments.

Once an initial decision has been made to proceed with a flood protection project, a feasibility study or project evaluation is conducted. This study involves a comprehensive analysis of flood characteristics based on historical records, defining embankment orientation and design options, and determining the financial feasibility of the project. The feasibility study might also include an environmental and social impact assessment (EIA/SIA) and extend to the detailed design of the primary components of the project. However, sustainability assessments are not currently included in feasibility studies, project evaluations, or other evaluations of flood protection levee projects. The results of the feasibility study form the basis for the issuance of approvals by state and/or national development management authorities, such as the Integrated Development Assessment System "IDAS" in Australia (DNRM, 2014). Once the necessary approvals and funding allocations have been secured, the detailed planning and design phase can commence.

Strategic planning and detailed design

During the planning and design stage, the detailed design and layout of the embankment and associated structures are prepared according to standard design standards (e.g. 1: 100-year recurrence interval (ARI) flood design level) and construction guidelines. In addition to the preparation of detailed work plans, financial plans and draft operations and maintenance manuals, emergency risk management plans including risk maps and evacuation routes are often prepared at this stage (Environment Agency, 2010; DNRM , 2014).

Execution: Project implementation may take between a few months to several

years. Some projects are implemented phase by phase, which may face uncertainty of funding for completing the whole project. Land acquisition and resettlement of existing inhabitants along the levee site might be necessary, which may delay the implementation where there are many disputes. Any major modifications of the levee design (e.g. changing the levee height in consideration of mitigating climate change induced extreme flood events) may delay the implementation as well (CIRIA, 2013).Moreover, although the environmental and social management plan needs to be implemented in this phase (DoWR, 2009; Environment Agency, 2010), this is usually not implemented properly due to ignorance by the implementing agency, and a shortage of funds.

Commencement, operation, and maintenance: At the commissioning stage, like other

infrastructure projects, it is important to do a post-implementation review of the levee projects to see their performance; however, this is rarely carried out because it is dependent on the flood event. Operation and maintenance of the levee and associated structures usually continue throughout the project life and beyond, especially after every flood (Environment Agency 2010; BWDB 2014). Currently, post flood evaluation only focuses to the levee structures (Environment Agency, 2010; DELWP, 2015); little or no focus on the flood risk prevails in the floodplain at the time of evaluation.

The Decision Support Framework (DSF) for evaluating the sustainability of flood mitigation projects and the implementation process

The key sustainability issues in flood mitigation projects encompass sustained flood mitigation, environmental, social, economic, and policy and institutional aspects (Carter et al., 2009). Some of these factors have been addressed in recent years during the planning of flood mitigation projects under the labels of strategic environmental assessment (SEA), environmental impact assessment (EIA), and social impact assessment (SIA) (Varey, 2004). These assessments explicitly spotlight the sustainability concerns of flood mitigation projects, assessing how long the project can consistently reduce flood risk in the area and whether it can contribute to the sustainable

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development of the region (DLPE, 2000; IBWC, 2007).

Considering the aforementioned sustainability aspects, this proposed decision support framework for the sustainability assessment of flood mitigation projects focuses on two main aspects: 1) sustained flood risk reduction by the project, and 2) enabling sustainable development of the floodplain. The outlined framework, presented in Figure 2, incorporates sustainability assessment components at each stage of the project, as discussed below. This framework is designed to evaluate flood mitigation projects (e.g., levees) in riverine and coastal floodplains. It takes into account all environmental, social, and economic elements in the project-affected area, emphasizing them proportionately based on their significance. The framework supports the adjustment of objectives and the revision of indicators (e.g., adding new assessment indicators or removing previous ones) at different stages of the project life cycle.

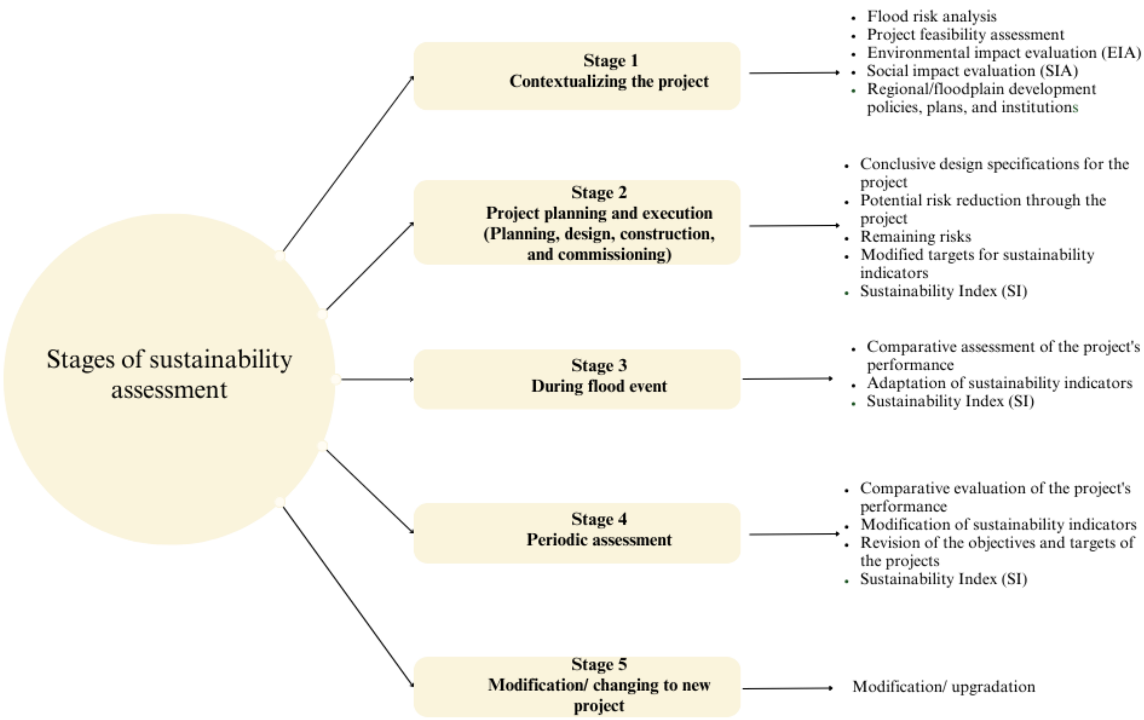

Figure 2: Overall layout of the DSF for sustainability assessment of flood mitigation

Stage 1-Contextualizing the project

To initiate the sustainability assessment, it is crucial to position the flood mitigation projects within the floodplain and establish their connection to regional development initiatives. Preliminary studies conducted at the project's outset, such as the flood risk management study encompassing hydrological and morphological impacts, the project feasibility study, environmental impact assessment (EIA), and social impact assessment (SIA), prove valuable in characterizing the flooding patterns and potential impacts of the project, including vulnerable populations and flood damages, within the floodplain. The percentage of total flood risk reduction achievable by the proposed flood mitigation project should also be ascertained (Smith, 2013). When determining the specific flood characteristics and impacts to be considered for the project's proposed alternatives, uncertainties in flood events, impacts, and flood risk estimations must be taken into account (Olbrich et al., 2009; Su and Tung, 2014).

Reviewing regional floodplain development policies and plans is essential to define sustainable development objectives, indicators, and targets for the region, aligning them with the main goal of the proposed project. Additionally, potential future developments in the project area, such as urban townships or agriculture, should be identified. Furthermore, the necessary policy and institutional provisions for planning, implementation, and operation of the project should be outlined. Collecting this information contributes to determining the project's status concerning its potential for flood risk reduction and its contribution to the sustainable development of the floodplain.

Stage 2-Project planning and execution (Planning, design, construction, and commissioning)

The sustainability assessment of the flood mitigation project commences at this stage, and this assessment process can be subdivided into three crucial phases of the project life cycle.

a) Planning and design phase:

Typically, during the planning and design phase, diverse design options are assessed with regard to economic, social, and environmental considerations, and the optimal design alternative is chosen. Incorporating these aspects, a sustainability assessment for each design option should be conducted using the indicators identified in the previous stage. Each sustainability indicator should encompass both spatial (local and regional) and temporal (inter- and intra-generational) dimensions of sustainable development. The Sustainability Index (SI) for each alternative design option should be determined through multi-criteria analysis (MCA) techniques (Edjossan-Sossou et al., 2014; Ness et al., 2007), integrating the sustainability indicators. The sustainability assessment process for the design alternatives involves three key steps: (a) identifying relevant indicators universally applicable to all alternative design options, (b) assigning numerical weightage values to each indicator to gauge their relative importance in achieving sustainability objectives, and (c) performing computational analysis to determine the SI for each alternative and establish their ranking.

b) Construction Phase:

During the construction phase, the focus should be on monitoring whether the sustainability indicators align with the sustainability assessment (SA) conducted in the planning phase. Additionally, the implementation of environmental and social management plans should be closely monitored, as these plans significantly impact the project's sustainability. Reporting on compliance and the attainment of project design targets is crucial. Any alterations to sustainability indicator targets due to modifications in the project design should be duly documented.

c) Commissioning phase:

Sustainability assessment becomes crucial in the commissioning stage due to the potential for changes both within and outside the project during implementation, particularly in the case of large projects. Factors such as socio-political and administrative shifts can significantly impact project execution. Currently, project completion reports typically present the 'design as constructed' and offer some operation and maintenance guidelines. However, there is usually no comprehensive review or further study conducted post-completion to compare variations with the assessment results obtained in the planning phase. It is essential to conduct a detailed post-implementation review to precisely define the finally constructed design and assess its influence on sustainability indicators. Additionally, the assessment should consider residual flood risks, especially in worst-case scenarios such as flooding beyond the design flood level or potential failure of the existing levee through various mechanisms and its subsequent impact on sustainability indicators.

Stage 3- SA during flood event

The actual performance of the SA flood protection project during the flood event can be observed during the flood event, so the sustainability assessment is carried out during such events from the beginning to the end of the flood event.is needed. Currently, only the technical performance of flood protection structures (such as embankments and auxiliary structures) is assessed under for whether they require repair or improvement.

However, the SA can provide further details regarding the performance of the project, considering all aspects of sustainability.The evaluation primarily focuses on the performance of the project in the event of a flood against sustainability indicator objectives such as flood risk reduction (how much damage was avoided) and minimizing negative environmental and environmental damage. It is necessary to evaluate the performance of remedial actions taken.Social impact of the project.This is to monitor the sustainability of the project.This evaluation provides a description of the project's performance compared to evaluations performed during the planning and post-construction stages .Sustainability indicators may need to be adjusted by incorporating new or revised indicators into the SA process to account for additional benefits and adverse effects of the project observed during the flood.Based on this evaluation, additional improvements and corrective actions can be incorporated into the project.

Stage 4- SA at Regular Intervals

Similar to regular monitoring of the project regardless of flood events, sustainability assessments are carried out at regular intervals, typically every 5 years or every year, depending on local regulations.should be executed. Regional Development Plan will impact land use and economic activity in the project area in the future.Therefore, periodic evaluations should estimate how much risk mitigation the project will provide.In addition, the positive and negative impacts of the project and changes in environmental, social and economic issues in the floodplain, including the project area (e.g.trends in changes in economic activities such as fishing, agriculture, industrialization, real value of real estate). It should be evaluated. It is also important to determine whether the project has facilitated the creation of new types of risks (pollution, internal drainage backups, etc.) in the project area.This periodic SA provides a comparative description of the performance of the project in relation to the results of the SA during the post-construction phase and, if necessary, adjusts the sustainability indicators based on the observed impacts.The purpose is You can also suggest revisions to Goal and project objectives and, where appropriate, link them to the enhanced sustainable development goals of Regional Development Plan .

Phase 5- SA in change/conversion phase to new project.

Flood control projects are subject to change due to failure of structures and upgrades to withstand extreme flooding.In such cases, the sustainability assessment process can be restarted in phases 2 to 4.In many cases, current projects can be redesigned for multiple purposes, such as converting an embankment project into an embanked road project. As a result, the original objectives of the project established during the planning and implementation stages will change. This phase of a project can be defined as a "transition point" to a new project.This project has the potential to further contribute to flood protection and sustainable development of floodplains.For this , when considering a new project, SA should start from stage 1 and run through stage 4 as .

IV. Discussion and Conclusions

Integrating sustainable development aspects into policies and strategies is essential. However, achieving it practically is impossible without integrating it into the decision-making processes of individual projects at the local level. Flood mitigation projects have significant impacts on the environment, society, and economy, making sustainability concerns a priority. To ensure sustainable development, decision-making processes for flood protection projects must be a continuous process throughout the project's life cycle. Currently available sustainability assessment approaches focus on selecting the most appropriate alternative strategy or project design, without going into detail about whether they are sustainable. To address this limitation, a proposed decision support framework for sustainability assessment has been developed, considering the entire life cycle of flood protection projects. This framework helps planners assess flood protection projects throughout their lifetime for compliance with sustainable flood management. The proposed framework identifies the project's impacts on flood control, environmental and socio-economic development in floodplains, helping planners and policymakers make decisions confidently. The framework's continuous evaluation process helps current and future generations address project deficiencies and develop adaptive flood protection measures. The framework adopted an indicator-based multicriteria analysis (MCA) approach to determine the sustainability index (SI) of a project. The set of indicators and their evaluation are case-specific and subject to change by decision-makers. The proposed framework provides a reliable set of metrics and standards that can be easily used by decision makers. Although this framework cannot capture all the complex relationships of social, environmental, and economic aspects and their impact on all possible projects, it includes simple calculations to ensure sustainability at the project level. Top of Form.

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