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Mobilizing Sustainable Investment for Vietnam's Coastal Dike System: Determinants and Policy Solutions

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Abstract

Coastal infrastructure development, particularly through sustainable investment in dike systems, represents a critical measure for enhancing climate adaptation and protection in vulnerable regions. In Vietnam, which faces escalating threats from climate change and sea-level rise along its extensive coastline, the need to upgrade and maintain coastal dikes is urgent. However, significant deterioration of existing dikes, coupled with constrained state budget resources, presents major challenges to financing such infrastructure. This study aims to identify the determinants of investment demand for Vietnam's coastal dike system and to propose policy solutions for mobilizing sustainable financing. The research employs a mixed-methods approach, combining exploratory quantitative analysis of data from 21 coastal provinces with qualitative SWOT assessment and international policy benchmarking. Findings reveal that the length of substandard dikes is the primary factor correlated with investment demand, while socio-economic indicators and typhoon frequency show weaker associations. Based on these results, the study develops an integrated six-pillar financing framework, emphasizing scientific capital allocation, a diversified financial ecosystem, transparent governance, innovative instruments, strategic international cooperation, and robust monitoring. The framework draws on lessons from countries such as Japan and the Netherlands, and proposes mechanisms including a dedicated coastal dike infrastructure fund, public-private partnerships, green financial instruments, and enhanced international cooperation. The study concludes that mobilizing diversified and timely resources is essential not only to address a projected adaptation financing gap of USD 6–12 billion for 2025–2030, but also to build long-term resilience, protect coastal communities, and support sustainable development in Vietnam.

1. Introduction

Vietnam's 3,260 km coastline and concentrated coastal population expose the country to severe climate change impacts, particularly in the Mekong Delta and central coastal regions [1] [2]. The Mekong Delta represents one of the most vulnerable areas to climate change and sea level rise, which significantly increases the risk of inundation from storm surges and wave impacts [1]. Projections indicate that a 1.0-meter sea level rise by 2100 could result in the loss of 7.6 million tons of rice annually, posing a serious threat to national food security [3]. Additionally, the central coastal region is frequently affected by intense tropical cyclones, causing heavy rainfall, widespread flooding, and substantial socio-economic losses [1].

Coastal dikes in Thanh Hoa and Ha Tinh provinces, designed for category 9-10 storms with 5% storm surge probability, are vulnerable to more intense category 13-14 storms [4]. In this context, coastal dike systems have demonstrated their critical role in flood prevention from storms and sea level rise, contributing to the protection of production areas as well as the livelihoods and safety of coastal communities [1] [5]. Specifically, the importance of coastal dike infrastructure is clearly evidenced by exemplary projects such as the Nam Dinh Vu coastal dike in Hai Phong, which is expected to protect approximately 2,000 hectares of industrial land, attract investment, and generate over 100,000 jobs [6]. Similarly, the West Ca Mau coastal dike project not only serves a coastal protection function but also creates opportunities for socio-economic development, tourism, and services, while simultaneously restoring 2,000 hectares of mangrove forests as a "green shield" against saltwater intrusion [5].

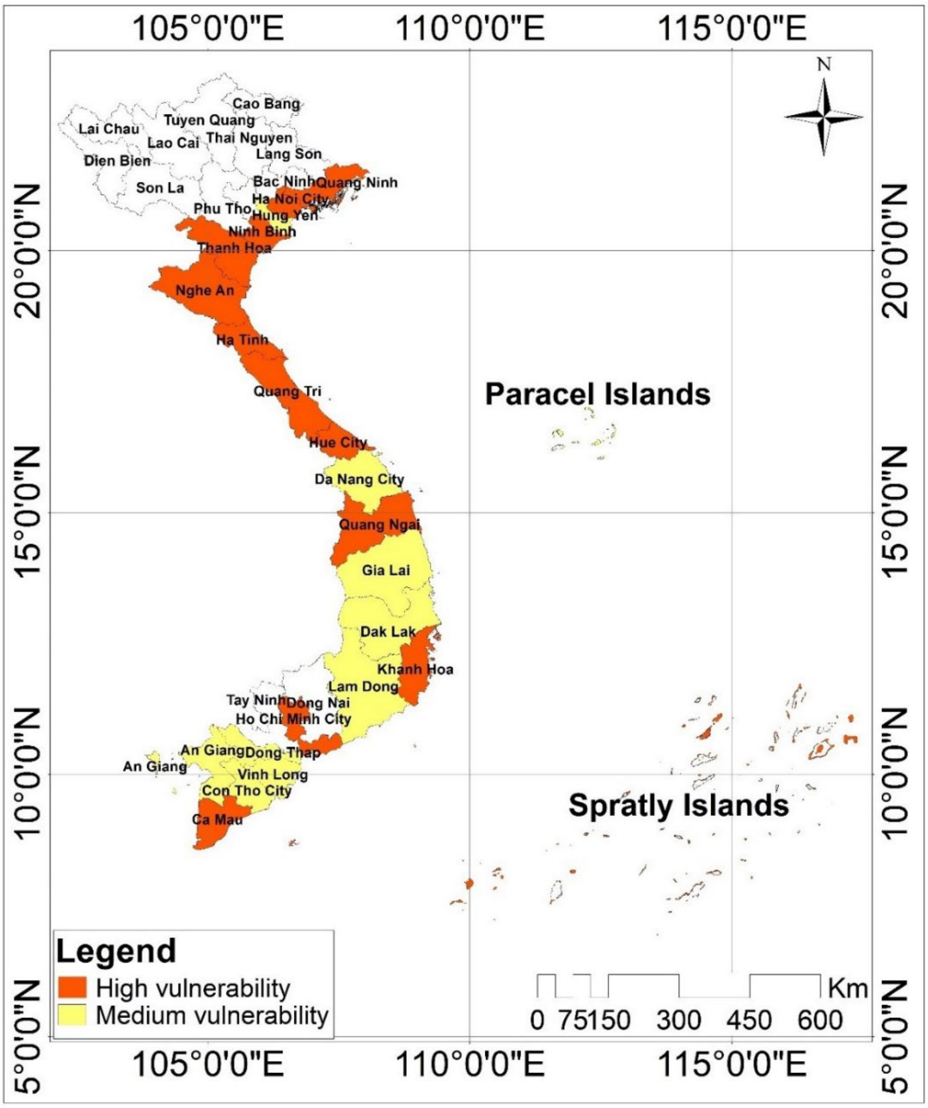

Fig. 1 *Map of Vietnam's provinces/cities in 2025 that employed GIS techniques to delineate and establish the precise spatial coordinates of the study area*

Current assessments indicate that many coastal dike segments fall below safety standards, necessitating priority investment [7]. Consequently, the reinforcement, upgrading, and construction of coastal dike infrastructure have been identified as national strategic priorities for climate change adaptation [1]. The investment requirements for construction, repair, upgrading, and reinforcement of flood prevention infrastructure, including coastal dike systems, demand substantial capital, while state budget resources remain constrained and insufficient to meet these comprehensive needs. Particularly, the gap between capital requirements and state budget capacity is considerable, as exemplified by Ho Chi Minh City's flood reduction program for 2016-2020, which required total funding of 73,359 billion VND, while the municipal budget could only allocate approximately 16,338 billion VND, with the remainder dependent on socialization and ODA funding [1]. This highlights the pressing necessity of establishing diversified and innovative financial mechanisms to secure adequate capital for the construction and long-term maintenance of Vietnam's coastal dike system, thereby enhancing resilience to the escalating impacts of climate change.

Furthermore, following the administrative consolidation at the provincial/municipal level effective June 12, 2025, Vietnam now has 21 out of 34 coastal provinces and cities, with the proportion of coastal localities increasing from 44% to 62% (Fig. 1) [8]. This underscores the increasingly vital role of coastal areas in socio-economic development, investment attraction, and climate change adaptation. Most post-consolidation coastal provinces and cities demonstrate an urgent need to implement specific financial mechanisms to ensure sustainable resources for infrastructure development, disaster risk management, and marine economic potential exploitation. Concurrently, capital allocation must be optimized based on comprehensive risk assessments and the specific needs of each locality, combined with international cooperation experience from countries with notable achievements in coastal socio-economic development, particularly in coastal protection.

While numerous prior studies have investigated the impacts of climate change and the construction and protection of coastal dikes, research on capital mobilization mechanisms for constructing and protecting coastal dike infrastructure in Vietnam remains limited and faces substantial challenges [9] [10]. In particular, due to the absence of quantitative analyses regarding the determinants of investment demand and financial mechanisms appropriate to the national context, programs and projects under implementation continue to encounter difficulties in determining capital scale, selecting effective mobilization instruments, and ensuring sustainable financial resources. Consequently, this study aims to address the following research questions: (i) What factors determine the investment capital demand for coastal dike systems? (ii) How can effective and sustainable capital mobilization mechanisms be developed? (iii) Which international experiences can be applied to Vietnam? Building upon these questions, this study analyzes the determinants of investment capital demand and proposes several solutions for diversifying capital mobilization sources for Vietnam's coastal dike system, to enhance resilience and adaptation capacity to climate change.

While acknowledging the well-established literature on climate finance instruments, this study aims to contribute by contextualizing these mechanisms for Vietnam's specific coastal infrastructure challenges. The primary contribution is a policy-oriented financing framework, empirically informed by a mixed-methods analysis of local conditions and international best practices.

2. Overview of Research

2.1 Overview of Global Studies

2.1.1 Determinants of Investment Needs and Cost Estimates

Global research on coastal protection investment needs has focused primarily on quantifying financial requirements under accelerating climate change and sea-level rise. These studies converge on the conclusion that global and regional financial demands are immense and are primarily determined by biophysical risks and existing infrastructure conditions. For instance, Robert J. Nicholls et al. (2019) estimate that global coastal protection costs could reach 18.3 trillion USD during the 21st century, with maintenance constituting the largest share [11].

In Asia, the scale of required investment is similarly daunting, with studies by Mikio Ishiwatari and Daisuke Sasaki highlighting a need for several hundred billion USD for flood management and coastal protection [12] [13]. Micro-level analyses of cost drivers complement these macro-level estimates. Research, such as that by Stephan Lenk et al. (2016), affirms that the technical parameters and degradation levels of coastal dikes are pivotal in estimating investment costs, establishing a foundational link between physical infrastructure condition and capital requirements [14]. Collectively, this body of work establishes a clear rationale for large-scale investment and underscores the technical condition of assets as a key determinant of financial need. Collectively, these studies establish that infrastructure condition is a primary, quantifiable driver of financial need for coastal protection.

2.1.2 Climate Finance Instruments and Mechanisms

A second, rapidly evolving research strand addresses the "financial gap" between identified needs and available public resources, exploring innovative instruments to mobilize private and international capital. Studies consistently document a significant shortfall in adaptation finance. Bhandary et al. (2021) note that while adaptation needs reach 1.8 trillion USD globally, only a fraction has been allocated [15], a gap echoed by UNEP (2022) and JICA reports [12] [16]. In response, literature extensively catalogues and evaluates a suite of financial mechanisms. Public-Private Partnerships (PPPs) are widely advocated for leveraging private sector efficiency and capital [17] [18]. Green bonds, loan guarantees, and dedicated infrastructure or climate funds are promoted as tools to attract institutional investors [15] [18] [20].

Furthermore, instruments like catastrophe bonds and parametric insurance are analyzed for their role in transferring climate risks to financial markets [21]. However, a critical sub-theme within this literature highlights persistent barriers to private capital mobilization, including project risk profiles, long investment cycles, and institutional hurdles [21] [22]. This strand thus moves beyond mere enumeration of instruments to engage with their practical feasibility and the governance structures needed for success. Thus, the literature moves beyond cataloging instruments to critically engage with their feasibility and the necessary conditions for mobilizing private capital.

2.1.3 Governance Models and International Best Practices

The third major strand critically examines the governance frameworks and institutional models that underpin successful coastal protection financing. This research emphasizes that financial mechanisms alone are insufficient without effective governance, transparent management, and equitable cost-sharing arrangements. Comparative case studies provide crucial insights. Japan's model of multi-level cost-sharing among central government, local authorities, and communities is frequently cited as a robust system for ensuring sustainable funding and local ownership [23] [24]. The Netherlands' "Delta Works" program is celebrated not only for its technical innovation but also for its integrated, long-term financial planning and dedicated funding schemes [25]. Conversely, literature also scrutinizes challenges such as policy instability, lack of transparency, and coordination failures, which can undermine investment and project efficacy [15] [26] [27]. This body of work argues that the "how" of governance—encompassing legal frameworks, accountability systems, and participatory processes—is as critical as the "how much" of financing. This strand concludes that robust governance is a critical enabler, often determining the success of financial mechanisms.

2.2 Overview of Research in Vietnam

Vietnamese coastal protection research has expanded to include vulnerability assessments, policy analyses, and infrastructure case studies of specific infrastructure projects. Scholarly analyses confirm Vietnam's extreme exposure to sea-level rise, coastal erosion, and typhoons, with hotspots in the Mekong Delta and Central Coast [1] [9]. Academic studies have utilized climate scenarios and simulation models to quantify inundation risks and economic impacts, such as projected rice production losses, providing a scientific basis for urgency [1] [28].

In the policy domain, literature has systematically reviewed Vietnam's evolving legal framework, including the Law on Natural Disaster Prevention and Control (2013) and national strategies on climate change and green growth [1]. These analyses often acknowledge the comprehensiveness of the policy architecture while identifying implementation challenges, particularly regarding inter-ministerial coordination, local capacity, and—most pertinent to this study—sustainable financing [9] [10]. Empirical research on financing has been more limited. Existing work tends to be descriptive, documenting the capital demands of major projects like the Nam Dinh Vu or West Ca Mau dikes, and highlighting reliance on state budgets and ODA [5] [6]. A notable study by Canh Vu et al. (2021) provides a critical field perspective on adaptation financing gaps but stops short of developing a quantitative, systemic framework for the dike sector [10]. While government reports from MARD and the World Bank offer invaluable data on dike conditions and investment shortfalls [3] [7], there remains a scarcity of peer-reviewed studies that empirically analyze the determinants of investment needs at a sub-national level or that synthetically propose integrated financing solutions tailored to Vietnam's governance context.

A limited but growing number of peer-reviewed studies have begun to empirically examine financing barriers and governance contexts. For instance, Khang, N. (2025) analyzes the role of public finance in supporting Vietnam’s green transition, drawing on international experience and emphasizing the importance of green public finance for sustainable development. The author identifies key challenges, including the absence of a green expenditure taxonomy and the underdevelopment of the green finance market. The study proposes a sustainable public finance model and the development of green financial instruments to support institutional reforms [29]. This study reinforces the need for integrated frameworks tailored to Vietnam's specific institutional landscape.

2.3 Research Gaps and Theoretical Positioning

Three research gaps emerge from existing literature, which this study addresses:

First, there is a scarcity of rigorous quantitative, evidence-based analysis on the determinants of investment demand for coastal dike systems in Vietnam. While the high-level investment needs are documented [7], and specific project cases are described [5] [6], province-level empirical analysis linking investment requirements to key factors—such as the technical degradation of infrastructure, socio-economic exposure, and hazard frequency—remains limited and insufficient for robust prioritization. This gap hinders the development of scientifically-grounded capital allocation strategies at the sub-national level.

Second, there is a lack of an integrated financing framework specifically contextualized for Vietnam's unique governance and fiscal landscape. Although international experiences with instruments like PPPs, green bonds, and climate funds are well-documented [15] [17] [21], their systematic assessment, contextual adaptation, and synthesis into a coherent, actionable policy framework suitable for Vietnam's institutional context are underdeveloped. The translation of global lessons into a tailored, multi-pillar strategy for Vietnam requires focused research.

Third, a methodological gap exists in prior work on this topic in Vietnam. Existing studies tend to be either qualitative policy analyses or descriptive project reviews, with limited application of rigorous mixed-methods approaches. An integrated methodology that combines exploratory quantitative analysis of investment determinants with qualitative assessment of financing mechanisms and governance (for example, through SWOT and comparative policy analysis) is needed to provide a comprehensive, evidence-based foundation for policy design.

This study directly addresses these gaps by:

- Employing exploratory quantitative techniques (while acknowledging sample size limitations) to identify key determinants of investment needs across Vietnam's coastal provinces;
- Developing a comprehensive, six-pillar financing framework that critically synthesizes international best practices with Vietnam's specific socio-economic and institutional context;
- Applying a deliberate mixed-methods methodology that integrates quantitative findings with qualitative SWOT and comparative policy analysis to derive context-sensitive recommendations. The proposed research framework is illustrated in Fig. 2.

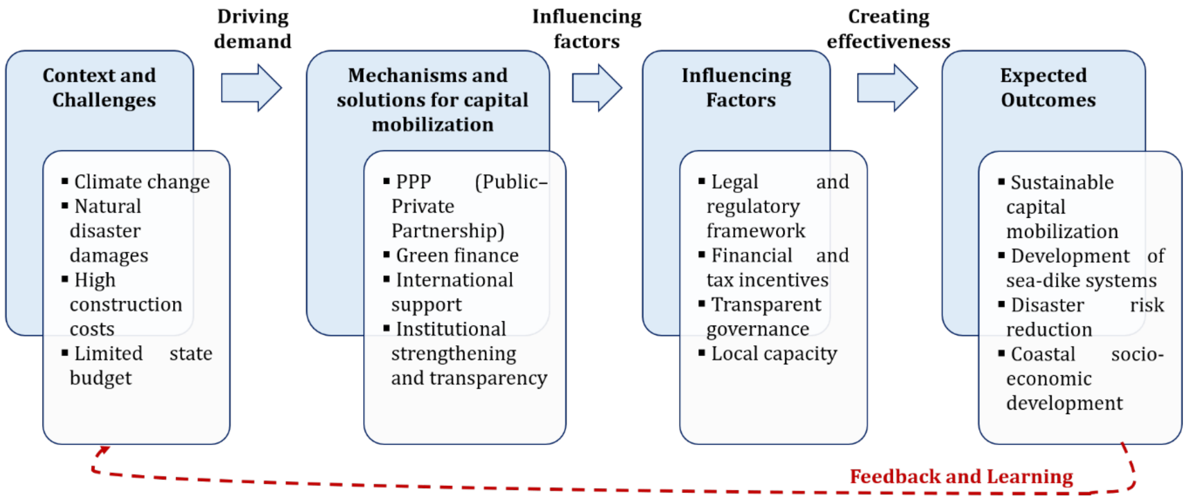

Fig. 2 *Research framework on the mechanism for attracting capital for the construction and protection of coastal dike systems in Vietnam*

3. Methodology

3.1 Research Design

This study employs a mixed-method, policy-oriented approach. The research is positioned as an applied study that contextualizes global climate finance mechanisms to Vietnam's coastal dike system. The quantitative component provides exploratory insights, while the qualitative analysis offers contextual depth, together informing the proposed financing framework. The quantitative analysis employs primarily descriptive statistics and correlation analysis to explore associations and present an overview of the investment landscape.

Given the constrained sample size (n=21 provinces), the analysis serves as an exploratory examination of associations and a descriptive tool rather than for definitive causal inference. Its purpose is to identify plausible associations within the Vietnamese context, which are then triangulated with qualitative insights to build a robust, context-specific framework. In terms of qualitative analysis, the study performs a SWOT analysis (Strengths–Weaknesses–Opportunities–Threats) and examines international experiences to elucidate the strengths, weaknesses, opportunities, and challenges in attracting sustainable investment capital. This analysis ultimately draws lessons and suggests suitable solutions for Vietnam's coastal dike system.

3.2 Scope and Research Subjects

This study analyzes data from Vietnam's 21 coastal provinces following the administrative reorganization effective June 2025. The study compiled research data from multiple reliable sources, ensuring consistency throughout 2020–2025. Sample units were selected based on the following criteria: (i) possession of existing coastal dike systems; (ii) availability of complete data on the length of coastal dikes meeting and not meeting safety standards; (iii) existence of official reports on investment capital requirements issued by competent authorities; and (iv) continuous data monitoring throughout the 2020–2025 period.

3.3 Data Collection

Secondary data were collected from official sources, including World Bank reports, status reports, and planning documents for coastal dike systems from the Ministry of Agriculture and Environment; statistical yearbooks from the General Statistics Office and provincial/municipal statistical departments; and international studies on coastal dike system management.

Secondary data comprised: (i) coastal dike length and technical condition by classification (km); (ii) capital requirements for upgrading and new construction (million USD); (iii) population of coastal provinces (persons); (iv) per capita GRDP (USD); and (v) typhoon frequency (events/year).

Table 1 *Variables description and theoretical justification*

Variable Name	Description	Unit	Theoretical justification and expected sign
INV_millionUSD	Total investment capital required for dike upgrading.	Million USD	Dependent variable. Reflects the financial scale of infrastructure needs.
INV_per_km	Investment capital required per kilometer of dike.	Million USD/km	Dependent variable (standardized). Allows comparison across provinces of different sizes.
Population	Total provincial population.	Persons	Proxy for social vulnerability and the scale of people/assets protected. Expected sign: Positive.
GRDP_per_capita	Gross Regional Domestic Product per capita.	USD	Proxy for regional economic capacity and fiscal potential to co-finance projects. Expected sign: Ambiguous. Could be positive (greater demand/ability) or negative (inherent resilience).
Storm	Annual average typhoon frequency.	Events/year	Proxy for exposure to hydrometeorological hazards causing dike damage. Expected sign: Positive.
P_BELOW	Proportion of provincial land area within the Low-Elevation Coastal Zone (LECZ; elevation < 10m above mean sea level)	%	Direct measure of geophysical flood risk and exposure. Expected sign: Positive.
Below_km	Length of dikes classified as "Below safety standard".	km	Core measure of existing infrastructure deficiency. Expected sign: Positive.
SBelow_km	Length of dikes "Significantly below safety standard".	km	Measure of critical infrastructure deficiency, implying higher unit repair costs. Expected sign: Positive (with a larger coefficient than Below_km).

Int. J. Sustain. Constr. Eng. Technol. Vol. 17 No. 1 (2026) p. 47-66

Special note on variable construction:

The GRDP per capita values were calculated by converting provincial GRDP in Vietnamese dong (VND) to US Dollars (USD) using the average annual exchange rate for the year 2023, sourced from the State Bank of Vietnam. To avoid misinterpretation of Vietnam's actual economic standing, we use the real USD values (ranging from approximately 2,542.46 to 4,458.72 USD per capita) in all analyses. The normalized comparative indices mentioned in earlier drafts were solely for internal scaling during preliminary checks and have been replaced with actual values in the final analysis. The correlation structure remains unchanged, but using real values enhances transparency and avoids misleading readers about Vietnam's income level.

The variable P_BELOW refers specifically to the 'Proportion of Provincial Land Area within the Low-Elevation Coastal Zone (LECZ)', defined as the land area contiguous to the coast with an elevation of less than 10 meters above mean sea level. This metric, derived from GIS analysis of digital elevation models, is used as a proxy for high exposure to sea-level rise and flooding, and can approach 100% in extensive, low-lying deltaic provinces such as Ca Mau (indicating that nearly the entire provincial area lies within this vulnerable coastal zone, not that it is literally below sea level).

Primary data consisted of supplementary information from management agencies and local reports, including the Vietnam Administration of Seas and Islands [8], and websites providing access to maps, population data, administrative centers, and provincial GRDP [30] [31].

Table 1 details the variables included in the analysis, along with their theoretical justification and hypothesized relationship with investment demand.

3.4 Descriptive and Correlation Analysis

3.4.1 Data Verification and Cleaning

Before analysis, the dataset was examined for completeness, consistency, and potential outliers. Missing values were negligible (<2% for any variable) and addressed via linear interpolation. The Interquartile Range (IQR) method was used to screen for univariate outliers. One observation for investment per kilometer (INV_per_km) in Hai Phong City was flagged but retained after verification with official project reports [6] confirmed its validity, reflecting the high unit cost of an urban, multi-functional dike project.

3.4.2 Analytical Strategy: Adopting Descriptive and Correlational Analysis

Given that our sample (n=21) comprises nearly all Vietnamese coastal provinces with dike systems, we employed descriptive and correlational analyses. This choice avoids the methodological risks of overfitting and unstable coefficient estimates that arise with limited degrees of freedom. The approach is sound for a census-type dataset where the goal is to describe patterns and associations within the population, rather than to make inferences to a larger sample.

Conceptual framework for analysis: Despite the shift in statistical technique, the analytical logic is guided by a conceptual model that posits investment need (INVINV) as a function of key provincial characteristics. We examine how INVINV associates with:

- Infrastructure Condition (proxied by Below_km, SBelow_km, P_BELOW), hypothesizing a positive relationship.
- Socio-economic Exposure and Capacity (Population, GRDP_per_capita), with an ambiguous expected relationship.
- Hazard Exposure (Storm), hypothesizing a positive relationship. The correlation analysis directly tests these bivariate associations.

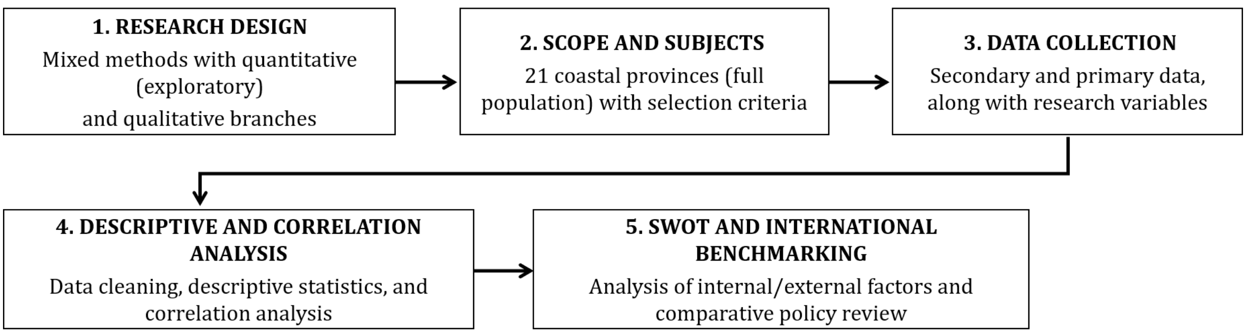

Fig. 3 *Steps in the mixed-methods research process*

3.4.3 Analytical Steps

The analysis proceeded in two stages, as shown in the Fig. 3:

Descriptive Statistics: All variables were summarized using measures of central tendency (mean, median) and dispersion (standard deviation, range) to provide a comprehensive overview of the investment landscape and provincial characteristics (see Table 3).

Bivariate Correlation Analysis: To explore relationships, Pearson correlation coefficients (r) were calculated between the primary dependent variable, total investment need (INV_millionUSD), and each of the key independent variables: Below_km, SBelow_km, P_BELOW, Population, GRDP_per_capita, and Storm. This matrix (presented in Table 4) transparently displays the strength and direction of linear associations without the confounding effects of other variables, offering clear, initial insights into what factors co-vary with investment demands.

3.4.4 Triangulation with Qualitative Analysis

The patterns identified in this quantitative analysis were not interpreted in isolation. They served as a critical input for triangulation with the subsequent structured SWOT analysis (Section 3.5) and the review of international financing models. For instance, a strong correlation between dike degradation (Below_km) and investment need would be discussed alongside the SWOT-identified "Weakness" of infrastructure quality and the "Opportunity" to use green bonds for rehabilitation.

3.5 SWOT Analysis

The study conducted a structured SWOT analysis to complement the quantitative findings and provide a holistic understanding of the institutional and financial context. Data for the SWOT were derived from three sources: (i) policy documents and project reports, (ii) insights from the quantitative analysis, and (iii) systematic synthesis of challenges and opportunities identified in the international literature review. This triangulation ensures the SWOT analysis directly informs the development of the financing framework. The SWOT items were independently coded and categorized by two researchers to enhance reliability and reduce bias.

4. Results

Based on the comprehensive database of coastal dike system length, current safety status, and investment capital requirements from the World Bank, the Ministry of Agriculture and Environment [3] [7] [11], combined with updated information on area, population, and socio-economic indicators of Vietnam's coastal provinces [8] [30] [31] [32], this study employs quantitative analysis methods through SPSS software to quantify the current financial gap. The primary objective is to accurately determine the necessary capital mobilization requirements for upgrading and maintaining Vietnam's coastal dike system, particularly in the context of increasingly intensified impacts of climate change and sea level rise. The analyzed dataset encompasses 21 coastal provinces and cities with diverse variables across geographical, economic, and financial dimensions, which are synthesized in detail in Table 2.

4.1 Descriptive statistics

Descriptive statistics reveal substantial variation across Vietnam's coastal provinces in terms of geographical and socio-economic characteristics and natural disaster risks. The average proportion of land area below mean sea level (P_BELOW) is 61.38%, with a range from 0% to 100%. This proportion reflects heterogeneous flood risk levels across different regions. Population size varies considerably, with a mean of 3.73 million people, ranging from 1.17 million to over 14 million, while gross regional domestic product per capita (GRDP_per_capita) reaches approximately 3,627 USD, with a variation from about 2,542.46 to 4,458.72 USD, indicating economic disparities in both population scale and economic indicators. Regarding natural disaster frequency, coastal provinces encounter an average of 3.05 typhoons annually, with a tendency to concentrate primarily in the Central and Northern provinces. The capital investment requirement for coastal dike construction (INV_millionUSD) averages 107.67 million USD per province (ranging from 2 to 354 million USD), equivalent to 0.82 million USD/km of coastline (0.087-1.891 million USD/km). The high dispersion of research variables highlights the heterogeneous conditions across coastal provinces, which supports the exploration of variable associations through descriptive and correlational analysis.

Table 2 *Socio-economic information and investment needs for coastal dike upgrading in Vietnam's coastal provinces*

No.	Province /City	Population (person)	GRDP (million Vietnam dongs)	Number of storms from 2020-2025	Meets safety standard (kilometres)	Below safety standard (kilometres)	Significantly below safety standard (kilometres)	Dike length (kilometres)	Investment needed (million Vietnam dongs)
1	Quang Ninh	1,381,200	347,534.38	2	58.7	99.7	19.6	178.0	2,784,800
2	Hai Phong	4,664,124	658,381.19	4	0	160.6	59.4	220.0	8,354,400
3	HungYen	3,567,943	292,602.49	2	0	102.4	30.6	133.0	4,743,600
4	NinhBinh	4,412,264	310,282.05	4	67.5	85.5	72.0	225.0	6,159,600
5	Thanh Hoa	3,739,500	316,995.27	7	5.0	85.9	22.1	113.0	3,115,200
6	Nghe An	3,442,000	216,994.24	4	13.5	64.0	45.5	123.0	637,200
7	Ha Tinh	1,323,700	112,855.28	5	96.0	8.8	21.2	126.0	1,227,200
8	Quang Tri	1,870,845	113,687.55	6	53.5	124.7	19.8	198.0	3,752,400
9	Hue	1,166,500	80,967.31	5	2.5	0	173.5	176.0	4,861,600
10	Da Nang	3,065,628	279,926.33	7	53.9	39.1	0	93.0	590,000
11	QuangNgai	2,161,755	173,526.46	6	35.0	16.0	0	51.0	377,600
12	Gia Lai	3,586,993	242,007.55	4	73.0	0	0	73.0	401,200
13	DakLak	3,346,853	198,132.95	3	3.5	0	51.5	55.0	2,147,600
14	Khanh Hoa	2,243,554	191,357.15	3	83.7	9.3	0	93.0	330,400
15	LamDong	3,872,999	319,878.84	1	22.5	0.5	0	23.0	47,200
16	HoChiMinh	14,002,598	2,715,782.23	1	4.5	10.0	33.5	48.0	1,722,800
17	DongThap	4,370,046	249,534.46	0	0	21.2	24.8	46.0	2,053,200
18	VinhLong	4,257,581	254,479.94	0	116.0	0	95.0	211.0	5,404,400
19	Can Tho	4,199,824	281,674.63	0	51.0	22.0	0.0	73.0	849,600
20	Ca Mau	2,606,672	297,735.68	0	110.0	55.9	67.1	233.0	1,416,000
21	An Giang	4,952,238	271,345.88	0	68.0	100.8	0	168.0	2,383,600

Source: Authors' compilation from references [3] [7] [8] [9] [30] [32]

Note: GRDP per capita values are presented in real USD (2023). Values range from approximately 2,542.46 to 4,458.72 USD across provinces, reflecting actual economic capacity. Earlier normalized indices were used only for preliminary scaling and have been replaced with real data in the final analysis to ensure clarity and avoid misinterpretation.

Table 3 *Descriptive statistics of research variables*

Model	N	Minimum	Maximum	Mean	Std. Deviation
P_BELOW (%)	21	.0000	100.0000	61.380952	34.3299813
Population (persons)	21	1,166,500	14,002,598	3,725,467.48	2,619,835.966
GRDP_per_capita (USD)	21	2,542.46	4,458.72	3,627.11	576.34
Number of storms (per year)	21	0	7	3.05	2.418
Investment demand (million USD)	21	2	354	107.67	95.653
INV_per_km (million USD/km)	21	0.0870	1.8913	0.822566	0.5821784

Note: All monetary values (GRDP per capita and Investment demand) are expressed in real USD (2023) to ensure consistency, clarity, and practical interpretability of the analytical results.

4.2 Exploratory Bivariate Correlation Analysis

The following correlation results are presented as exploratory insights into variable associations, acknowledging the sample size limitations. They serve to identify patterns that, when combined with qualitative evidence, inform the framework development. Given the limited sample size (n=21), which constitutes the full population of Vietnam's coastal provinces with dike systems, multivariate analysis was deemed inappropriate for drawing robust causal inferences. Instead, a simple Pearson correlation analysis was employed to explore pairwise relationships between total investment needs (INV_millionUSD) and key potential influencing factors. This approach allows for a transparent examination of associations without overinterpreting the data or violating statistical assumptions related to small-sample analysis.

Table 4 shows that dike length significantly below safety standards (SBelow_km) correlates moderately with investment needs ($r=0.598$, $p<0.01$), explaining approximately 36% of variance. These results visually corroborate the trend illustrated in Fig. 4 and suggest that provinces with greater extents of degraded coastal dikes and higher exposure to low-lying geography tend to report higher capital requirements.

In contrast, correlation coefficients for socio-economic and disaster frequency variables are very weak and lack a clear pattern. Both storm frequency ($r = 0.046$) and population size ($r = 0.031$) show negligible positive associations with investment needs. GRDP per capita ($r = 0.085$), now expressed in USD to match the unit of the investment variable, also shows a very weak positive correlation.

These exploratory findings underscore that the physical degradation level of the dike system is consistently and moderately associated with higher reported investment requirements across provinces. While this analysis does not establish causality, it provides empirical, data-driven support for prioritizing dike condition metrics in investment planning. This quantitative insight aligns with and informs the subsequent qualitative SWOT analysis.

Table 4 *Correlation matrix between investment needs and selected factors*

Variable	Pearson Correlation Coefficient (r) with INV_millionUSD	Strength of Association
SBelow_km (km)	0.598	Moderate positive
Below_km (km)	0.581	Moderate positive
P_BELOW (%)	0.576	Moderate positive
GRDP_per_capita (USD)	0.085	Very weak positive
Storms (events/year)	0.046	Very weak positive
Population (persons)	0.031	Very weak positive

Source: Authors' calculations based on research data using SPSS (2025).
Note: Correlation strength guidelines: $|r| \geq 0.7$ (Strong); $0.4 \leq |r| < 0.7$ (Moderate); $|r| < 0.4$ (Weak).

All monetary values (INV_millionUSD and GRDP_per_capita) are expressed in actual USD using the appropriate exchange rate, ensuring consistency and interpretability of the analysis.

4.3 SWOT Analysis

A structured SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis was conducted to synthesize qualitative insights from multiple sources. The framework was populated through a systematic review of: (i) Internal factors (Strengths/Weaknesses): drawn from the results of our quantitative analysis (e.g., financial gap as a Weakness) and from official policy and assessment reports on Vietnam's dike system [1] [7]; (ii) External factors (Opportunities/Threats): derived from the review of international climate finance literature (Section 2.1) and case studies like Netherlands, Japan, as well as from climate change projection reports for Vietnam [3] [28]. This synthesis provides a holistic view of the strategic landscape for financing coastal dikes in Vietnam.

The SWOT analysis reveals that Vietnam's coastal dike system possesses advantages in terms of legal frameworks, management experience, and potential for international cooperation, yet it also exhibits significant limitations related to infrastructure, financial resources, and coordination mechanisms. In the context of accelerating climate change, the substantial investment capital requirements have generated considerable pressure while simultaneously opening up opportunities to access multilateral climate funds, green finance mechanisms, and advanced technology transfers from developed countries. Consequently, the mobilization and allocation of financial resources require a comprehensive and balanced strategy aimed at leveraging strengths, effectively exploiting opportunities, addressing inherent weaknesses, and building proactive adaptive capacity to long-term challenges posed by climate change.

Int. J. Sustain. Constr. Eng. Technol. Vol. 17 No. 1 (2026) p. 47-66

Table 5 *SWOT Analysis (Strengths – Weaknesses – Opportunities – Threats) for capital mobilisation for the construction and protection of the coastal dike system in Vietnam*

Strengths (S) Internal, supportive factors	Weaknesses (W) Internal, challenging factors
• Institutional and policy framework: Existence of a recognized legal and strategic foundation for disaster risk management and climate adaptation, like the Law on Natural Disaster Prevention and Control 2013, the Climate Change Strategy [1]. • Technical experience and human capital: Historical expertise in dike engineering and a base of skilled personnel for construction and maintenance. • Proven International Collaboration: Track record of successful, co-financed projects delivering multi-dimensional benefits like the West Ca Mau dike, the An Bang dike [5] [35].	• Infrastructure deficit: A high proportion of the dike network is substandard and vulnerable to current and projected climate hazards [3] [7]. • Financial constraints: Chronic underfunding for maintenance, over-reliance on state budget, and underdeveloped mechanisms for cost-sharing and private investment [7] [21] [33] [34]. • Governance and efficiency challenges: Procedural delays, coordination gaps, and risks related to transparency and fund utilization efficiency [1] [6].
Opportunities (O) External, supportive factors	**Threats (T) External, challenging factors**
• Access to global climate finance: Growing availability of dedicated funds (Green Climate Fund - GCF, Adaptation Fund) and market mechanisms (carbon credits, ESG investing) for adaptation projects [21]. • Innovative financial instruments: Potential to deploy insurance products, catastrophe bonds, public-private partnerships (PPPs) models, and domestic green bonds to diversify capital sources [21]. • Strategic partnerships and technology transfer: Ongoing cooperation with major development banks (Asian Development Bank - ADB, World Bank - WB, European Union - EU, Agence Française de Développement - AFD) offers avenues for knowledge exchange, technology adoption, and integrated project development [5] [6] [33].	• Escalating climate hazards: Accelerating sea-level rise, storm intensity, and coastal erosion, which increase system pressure and costs [1] [3]. • Macro-Financial Pressures: High total investment requirement exceeds USD 2.2 billion, competing fiscal priorities, inflation, and cyclical "disaster-rebuild" investment patterns [7] [21]. • Institutional and commitment risks: Potential for deprioritization amid other socio-economic needs and challenges in securing sustained international partner engagement.

4.4 Classification of Investment Priority by Region

Based on quantitative analysis, this study identifies priority localities for investment. At the same time, informed by the correlation between P_BELOW and INV_millionUSD (R^2 = 0.332), confirming that the length of dikes failing to meet safety standards and investment capital requirements determines the priority level among localities. The categorization of these localities into three distinct priority levels, reflecting their specific dike degradation status and financial demands, is detailed in Table 6. The study underscores the urgent need to mobilise financial resources promptly, as delays may exacerbate disaster risks. Such mobilisation is strategically vital for safeguarding populations and infrastructure, while simultaneously promoting sustainable economic development in coastal regions.

Through analysis, Fig. 4 below demonstrates a positive relationship between the proportion of land area below sea level (P_BELOW) and investment capital requirements for coastal dikes (INV_millionUSD) across 21 coastal provinces. The analysis results indicate R^2 = 0.332, meaning that approximately 33.2% of the variation in investment demand is explained by P_BELOW. This trend is economically reasonable, as severely degraded coastal dikes require greater investment capital. However, the data dispersion, particularly in provinces where P_BELOW > 60%, implies that population dynamics, GRDP levels, and typhoon occurrence must be accounted for within a multivariate analytical approach. This indicates that, beyond the technical condition of coastal dikes, other socio-economic and hazard factors may also influence investment requirements. A comprehensive understanding of these dynamics would benefit from future research with expanded datasets capable of supporting more complex multivariate analysis.

Table 6 *Priority provinces/cities for coastal dike investment in Vietnam*

No.	Province /City	Total dike length below safety standard (km)	Of which Significantly below safety standard (km)	Investment needed (million USD)	Remarks
I	Group 1 – Highest priority				
1	Hai Phong	220.0	59.4	354	Largest total length of degraded dikes
2	Hue City	173.5	173.5	206	The entire major system is in critical condition
3	Quang Tri	144.5	19.8	159	High disaster risk, Central Coast
4	HungYen	133.0	30.6	201	Red River Delta, densely populated
II	Group 2 – Medium priority				
1	NinhBinh	157.5	72.0	261	A combination of moderately and severely degraded sections
2	ThanhHoa	108.0	22.1	132	Dikes protect extensive residential areas
3	Nghe An	109.5	45.5	27	Lower investment due to a small capital/km ratio
4	Ca Mau	123.0	67.1	60	Mekong Delta, severe coastal erosion
III	Group 3 – Additional priority				
1	Ha Tinh	30.0	21.4	52	Short dikes are critical for local protection
2	DongThap	46.0	24.8	87	Inland dikes are important for agricultural production
3	Vinh Long	95.0	95.0	229	High investment needs, widespread distribution
4	Others	<100	–	14–101	Moderate/short degraded dikes, lower urgency

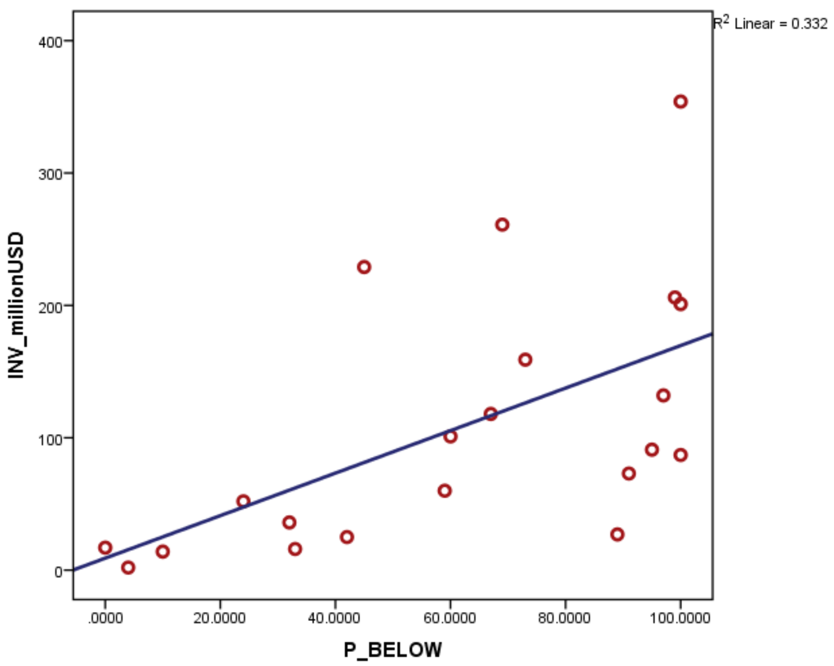

Fig. 4 *The link between embankment deterioration and required investment funds*

5. Discussion and Policy Implications

We integrate quantitative findings, SWOT analysis, and international case studies to develop a context-specific financing framework for Vietnam's coastal dikes. The framework aims to translate global climate finance instruments into actionable strategies grounded in local evidence. The exploratory findings of this study highlight a consistent association between the technical degradation of coastal dikes and higher estimated investment requirements. Specifically, the correlation analysis indicates that variables representing dike condition—such as the proportion of land area below sea level (P_BELOW) and the length of dikes classified as 'below standard' and 'significantly below standard'—show statistically significant positive correlations with investment needs (see Table 4). In contrast, socio-economic variables (population, GRDP per capita) and typhoon frequency did not demonstrate statistically significant associations within our limited sample and model specifications. This pattern is consistent with engineering logic and aligns with studies emphasizing infrastructure condition as a cost driver, such as Lenk et al. (2016) [14]. It is important to reiterate that these correlations indicate association, not causation. However, the consistent and moderate strength of the link between degradation metrics and investment needs provides a strong empirical basis for considering dike condition as a primary criterion in resource allocation frameworks. Consequently, from a resource allocation perspective, the analysis suggests that prioritizing investment based on the severity of dike degradation could be an efficient strategy, complementing other socio-economic or risk-based criteria.

International experience reveals a trend toward multi-source capital models for coastal dikes. These models encompass public funds, private capital, and global climate finance. Crucially, their success often depends on transparent governance to attract and blend these diverse sources [15] [19]. A notable example is the Netherlands, which achieved success through its "Delta Works" programme by utilizing public capital as leverage to attract private investment, whilst simultaneously establishing dedicated funds to ensure long-term financial sustainability [25]. At the global scale, international climate funds such as the Green Climate Fund (GCF) with a scale of 100–150 million USD, the Adaptation Fund (50–80 million USD), EU Climate Investment (200–300 million EUR), and the Asian Development Bank (ADB) with support levels of 300–500 million USD [16] [17] have demonstrated substantial potential in providing financial support for climate change adaptation projects. The capital scale from these announcements can serve as crucial reference material for estimating potential investment sources for Vietnam's coastal dike system, contingent upon the design of a transparent governance system, effective risk-sharing mechanisms, and an appropriate legal framework to generate confidence and attract participation from international donors as well as private investors.

5.1 Key Lessons for Vietnam

The following policy directions are synthesized from multiple strands of evidence in this study: the indicative relationships found in the quantitative analysis, the systemic strengths and weaknesses identified in the SWOT analysis (Table 5), and lessons from international experiences reviewed in Section 2.1. Including:

- Diversification of financial mechanisms and funding sources: Mobilizing resources simultaneously from multiple channels, including central and local budgets, community contributions, the private sector, and international organizations. Instruments such as PPP, green bonds, climate funds, loan guarantees, and National Development Banks (NDBs) have demonstrated effectiveness in developed countries [15]. For Vietnam, the allocation of financial responsibilities across governmental levels may contribute to reducing the burden on the central budget and enhancing local autonomy. This lesson is directly informed by the significant financing gap and heavy reliance on state budget identified as a key weakness in our SWOT analysis (Table 5), as well as the substantial investment requirements quantified in Table 2.
- Legal framework and transparent governance: International studies indicate that investor confidence depends heavily on governance mechanisms and transparency [27]. Therefore, Vietnam needs to improve the legal framework for PPPs, green bonds, and climate funds to facilitate the attraction of private and international capital. This is critical to address the management and transparency challenges noted in the SWOT analysis, which currently pose risks to capital efficiency and stakeholder trust.
- Resilience and sustainability: Coastal dikes should be designed to adapt to future changes over time, integrating technical elements with socio-cultural factors and community participation, similar to Japan's experience in multi-level financial responsibility sharing [23]. This approach is supported by the study's finding that degradation is a primary correlate of need, suggesting that building resilient infrastructure from the outset can reduce future capital demands for emergency upgrades.
- Risk management and policy stability: Climate finance policy stability is a prerequisite for maintaining long-term capital flows, particularly in the context where physical risks and legal instability often hinder investment [16] [26]. The threat of climate change and economic competition for funds, outlined in the

SWOT analysis, underscores the urgency of establishing stable, long-term policy frameworks to secure investment.

- Addressing the financing gap: According to the Climate Policy Initiative (2021), the global financing gap for climate change adaptation ranges from USD 140–300 billion per year [16]. For Vietnam, analysis suggests a substantial need, with the total investment requirement for the 21 coastal provinces surveyed exceeding USD 2.2 billion [7], highlighting a gap that the state budget alone cannot fill. This gap may reach USD 6–12 billion during the 2025–2030 period when considering broader adaptation needs, with investment in coastal dike systems accounting for approximately 15–20%. This figure is estimated based on the proportion of coastal infrastructure in total adaptation investment in developing coastal nations [15].
- Innovation in financial instruments: Mechanisms such as green bonds, catastrophe insurance, and adaptation funds have proven effective in mobilizing capital in Europe and Japan [21] [27]. For Vietnam, piloting these instruments alongside transparent environmental and social impact assessment may enhance confidence among investors and international organizations. This innovation is presented as an opportunity in the SWOT analysis to leverage global climate finance trends and overcome domestic fiscal constraints.

5.2 Proposed Framework for Vietnam

Building upon the empirical insights and identified gaps from this study, we propose a comprehensive financing framework comprising six core pillars. This framework is designed to translate the diagnosed needs—such as prioritization based on degradation, diversification of funding, and enhanced governance—into actionable strategies, informed by adaptable international models.

Fig. 5 presents the conceptual framework linking the analytical components to policy pillars. Each pillar is justified by specific empirical or contextual evidence from our mixed-methods analysis, as detailed below.

- Pillar 1 – Scientific capital allocation mechanism:

Rationale: This pillar is proposed because our correlation analysis identified dike degradation (SBelow_km, r=0.598) as the strongest associate of investment need, suggesting allocation efficiency can be improved by prioritizing technical condition.

Proposed Mechanism: Application of Multi-Criteria Decision Making (MCDM) integrating degradation data with socio-economic risk profiles.

Contextual Support: This prioritization is crucial given the financial constraints (SWOT Weakness) and need to optimize limited resources, aligning with technical approaches used in the Netherlands' delta program [25].

- Pillar 2 – Diversified financial ecosystem:

Rationale: Proposed to mitigate the high state budget dependence and lack of private participation (a critical Weakness in SWOT) while harnessing opportunities in green finance and international funds (SWOT Opportunities).

Proposed mechanism: This pillar proposes a deliberate shift towards a blended finance model. The rationale stems from our SWOT analysis, which highlighted 'Financial constraints' and 'over-reliance on state budget' as critical Weaknesses, while identifying 'Access to global climate finance' and 'Innovative financial instruments' as key Opportunities. Therefore, a strategic mix of public, private, and international capital is implied as necessary to bridge the identified financing gap. This aligns with successful models in the Netherlands and Japan, suggesting that policy should incentivize private sector participation and leverage international climate funds.

Contextual support: The ratio adapts successful models from the Netherlands and Japan [31] [33], while the green bond component is validated by regional benchmarks from the Philippines and Indonesia (Table 7) [15].

- Pillar 3 – Transparent and accountable governance:

Rationale: This responds directly to the 'Weakness' of governance and transparency challenges identified in our SWOT analysis (Table 5), which are critical for investor confidence.

Proposed Mechanism: Establishment of a three-tier governance system: (1) a Prime Minister-level Steering Council for strategic direction and inter-ministerial coordination; (2) specialized ministries/departments for sectoral implementation and operational management; and (3) an independent monitoring system to ensure transparency, accountability, and efficient public resource utilization.

Contextual Support: This structure is critical for building investor confidence, which international studies indicate depends heavily on governance mechanisms and transparency [27]. It responds directly to the institutional and transparency gaps noted as weaknesses and is a prerequisite for the successful implementation of PPPs and access to international climate funds.

- Pillar 4 – Financial instrument innovation:

Rationale: Designed to seize the opportunities in innovative finance and access to international green capital identified in the SWOT analysis (Table 5). It tackles the financial constraints and lack of private sector participation (SWOT Weaknesses) by introducing attractive, de-risked investment vehicles to mobilize non-state capital.

Proposed Mechanism: Development of a portfolio of innovative instruments, including: specialized green bonds for coastal dikes (targeting USD 200-300 million initially), parametric insurance, blended finance mechanisms, payment for ecosystem services (PES), and carbon credits from mangrove/coastal restoration projects.

Contextual Support: The green bond target is based on successful issuances in the Philippines and Indonesia [15], as shown in our policy benchmark (Table 7). Instruments like parametric insurance and blended finance are informed by their growing application in Europe and Japan for climate resilience [21] [27], aligning with the global trend toward diversified funding noted in our literature review.

- Pillar 5 – Strategic international cooperation:

Rationale: Leverages Vietnam's existing strength in international cooperation (a noted SWOT Strength) and the significant opportunities presented by multilateral climate funds (a SWOT Opportunity) to address the immense financial scale of the challenge, which far exceeds domestic fiscal capacity.

Proposed Mechanism: Implementation of a targeted multilateral capital mobilization strategy with key partners: the EU Climate Investment programme (EUR 200-300 million), the Green Climate Fund (USD 100-150 million), ADB Climate Finance (USD 300-500 million), the Adaptation Fund (USD 50-80 million), and bilateral mechanisms.

Contextual Support: The funding estimates are derived from analyses of average commitments to ASEAN countries [16] [20], presented in Table 7. This pillar builds directly on Vietnam's successful project-level experience with donors like the EU, AFD, and the Netherlands [5] [35] (a SWOT Strength) to secure programmatic, long-term funding.

- Pillar 6 – Impact Monitoring and Evaluation:

Rationale: Essential for ensuring accountability, learning, and adaptive management—a critical need implied by the governance and transparency weaknesses in the SWOT. It ensures that the substantial capital mobilized under this framework achieves its intended outcomes in resilience, safety, and socio-economic development.

Proposed Mechanism: Establishment of an integrated Monitoring and Evaluation (M&E) system with clear Key Performance Indicators (KPIs) across three domains: (1) financial efficiency and capital utilization, (2) improvements in coastal dike system safety and technical standards, and (3) positive socio-economic and environmental impacts on communities.

Contextual Support: A robust M&E system is a fundamental requirement of major international climate funds like the GCF and Adaptation Fund [16] [19], facilitating continued access to such resources. It operationalizes the principles of transparency and accountability needed to address the management weaknesses and provides the data necessary for the scientific capital allocation (Pillar 1) to be dynamically updated.

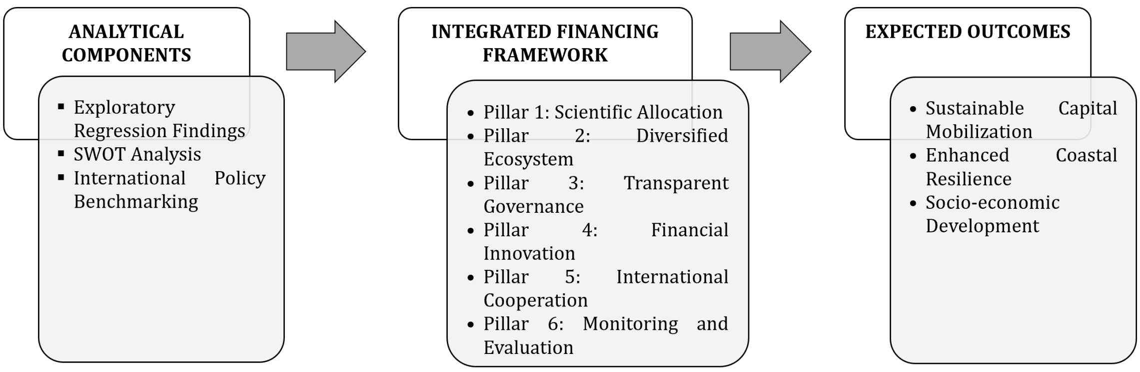

Fig. 5 *Conceptual framework for financing Vietnam's coastal dike system: from mixed-methods analysis to policy pillars*

5.3 Policy Implications

Based on the aforementioned framework, this study proposes several key policy implications as follows: (i) Allocating capital according to technical conditions rather than through administrative mechanisms; (ii) Developing multi-channel financing mechanisms instead of relying solely on state budget; (iii) Establishing specialized funds with modern governance mechanisms; (iv) Implementing innovative financial instruments to enhance sustainability and investor confidence [15] [16].

5.4 Solutions for Mobilizing Capital for the Construction and Protection of Vietnam's Coastal Dike System

Building on the empirical findings and policy implications, this study advances a set of comprehensive strategies aimed at enhancing investment efficiency and strengthening the management of Vietnam's coastal dike system. These solutions are developed by integrating scientific evidence from quantitative models with international experience in climate finance and coastal infrastructure management. The proposed framework comprises four strategies:

(1) Priority-based allocation: Target investments to provinces with degradation rates >80%. This approach ensures that financial resources are concentrated in the highest-risk areas, thereby minimizing the risk of serious incidents that could cause significant economic and social damage. The application of a priority matrix provides a scientific and transparent foundation for decision-making processes, limiting inefficient and dispersed capital allocation. Moreover, this method allows policymakers to flexibly adjust priority levels based on actual conditions and available financial capacity. A periodic evaluation mechanism and regular updates to the priority matrix are also recommended to ensure the timeliness and accuracy of input information.

(2) Infrastructure fund: Establish dedicated fund with 30% state, 40% private, and 30% international capital. The reference to Japan's Disaster Prevention Fund and the Netherlands' Delta Works Fund highlights established models that have successfully demonstrated the capacity to mobilize and govern resources dedicated to coastal infrastructure development [23] [25]. When the fund is managed by the Government, it gains stronger legal support and better coordination between sectors. Its diverse funding sources bring balance — government money keeps it stable, private funds make it flexible, and international support makes it sustainable. Risk management and performance checks will also be applied to make sure the Fund is run efficiently and openly.

(3) Financial innovation: Issue 200-300 million USD green bonds with parametric insurance. This proposal is based on an analysis of successful experiences from coastal countries in East Asia, such as Singapore, Malaysia, and South Korea, in mobilizing capital for climate change adaptation infrastructure [21]. These instruments contribute to mobilizing stable long-term capital flows and effectively distributing financial risks, which is particularly important in the context of increasingly complex and unpredictable climate change. Referencing the East Asian experience ensures high feasibility and alignment with Vietnam's specific socio-economic conditions. Additionally, green financial instruments enhance international credibility and access to concessional funding from the international community.

(4) International cooperation: Mobilize Green Climate Fund (GCF), EU Climate Investment Partners, and Asian Development Bank, while closely integrating advanced technology transfer. Specifically, Vietnam should learn from and apply submerged dike technology from the Netherlands, early warning systems from Japan, and sustainable construction materials from Germany to improve the quality and effectiveness of coastal dike infrastructure, thereby bringing concessional funding with low interest rates and long terms, and accessing the latest knowledge and technology in climate change adaptation coastal infrastructure construction. Furthermore, combining capital mobilization with technology transfer creates positive synergies, increasing initial investment efficiency and reducing long-term operation and maintenance costs. Additionally, diversifying international partners helps minimize dependency risks and strengthens negotiating capacity in cooperation agreements.

Table 7 *Proposed financial estimates for Vietnam's coastal dike system (Illustrative, internationally referenced)*

No.	Proposed figure	Rationale/Calculation basis	International reference
1	200–300 million USD (Green Bonds for coastal dikes)	Estimated based on the issuance scale of green bonds in the Philippines (USD 225 million) and Indonesia (USD 300 million) during 2018–2020 for climate-resilient infrastructure.	[15]
2	100–150 million USD (Green Climate Fund)	The average level of GCF funding for adaptation projects in Southeast Asia over the past decade.	[19]
3	50–80 million USD (Adaptation Fund)	Typical funding ranges from the Adaptation Fund for national-scale projects in the Asia–Pacific region.	[16]
4	200–300 million EUR (EU Climate Investment)	Referenced from EU support levels for climate resilience projects in Bangladesh and Indonesia.	[19]
5	300–500 million USD (ADB Climate Finance)	Based on concessional loans approved by ADB for coastal infrastructure projects in the Philippines and Fiji.	[16]

Int. J. Sustain. Constr. Eng. Technol. Vol. 17 No. 1 (2026) p. 47-66

6	6–12 billion USD (adaptation finance gap for Vietnam, 2025–2030)	Estimated by applying 3–5% of GDP for climate adaptation in developing coastal countries, adjusted to Vietnam's projected GDP in 2025–2030.	[15]
7	15–20% (share of coastal dike investments in total adaptation costs)	Based on expenditure structure analyses in the Netherlands, Bangladesh, and Japan, it is found that coastal infrastructure accounts for 15–25% of total adaptation costs.	[23] [25]
8	Cost-sharing ratio (Central Gov. 50/30; Local 30/40; Community/Private 20/30)	Modelled after Japan's traditional cost-sharing system for flood control, adjusted for Vietnam's fiscal context.	[23] [24]

Table 7 below presents illustrative financial estimates developed based on the practical experiences of countries worldwide and adjusted to suit Vietnam's specific socio-economic context. These estimated figures are referenced from reputable international studies and successful financial models of coastal nations in the region.

6. Conclusion

This study proposes a six-pillar financing framework for Vietnam's coastal dikes, integrating quantitative analysis of 21 provinces, SWOT assessment, and international best practices. The framework addresses the projected USD 6-12 billion adaptation financing gap for 2025-2030, a diversified financial ecosystem, transparent governance, innovative financial instruments, strategic international cooperation, and monitoring–evaluation systems—which provide a foundation for designing sustainable and feasible financial solutions. The study underscores that beyond filling the significant financing gap illustrated by our provincial data, the mobilization of timely and varied resources plays a pivotal role in resilience building, coastal population protection, and the pursuit of sustainable development pathways.

The main contributions of this research are threefold: (i) providing an empirical, context-specific diagnosis of Vietnam's coastal dike investment needs through a mixed-methods approach that acknowledges data constraints while extracting actionable insights; (ii) proposing and operationalizing a novel six-pillar financing framework that systematically translates global climate finance instruments into a strategy tailored to Vietnam's institutional and geographical context; and (iii) offering practical, evidence-informed policy implications for the formulation and implementation of climate change adaptation strategies in Vietnam. This framework underscores that mobilizing timely and varied resources is pivotal not only for addressing the projected 6–12 billion USD adaptation financing shortfall for 2025–2030 but also for building long-term resilience, protecting coastal populations, and supporting sustainable development pathways.

Three limitations warrant consideration. First, our cross-sectional design with 21 provinces limits causal inference but provides comprehensive coverage of Vietnam's coastal dike systems and generalizability of the correlation analysis. Future research should seek to incorporate panel data or a larger dataset to validate and refine these relationships. Second, while the selected independent variables are conceptually justified, the models may not capture all relevant determinants of investment, such as governance quality, political priorities, or historical funding patterns. Third, certain data points, such as the proportion of land below sea level (P_BELOW) and the GRDP per capita in USD, require careful interpretation due to potential measurement and scaling issues. These limitations underscore the exploratory nature of the quantitative findings and highlight the need for complementary qualitative and case-study approaches.

Therefore, future research should advance this foundation by employing more advanced multivariate or spatial econometric techniques with expanded datasets, broadening the scope of comparative international analysis, and conducting applied policy trials at the local scale to test and refine the proposed mechanisms before scaling them up to the national level.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Author Bui Thi Ngoc Lan;* ***data collection:*** *Author Bui Thi Ngoc Lan, Author Le Cong Thanh, Author Trinh Thi Phin;* ***analysis and interpretation of results:*** *Author Bui Thi Ngoc Lan, Author Dao Truong Thanh, Author Le Cong Thanh, Author Trinh Thi Phin;* ***draft manuscript preparation:*** *Author Dao Truong Thanh and author Le Cong Thanh. All authors reviewed the results and approved the final version of the manuscript.*

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