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Environmental Impact Assessment of the Patuakhali Town Protection Embankment, Bangladesh

Md Afjal Hossain[1*], Md. Hamidul Islam[2], and Sanjit Kumar Mondal[3]

[1]Department of Disaster Risk Management, Faculty of Environmental Science and Disaster Management, Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh; Email: drmafjal@pstu.ac.bd

[2]Department of Building Engineering and Construction Management (BECM), Khulna University of Engineering & Technology (KUET), Khulna-9203, Bangladesh; Email: engineerhamid@becm.kuet.ac.bd

[3]Faculty of Environmental Science and Disaster Management, Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh; Email: sanjupstudm@gmail.com

***Correspondence:** drmafjal@pstu.ac.bd; Tel: +82-10-4324-6943

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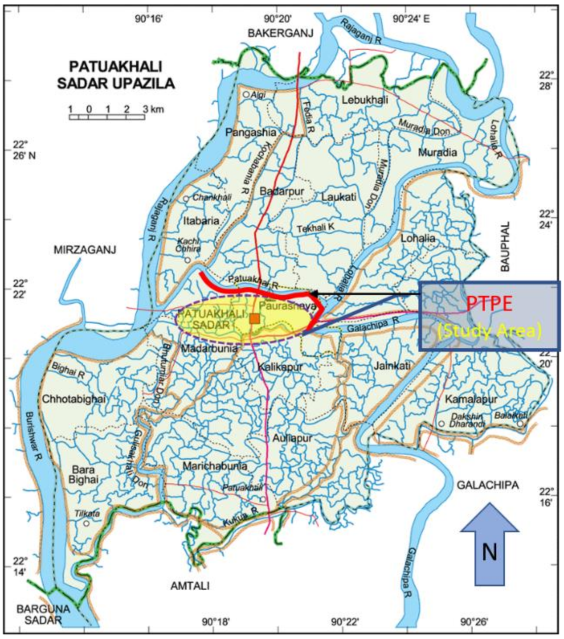
Abstract: Environmental impact assessment provides a systematic basis for identifying the beneficial and adverse consequences of development projects and formulating measures to manage those consequences. This study assessed the environmental implications of the Patuakhali Town Protection Embankment (PTPE), a flood-protection and drainage-improvement project in coastal southern Bangladesh. The study used primary data gathered from field observations, respondent surveys, focus group discussions, and key-informant interviews, together with secondary information drawn from project documents and records of relevant government institutions. Potential impacts were classified into ecological, physicochemical, and human-interest domains and evaluated using a weighted Environmental Impact Value (EIV) method. The assessment produced negative scores for the ecological domain (−45) and physicochemical domain (−100), but a positive score for the human-interest domain (+150), resulting in an overall EIV of +5. The strongest beneficial contribution was flood protection (+200), followed by compensatory plantation (+100), improved road communication (+40), and local economic development (+30). The largest adverse contributions were water stagnation (−90), waterlogging (−80), fisheries loss (−45), habitat loss (−40), vegetation loss (−40), and water pollution (−40). These results indicate that the PTPE project has a marginally positive net environmental balance because flood-protection and socioeconomic benefits slightly outweigh ecological and drainage-related costs. However, this balance is conditional on regular maintenance of regulators, outlets, culverts, and internal drainage channels; effective solid-waste management; riverbank protection; preservation of aquatic connectivity; compensatory plantation; livelihood support; and enforcement against land and river encroachment. The findings suggest that the PTPE can remain environmentally acceptable only if its structural benefits are supported by continuous drainage management, environmental monitoring, and implementation of the proposed mitigation measures.

Keywords: Coastal embankment; Tidal flooding; Waterlogging; Drainage management; Mitigation measures; Weighted scoring.

INTRODUCTION

Environmental impact assessment (EIA) is a structured process that supports development planning by anticipating, assessing, and managing the possible biophysical, socioeconomic, cultural, and health-related effects of a proposed project before key decisions are finalized. EIA integrates environmental considerations into project planning by identifying significant impacts, comparing alternatives, recommending measures to avoid or mitigate adverse effects, enhancing beneficial outcomes, and establishing environmental-management and monitoring arrangements (Canter, 1996; IAIA and IEA, 1999; UNEP, 2002; Morgan, 2012).

The principal objectives of EIA are to incorporate environmental considerations into development decisions; foresee and reduce significant adverse impacts, restore or compensate for unavoidable damage, and safeguard the productivity and resilience of natural and human systems;



PTPE embankment alignment (schematic; see Figure 2 for surveyed alignment)
Study area–Patuakhali Paurashava, Patuakhali Sadar Upazila
Location: Patuakhali District, south-central coastal Bangladesh (≈ 22°21′ N, 90°20′ E)
Base map source: Banglapedia (2021), "Patuakhali Sadar Upazila", https://en.banglapedia.org; annotated by the author.

Figure 1. Location of Patuakhali Paurashava (yellow ellipse) within Patuakhali Sadar Upazila, Bangladesh.

Figure 2. Approximate alignment of the Patuakhali Town Protection Embankment along the northern and eastern margins of Patuakhali town. The red line is the project-area annotation supplied with the original image. Imagery ©2013 CNES/Spot Image, DigitalGlobe; map data ©2013 Google.

and promote environmentally sound and socially acceptable development (IAIA and IEA, 1999; UNEP, 2002). In Bangladesh, environmental assessment and clearance requirements are grounded in the Bangladesh Environment Conservation Act, 1995 and the Environment Conservation Rules, 2023 (Government of Bangladesh, 1995, 2023).

Coastal embankments are an important component of flood-risk management in Bangladesh, where low-lying settlements are exposed to tidal flooding, monsoon rainfall, river flooding, storm surges, drainage congestion, and waterlogging. Such structures can protect lives, settlements, agricultural land, transportation networks, and public infrastructure. However, embankments may also alter natural drainage and sediment exchange, obstruct internal drainage, modify floodplain connectivity, and increase waterlogging where regulators, culverts, and drainage channels are inadequate or poorly maintained. Previous studies in coastal Bangladesh have shown that embankments can reduce exposure to some fluvio-tidal hazards while increasing susceptibility to pluvial flooding and longer-term hydro-geomorphological change (Auerbach et al., 2015; Adnan et al., 2019).

Patuakhali town is located in the low-lying coastal region of southern Bangladesh and is influenced by a network of tidal rivers and internal drainage channels. According to the project feasibility study, the PTPE project covers approximately 654 ha and is influenced by the Patuakhali, Lohalia, Payra, and Bolgachia river systems (Figure 1 and Figure 2). Average annual rainfall is approximately 2,600 mm, about 90% of which occurs between May and October. The low elevation of the town, monsoon rainfall, tidal inflow, and occasional overtopping of low sections of the existing road-cum-embankment historically caused recurrent inundation and drainage congestion (BWDB, 2006).

Before implementation of the project, tidal water entered the town through uncontrolled drainage channels, and approximately one-third of Patuakhali town was reportedly inundated during severe monsoon and tidal-flooding conditions. Residential areas, shops, roads, markets, offices, educational institutions, and other public facilities were affected, disrupting transportation, economic activity, public services, and daily life (BWDB, 2006).

The PTPE project was sponsored by the Ministry of Water Resources and implemented by the Bangladesh Water Development Board (BWDB). It was designed to protect the town from recurrent tidal flooding, reduce drainage congestion and waterlogging, and improve the safety of people, property, and infrastructure. The project included new and rehabilitated flood embankments, raised road-cum-embankment sections, a sheet-pile floodwall, re-excavation of internal drainage channels, drainage-cum-flushing regulators, surface-drainage outlets, and pipe and box culverts (BWDB, 2006). Representative structural elements are shown in Figure 3.

Although the project is expected to provide substantial flood-protection and socioeconomic benefits, interventions of this nature can also produce unintended ecological, hydrological, public-health, and social consequences. A systematic assessment is therefore required to determine whether the anticipated benefits outweigh the adverse effects and whether those effects can be effectively managed.

Accordingly, this study aimed to: (i) identify and evaluate the positive and negative environmental impacts of the PTPE project; (ii) recommend measures to mitigate adverse impacts and enhance beneficial outcomes; (iii) examine feasible project, design, and environmental-management alternatives; and (iv) estimate the overall Environmental Impact Value of the project using a weighted assessment framework.

MATERIALS AND METHODS

Study design

A mixed-method case-study approach was used to assess the environmental implications of the PTPE project. The

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assessment combined field observation, an individual respondent survey, focus group discussions (FGDs), key-informant interviews (KIIs), and secondary-document analysis. A semi-quantitative EIA framework was then applied to identify and evaluate impacts, formulate mitigation and enhancement measures, examine alternatives, and estimate the overall EIV.

Study area

The project is located within Patuakhali Municipality in Patuakhali Sadar Upazila, in south-central coastal Bangladesh. The project area lies between approximately 22°20′21″ and 22°22′35″ N and 90°16′14″ and 90°21′11″ E and covers about 654 ha. It is bounded by the Bolgachia River to the south, the Lohalia River to the east, and the Payra river system to the north and west (Figure 1). The area is low-lying and its hydrology is governed by monsoon rainfall, tidal fluctuations in the surrounding rivers, and drainage through internal natural and artificial channels (BWDB, 2006). The location of Patuakhali Paurashava within Patuakhali Sadar Upazila is shown in Figure 1, whereas the approximate alignment of the PTPE around the town is shown in Figure 2.

The principal structural components of the project are summarized in Table 1. The field photographs in Figure 3 show two representative river-protection elements within the project area.

Table 1. Principal components of the Patuakhali Town Protection Embankment project

Project component	Specification	Primary function
New flood embankment	Approximately 1,172 m	Tidal-flood protection
Rehabilitation of existing embankment	Approximately 260 m by re-sectioning	Restoration of flood-protection capacity
Raised road-cum-embankment	Approximately 2.05 km	Flood protection and road communication
Sheet-pile floodwall	Approximately 250 m	Protection of constrained riverbank sections
Internal drainage-channel re-excavation	Approximately 5 km	Improvement of internal drainage
Drainage-cum-flushing regulators	Six structures	Control of tidal inflow and drainage outflow
Surface-drainage outlets	Seventeen outlets	Drainage of small confined areas
Box culverts	Nine structures, with associated pipe culverts	Cross-drainage and hydraulic connectivity

Source: BWDB (2006).

(a) **(b)**

Figure 3. Representative physical structures of the PTPE project: (a) steel sheet-pile floodwall with concrete capping and toe protection; and (b) riverbank revetment adjacent to residential development. Source: field photographs taken by the authors.

Primary data collection

A reconnaissance survey was first undertaken to examine the embankment, floodwall, internal drainage channels, regulators, outlets, culverts, adjacent rivers, waterlogged locations, settlements, agricultural areas, and other environmentally sensitive sites. Field observations were used to verify project conditions and to support the identification of ecological, physicochemical, public-health, and socioeconomic impacts.

A semi-structured questionnaire was administered to 50 respondents who were selected purposively because they were directly or indirectly affected by the PTPE project. The survey examined respondents' experiences of tidal flooding and drainage congestion; changes in waterlogging and drainage conditions; effects on fisheries, agriculture, vegetation, land use, transportation, employment, and public health; the operation and maintenance of project structures; and perceptions of the project's benefits, adverse effects, and mitigation priorities.

A total of four focus group discussions (FGDs) were conducted, with approximately 12 participants in each group. The participants included shopkeepers, individuals involved in small and medium-sized enterprises (SMEs), fishers, and farmers. The discussions were used to identify common concerns, compare experiences among stakeholder groups, and validate the impacts identified through the questionnaire survey and field observations.

In addition, six key-informant interviews (KIIs) were conducted with representatives of the Bangladesh Water Development Board (BWDB), Patuakhali Municipality, Local Government Engineering Department (LGED), Bangladesh

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Agricultural Development Corporation (BADC), Department of Public Health Engineering (DPHE), and Department of Fisheries (DoF). The interviews focused on project design, drainage performance, maintenance practices, river and land encroachment, institutional responsibilities, and feasible mitigation measures.

Secondary data

Secondary information was obtained from government reports, project documents, maps, statistical publications, institutional records, and relevant literature. The principal sources included BWDB, the Bangladesh Bureau of Statistics, the Water Resources Planning Organization, the Bangladesh Meteorological Department, the Local Government Engineering Department, the Department of Fisheries, Patuakhali Municipality, and other relevant institutions. The December 2006 BWDB feasibility study was the principal source of project-design and baseline information.

Impact identification and evaluation

Potential impacts were identified by comparing project activities with the environmental and socioeconomic components likely to be affected. Evidence from field observation, survey responses, FGDs, KIIs, project documents, and relevant literature was triangulated. The environmental parameters were organized into three domains: ecological, physicochemical, and human interest. Where relevant, both construction-stage and operation-and-maintenance-stage effects were considered.

An interaction-matrix approach was used to relate project activities to environmental receptors. Impact significance was evaluated in terms of direction, magnitude, duration, spatial extent, reversibility, and potential for mitigation. Comparable matrix and weighted-scoring approaches have been used in infrastructure EIAs in coastal Bangladesh (Islam et al., 2015; Faisal et al., 2018).

Impact scores and relative importance weights

The expected change in each environmental parameter was represented by an impact score, Vi, ranging from −5 to +5. Negative values shown adverse effects, positive values shown beneficial effects, and zero indicated no discernible change. Scores of ±1, ±2, ±3, ±4, and ±5 represented very low, low, moderate, high, and very high or severe change, respectively.

A relative importance weight, Wi, was assigned to each parameter according to its ecological or socioeconomic importance, the number of people or resources potentially affected, spatial extent and duration, stakeholder concern, reversibility, mitigability, and relevance to the objectives of the PTPE project. Within each environmental domain, the weights summed to 100. Scores and weights were assigned after reviewing the available field and documentary evidence.

Calculation of Environmental Impact Value

$$\mathrm{Ii} = \mathrm{Wi} \times \mathrm{Vi}$$

where Ii is the weighted impact score for parameter i, Wi is the relative importance weight, and Vi is the magnitude and direction of environmental change. The EIV for each environmental domain was calculated as:

$$\mathrm{EIVk} = \Sigma(\mathrm{WiVi})$$

The overall project EIV was the sum of the ecological, physicochemical, and human-interest subtotals. A positive value indicated that weighted beneficial effects exceeded weighted adverse effects, whereas a negative value indicated that adverse effects predominated. A value close to zero represented a limited net difference under the adopted scoring framework (Wilson, 1998; Saha, 2007; Islam et al., 2015).

Mitigation measures and alternatives

Mitigation measures were formulated for significant adverse impacts using the hierarchy of avoidance, minimization, restoration, and compensation. Enhancement measures were identified for beneficial outcomes. Alternatives were examined qualitatively in relation to flood-protection effectiveness, drainage performance, environmental and social impacts, technical feasibility, maintenance requirements, and likely cost implications.

Data analysis and ethical considerations

Closed-ended survey responses were summarized using frequencies and percentages, whereas open-ended responses, FGD notes, and KII records were organized thematically. Findings were cross-checked across data sources. The preliminary impact list and scores were reviewed against field observations, stakeholder statements, project documents, and relevant studies.

Before data collection, participants received an explanation of the study aims and were informed that they could choose whether or not to participate.

RESULTS AND DISCUSSION

Environmental components considered

The assessment identified ecological, physicochemical, public-health, and socioeconomic effects associated with the PTPE project. The effects reflected both the benefits of external tidal-flood protection and the risks created when internal drainage, ecological connectivity, and land-use control are inadequate. The assessed parameters are summarized in Table 2.

Table 2. Environmental domains and principal parameters considered in the assessment

Environmental domain	Principal parameters
Ecological environment	Fisheries; aquatic habitat; species diversity; vegetation loss; ecosystem disturbance; compensatory plantation
Physicochemical environment	Drainage; water stagnation; erosion and sedimentation; bank stability; surface-water quality; local hydrology; wastewater flow; river excavation; land-use change
Human interest and socioeconomic environment	Flood protection; waterlogging; public health; agricultural land; livelihood and income; displacement; transportation; employment; commercial development; land and river encroachment

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Ecological impacts

Fisheries and aquatic habitat: Construction of the embankment and associated hydraulic structures can alter the connection between peripheral rivers, internal channels, floodplains, and water bodies. Restricted lateral and longitudinal movement may reduce access to seasonal breeding and feeding grounds and affect capture fisheries and fisheries-dependent livelihoods. The effect is particularly important where natural drainage channels are narrowed, blocked, or regulated without sufficient provision for aquatic connectivity. Regular maintenance of channels and regulators, preservation of river-channel connections, sustainable pond aquaculture, and a technically assessed fish sanctuary in the Bolgachia Channel could reduce these effects. The location and management of any sanctuary should be determined with the Department of Fisheries and local fishers.

Vegetation and ecosystem disturbance: Construction and rehabilitation of the road-cum-embankment placed pressure on roadside vegetation and other plant resources within the project corridor. Removal of mature trees can reduce habitat, shade, aesthetic value, and erosion control. Unnecessary clearing should be avoided, and compensatory plantation should use native or locally adapted species. Plantation performance should be evaluated through survival and maintenance monitoring rather than only by the number of seedlings planted.

Physicochemical and public-health impacts

Erosion, sedimentation, and bank stability: Floodwalls, revetments, and embankments along riverbanks can modify near-bank flow and sediment transport. Inadequately protected sections may experience erosion, whereas reduced flow velocity elsewhere may promote sediment deposition. Site-specific river-training and bank-protection works, combined with monitoring of bank condition, channel depth, sediment accumulation, and structural stability, are therefore required. Dredging should be undertaken only where supported by hydro-morphological assessment because poorly planned dredging can transfer erosion and sedimentation problems to adjacent reaches.

Drainage congestion and waterlogging: Although the project was designed to reduce tidal flooding and longstanding drainage congestion, the field assessment indicated that it can create a new pattern of internal waterlogging where outlets, regulators, culverts, and channels are obstructed, insufficient, or poorly maintained. Solid-waste dumping further reduces flow capacity and can block regulator gates. This trade-off is central to the environmental performance of the project: exclusion of external tidal water does not automatically ensure drainage of rainfall and wastewater generated inside the protected area. Long-term performance depends on coordinated regulator operation, maintenance of outlets and culverts, periodic re-excavation of channels, effective waste collection, public awareness, and regulatory enforcement.

Disease transmission and mosquito breeding: Persistent waterlogging and stagnant polluted water create favourable conditions for mosquito breeding and increase exposure to water-related and vector-borne diseases. The principal control measures are rapid drainage of stagnant water, regular cleaning of outlets, improved solid-waste management, public-health surveillance, and coordinated action among BWDB, Patuakhali Municipality, health authorities, and local communities.

Changes in local hydrology and wastewater flow: The raised road-cum-embankment, floodwall, regulators, and culverts alter the direction and timing of surface-water flow and may redistribute water to confined locations. Drainage openings should therefore be located and operated according to local topography, rainfall-runoff conditions, and tidal cycles. Domestic wastewater and polluted stormwater require adequate crossing structures and maintained outlets; otherwise, accumulated sewage and urban runoff may deteriorate surface-water quality and create sanitation problems.

Human-interest and socioeconomic impacts

Flood protection and safety: Flood protection was the dominant beneficial outcome. The project reduces tidal-water entry and protects homes, roads, markets, offices, educational institutions, and other infrastructure from recurrent inundation. These benefits can reduce property damage, disruption of economic activity, and risks to urban residents. Their magnitude, however, depends on structural integrity and the performance of the internal drainage system; flood protection and drainage must therefore be managed as interdependent functions.

Agricultural land and livelihoods: Project construction and subsequent urban expansion may reduce agricultural land and change traditional cropping conditions. Improved irrigation and drainage, access to suitable crop varieties, agricultural extension, and livelihood support can partially offset these effects. Compensation should be considered where project interventions directly cause permanent loss of productive land or livelihood assets.

Land and river encroachment: Improved accessibility along the embankment may encourage shops, housing, and other structures on the embankment slope, riverside land, or drainage-channel margins. Encroachment can narrow drainage paths, obstruct maintenance access, add loads to the embankment, and reduce flood-protection effectiveness. Protection zones should be clearly demarcated and routinely inspected, and unauthorized development should be prevented through coordinated action by BWDB, the district administration, and Patuakhali Municipality.

Employment, transport, and economic activity: The project generated temporary construction employment and can support longer-term work in maintenance, transport, trade, and services. Use of the road-cum-embankment improves local connectivity and can reduce travel disruption. These benefits should be enhanced by prioritizing qualified local workers and regulating roadside development so that new commercial activity does not create congestion, waste accumulation, or further encroachment.

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Table 3. Principal project actions, environmental impacts, and recommended mitigation or enhancement measures

Project action or component	Principal impact	Direction	Recommended mitigation or enhancement
Embankment, floodwall, and hydraulic structures	Restricted fish movement and altered aquatic habitat	Negative	Maintain aquatic connectivity; operate regulators appropriately; preserve internal water bodies; assess a fish sanctuary; promote sustainable aquaculture.
Clearing of the construction corridor	Loss of roadside trees and habitat	Negative	Minimize clearing; undertake compensatory plantation with native species; monitor tree survival.
Construction along riverbanks	Local erosion, sedimentation, and bank instability	Negative	Implement site-specific river-training and bank-protection works; monitor bank condition and channel morphology.
Regulators, outlets, and channel improvement	Reduced tidal inflow and improved drainage	Positive	Maintain operating schedules; inspect gates, outlets, channels, and culverts before and during the monsoon.
Poorly maintained drainage infrastructure	New internal drainage congestion and waterlogging	Negative	Remove blockages; maintain regulators and culverts; periodically clean and re-excavate channels.
Solid-waste disposal in channels	Blocked flow, polluted stagnant water, and mosquito breeding	Negative	Improve waste collection; prohibit dumping; combine awareness with regulatory enforcement.
Raised road-cum-embankment	Obstruction of stormwater and wastewater flow	Negative	Provide adequate cross-drainage structures and maintained wastewater outlets.
Flood-protection structures	Reduced tidal flooding and protection of life and property	Positive	Conduct routine structural inspection, emergency preparedness, and timely maintenance.
Use of embankment as a road	Improved transport, trade, and access to services	Positive	Maintain road condition; manage traffic; regulate roadside development.
Development adjacent to embankment	Land and river encroachment and restricted maintenance access	Negative	Demarcate protection zones; enforce land-use regulation; conduct routine inspections.
Land occupation and urban expansion	Agricultural-land loss and livelihood disruption	Negative	Provide compensation where applicable; support irrigation, agricultural extension, and alternative livelihoods.
Operation and maintenance	Local employment generation	Positive	Prioritize qualified local workers and establish a funded maintenance programme.

Assessment of alternatives

The no-project alternative would avoid construction-related effects but would leave the town exposed to recurrent tidal flooding, drainage congestion, infrastructure damage, transport disruption, and public-health risks. The preferred alternative is therefore not simply the embankment itself, but an integrated system combining structural flood protection with effective drainage, channel maintenance, ecological restoration, controlled land use, and institutional monitoring.

Table 4. Principal alternatives considered for the PTPE project

Alternative	Assessment and preferred approach
No-project alternative	Would avoid construction effects but retain recurrent flooding, waterlogging, infrastructure loss, transport disruption, and health risks; therefore, not preferred.
Structural and technological alternative	Use an integrated combination of earthen embankment, raised road sections, floodwall, regulators, culverts, and bank protection rather than relying on a single measure.
Drainage-management alternative	Re-excavate internal channels; maintain adequate regulators, outlets, culverts, stormwater and wastewater crossings; assess pumping at Hetalia Point.
Fisheries and aquatic-habitat alternative	Preserve aquatic connectivity, promote pond aquaculture, and assess a fish sanctuary in the Bolgachia Channel.
Vegetation-restoration alternative	Undertake compensatory plantation with native species and long-term survival monitoring.
Resettlement and livelihood alternative	Provide compensation, suitable relocation support, and alternative livelihood opportunities before displacement.
Transportation and access alternative	Use the road-cum-embankment to improve connectivity while regulating traffic, roadside commerce, and encroachment.
Ferry, bathing-ghat, and river-access alternative	Provide designated access points to preserve transport and bathing functions without damaging the floodwall or embankment.

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Raising existing low road sections	Raise known low reaches and combine them with adequate cross-drainage to prevent overtopping without creating internal waterlogging.

Environmental Impact Value

The weighted assessment produced negative ecological and physicochemical subtotals and a positive human-interest subtotal. The positive human-interest score was driven primarily by flood protection and improved road communication, whereas the main negative contributions arose from water stagnation, waterlogging, fisheries and habitat loss, vegetation loss, and water pollution.

Table 5. Calculation of the Environmental Impact Value of the PTPE project

Environmental domain	Parameter	Relative importance weight (Wi)	Impact score (Vi)	Weighted impact (WiVi)
Ecological	Fisheries loss	15	−3	−45
	Habitat loss	20	−2	−40
	Vegetation loss	20	−2	−40
	Ecosystem disturbance	20	−1	−20
	Plantation	25	+4	+100
	Ecological subtotal	**100**		**−45**
Physicochemical	Water stagnation	30	−3	−90
	Erosion and sedimentation	10	−2	−20
	Change in local hydrology	10	−1	−10
	Water pollution	20	−2	−40
	River excavation and channel improvement	20	+2	+40
	Land-use improvement or change	10	+2	+20
	Physicochemical subtotal	**100**		**−100**
Human interest	Waterlogging	20	−4	−80
	Flood protection	40	+5	+200
	Road communication	10	+4	+40
	Income reduction	10	−2	−20
	Displacement or migration	10	−2	−20
	Economic development	10	+3	+30
	Human-interest subtotal	**100**		**+150**
	Overall EIV			**+5**

The overall EIV was +5. This value indicates a marginally positive net balance under the adopted weighting and scoring system; it does not show that all adverse effects are negligible and does not itself constitute formal environmental clearance. The result is close to neutral and is highly sensitive to the performance of the internal drainage system. Failure to maintain regulators, outlets, culverts, and channels could increase water stagnation and waterlogging and shift the overall balance in a negative direction.

The separate treatment of water stagnation and waterlogging reflects different dimensions of the same drainage problem. Water stagnation represents the physical accumulation and deterioration of water within the physicochemical environment, whereas waterlogging represents consequences for households, mobility, health, property, and economic activity. This distinction should be retained to avoid double counting in interpretation.

Overall, the assessment suggests that the PTPE project can produce a net benefit only when flood-protection structures are coupled with effective drainage maintenance, erosion control, ecological restoration, encroachment prevention, and environmental monitoring. The project should therefore be understood as an integrated flood-and-drainage management system rather than solely as an embankment.

CONCLUSION

The Patuakhali Town Protection Embankment provides an important structural response to recurrent tidal flooding and associated hazards in Patuakhali town. Its principal benefits are protection of lives, property, roads, markets, public institutions, and economic activities, together with improved road communication and employment opportunities. These benefits explain the strongly positive human-interest component of the assessment.

The project also creates or intensifies several environmental risks. The most important are altered aquatic connectivity, fisheries and habitat loss, vegetation removal, erosion and sedimentation, water pollution, possible creation of new internal drainage congestion, stagnant-water-related disease risk, agricultural-land loss, displacement, and land or river encroachment. Many of these effects are not inevitable consequences of the embankment itself; they arise from inadequate design capacity, poor maintenance, obstructed drainage channels, uncontrolled waste disposal, and weak land-use enforcement.

The calculated overall EIV of +5 indicates only a marginally positive balance between weighted benefits and adverse effects. Environmental acceptability is therefore conditional rather than automatic. Regular maintenance of regulators, outlets, culverts, and channels; effective waste

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management; hydrologically appropriate river-training and bank-protection works; preservation of aquatic connectivity; compensatory plantation; livelihood and resettlement support; enforcement against encroachment; and continuous environmental monitoring are required to maintain the project's benefits. With these measures in place, the PTPE can contribute to flood resilience and urban development while limiting ecological and social costs.

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Conflict of Interest

The authors declare no conflict of interest.

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