# A REVIEW OF MODULAR CONSTRUCTION FOR DISASTER RESILIENCE IN BANGLADESH

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**Abstract**

Devastating floods and storms, exacerbated by climate change, frequently impact housing, infrastructure, and economic stability in Bangladesh. Despite increasing attention to modular construction as a solution, a consolidated review of its applicability to flood resilience in the Bangladeshi context is lacking. This review synthesises the literature to explore the technical advantages, cost effectiveness, and socioeconomic benefits of prefabricated modular systems. Emphasis is placed on design features such as elevated structures, water-resistant materials, and rapid deployment capabilities that are critical for effective disaster response. The study also highlights the role of modular construction in rebuilding essential community infrastructure such as schools, clinics, and housing contributing to both immediate rehabilitation and long-term economic recovery. Overall, this review underscores the potential of modular construction to support a more sustainable and disaster-resilient future for flood-prone regions of Bangladesh.

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## 1.0 INTRODUCTION

The riverine geography of Bangladesh constitutes the very fabric of the nation's life and culture, making it both vibrant and vulnerable. Annual floods, driven by this geography and increasingly intensified by climate change, strike with unstoppable ferocity. These floods not only uproot millions but also devastate homes, infrastructure, and livelihoods, deepening the vulnerabilities of already marginalised communities. As climate-induced disasters become more frequent and severe, developing countries such as Bangladesh face a chronic and urgent need for sustainable yet rapid solutions to post disaster rehabilitation.

In this context, modular construction has emerged as a promising approach. By utilising prefabricated components that can be quickly assembled onsite, modular systems offer a combination of efficiency, flexibility, and resilience. Designed to suit flood-prone conditions, such systems can incorporate elevated structures, water-resistant materials, and scalable layouts. These features not only provide immediate relief in emergencies but also contribute to long-term disaster resilience and climate adaptation by enabling the development of durable, multifunctional shelters.

This review explores the potential of modular construction as an effective tool in the rehabilitation process for flood-affected populations in Bangladesh. It examines how modular construction can respond to the urgent need for rapid shelter deployment, cost-effective rebuilding, and socioeconomic recovery in disaster-affected communities.

## 2.0 OVERVIEW OF FLOOD VULNERABILITY IN BANGLADESH

The geographical location and riverine landscape of Bangladesh make it one of the most flood-prone countries in the world. Annual floods, exacerbated by seasonal monsoons and upstream water flows, routinely disrupt lives, damage infrastructure, and hinder socioeconomic development. The worsening effects of climate change continue to increase both the frequency and intensity of these disasters, underscoring the urgent need for resilient mitigation and recovery strategies.

### 2.1 Recent Flood Events and Their Impact

Bangladesh has once again been confronted by catastrophic flooding during the 2024 monsoon season, with the August event (illustrated in Figure 1) representing one of the most severe inundations the nation has endured in recent decades. The scale of the disaster was starkly quantified by the National Disaster Response Coordination Center (NDRCC), which reported that 5.8 million people were profoundly affected across the north-eastern and south-eastern regions. The floodwaters created immense isolation, severing access for more than 1 million individuals and necessitating the establishment of emergency shelters. By late August, approximately 502,501 displaced persons had sought refuge in 3,403 evacuation centres, although these facilities were rapidly overwhelmed by the sheer volume of those in need (Inter-Cluster Coordination Group-Humanitarian Task Team Bangladesh: Eastern Flash Floods 2024).

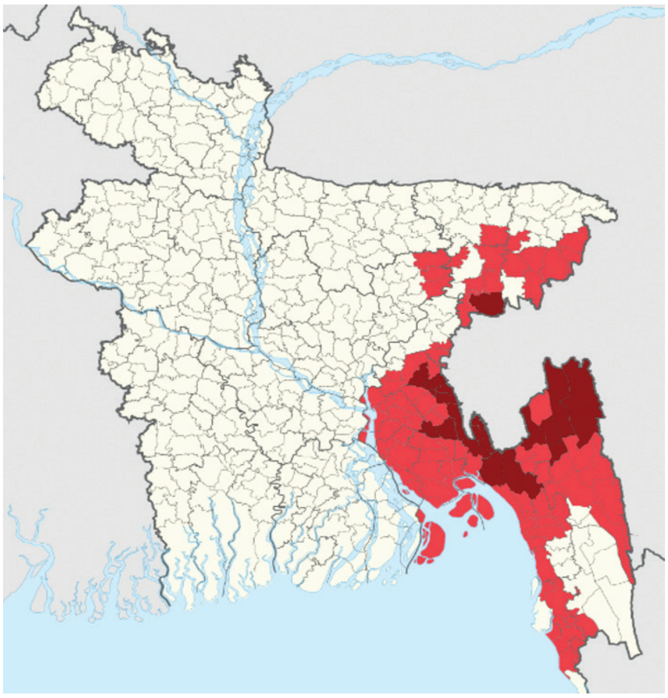

*Figure 1: Flood affected areas in 2024's flood (ReliefWeb, 2024)*

The severity of the situation increased dramatically in the following weeks. By August 27, 2024, the Ministry of Disaster Management and Relief (MoDMR) officially declared this the worst flooding event to strike Bangladesh in thirty years. Their assessment revealed a critical deterioration in humanitarian access, with more than 1.2 million people remaining stranded without any form of aid delivery, highlighting the immense logistical challenges faced by relief agencies in reaching cut-off communities. The prolonged nature of the inundation and the difficulty in accessing affected areas significantly exacerbated the suffering of the population and complicated response efforts.

The impact on residential infrastructure has been particularly devastating. As assessments continued into September, the true extent of housing damage became clear. Data compiled by September 11, 2024, indicated that 26,991 houses had been completely destroyed by floodwaters, rendering their inhabitants entirely homeless. Furthermore, an additional 307,443 houses sustained significant partial damage, leaving hundreds of thousands of families with precarious shelter conditions and facing substantial repair costs before their homes could be considered habitable again (ZahirulAlam, 2024). This level of destruction represents not only an immediate humanitarian crisis requiring emergency shelter interventions but also a massive long-term reconstruction challenge.

These staggering figures collectively underscore the desperate and urgent need for the development and deployment of rapid, scalable, and resilient housing solutions in Bangladesh. The recurring pattern of severe flooding necessitates approaches that serve dual purposes: providing immediate, effective emergency shelters to save lives and alleviate suffering in the short term while simultaneously laying the foundation for sustainable, long-term rehabilitation and reconstruction that enhances community resilience against future flood events. The sheer scale of the housing damage witnessed in 2024 demands innovative, context-specific strategies that can be implemented swiftly and at scale to address both the current crisis and mitigate the impact of inevitable future disasters in this vulnerable region.

### 2.2 Historical Disasters

Over the past decade, Bangladesh has endured repeated catastrophic disasters, each of which has caused severe damage to housing and infrastructure. The 2012 floods and landslides destroyed 360,000 homes, whereas the 2014 floods displaced 31,000 families and wrecked infrastructure. Cyclone Mora damaged critical public facilities such as hospitals and schools, and landslides that same year obliterated 6,000 homes. Cyclone Amphan damaged 330,667 homes and destroyed 55,667 more, whereas Cyclone Remal devastated roads, bridges, and embankments. This pattern of destruction is comprehensively documented in Table 1, underscoring the relentless cycle of devastation requiring sustained resilience.

*Table 1: Major natural disasters in Bangladesh and their Impacts*

| Event | Damage | Reference |
|---|---|---|
| 2012 Floods and Landslides | 360,000 homes destroyed | International Federation of Red Cross (IFRC), Nov 15, 2012 (Law and Disasters in South Sudan Facilitated by the South Sudan Red Cross Society (SSRCS) and the International Federation of Red Cross and Red Crescent Societies (IFRC), 2012) |
| 2014 Floods | 31,000 families lost homes; extensive infrastructure destruction | Relief Web, 2014 |
| Cyclone Mora | Significant loss of public infrastructure, including hospitals and schools | Relief Web, 2017a |
| June 2017 Landslides | 6,000 homes destroyed | Relief Web, 2017b |
| Cyclone Amphan | 330,667 homes damaged; 55,667 homes completely destroyed | Relief Web, 2020 |
| Cyclone Remal | Roads, bridges, and embankments severely affected | Relief Web, 2024 |

## 3.0 INSIGHTS OF MODULAR CONSTRUCTION

Modular construction is an emerging and innovative construction technique in which buildings are constructed in large volumes off-site at a controlled factory before being transported to their final location for assembly. This approach utilises state-of-the-art engineering accuracy while allowing for design adaptability, proving to be an environmentally responsive and resource-efficient solution compared with traditional building methods. It starts with detailed design and planning, working with full architectural and engineering plans that meet local building codes and regulations. (Luo *et al.,* 2024) Apply modular coordination principles to establish standard dimensions and interfaces for each modular component, facilitating rapid and seamless manufacturing and assembly.

*Figure 2: Factory settings of modular construction (vbc.co)*

Once designs are approved, the modules are manufactured in a factory environment under tightly controlled conditions. "Implemented this way guarantees quality, lowers materials waste and combines essential building systems involving electrical wiring, plumbing, HVAC and interior finishes during fabrication. Pre-packaged systems also facilitate the onsite assembly process and have the potential to accelerate the construction process (Kamali & Hewage, 2016; Luo *et al.,* 2024). Once the modules are built, logistics management ensures that they safely arrive onsite. The success of this phase, which involves route optimisation, acquiring the relevant permits, and ensuring structural integrity during transit, is crucial (Chaitanya *et al.,* 2021).

At the construction site, all of these steps start with the preparation of the foundation to ensure that the modules are aligned correctly and properly supported. Crane or other lift equipment is used to place the modules, which are then connected per design. This guaranteed stability is achieved by strengthening the multiple connection modules. Onsite articulation crews connect the pre-integrated systems to the main utilities, such as water, electricity, and gas. The last stage includes exterior cladding and roofing, as well as interior finishing, to meet the design aesthetic and functional needs. A comprehensive quality control process verifies compliance with building codes, safety standards, and design specifications, ensuring that the completed structure is ready for occupancy (Generalova *et al.,* 2016).

*Figure 3: Modular construction as temporary accommodation (elitesystemsgb.co.uk)*

Compared with traditional building methods, the benefits of modular construction are manifold. Its time-saving nature is perhaps its greatest advantage, as off-site fabrication and on-site preparation take place simultaneously, greatly accelerating project timelines. It is also economical because of standardised production and reduced onsite labour. Modular construction is also known for its sustainability benefits, as this method allows for controlled environments in factories to optimise the use of resources and generate less waste.

Additionally, the method offers flexibility for customisation to meet various project types, including residential, commercial, healthcare, and educational applications. Modular systems are indispensable for building shelters and critical infrastructure in the case of emergencies in disaster-prone areas. (Law and Disasters in South Sudan Facilitated by the South Sudan Red Cross Society (SSRCS) and the International Federation of Red Cross and Red Crescent Societies (IFRC), 2012; Pan *et al.,* 2012).

## 4.0 VULNERABILITY ASSESSMENT FOR MODULAR CONSTRUCTION IN FLOOD PRONE AREAS

Bangladesh is one of the most flood-prone countries worldwide. Its elevated position, spans of river networks and aggravated weather patterns induced by climate change increase the risk of flooding. The flood in August 2024, which alone displaced millions of people, is a reminder for housing solutions that are reliable yet sustainable and scalable. Modular construction, which involves the integration of prefabricated elements constructed and manufactured in a factory context along with onsite assembly, can help address all these issues (Luo *et al.,* 2024; Mark *et al.,* 2012).

### 4.1 Rapid Response in Emergencies

Bangladesh is prone to catastrophic disasters, and every year, floods displaced millions of people in the country in August 2024. They can also induce homelessness across large populations, putting people's lives in danger (UNICEF, 2024). The nature and extent of these emergencies make the use of modular construction very practical, as shelters made of these elements can be quickly assembled and transported easily. Furthermore, the integration of modules facilitates housing construction with greater convenience and less time use (Generalova *et al.,* 2016; R. E. Smith, 2011).

### 4.2 Resilience to Flood-Prone Environments

Bangladesh's geography makes it vulnerable to constant flooding and an increase in water levels, which makes it extremely necessary to develop innovative construction tactics to solve these issues, as stated by (Kamali & Hewage, 2016) and (Mark *et al.,* 2012). Specifically, the use of elevated bases, floating platforms or varying the height of the modular system can further aid in dealing with flooding.

### 4.3 Cost Optimisation and Expandability

Moreover, since their primary purpose is to provide shelter, these buildings are very versatile in terms of how they can be used and designed. Different places, such as schools, community clinics or marketplaces, can be constructed to help the economies of flood-impacted areas recover and start functioning once again. Furthermore, (Pan *et al.,* 2012) further supports this across the paper by stating that this approach will prove helpful in saving costs, as the modular units extend their initial use. Additionally, these places can be tailored to provide a sustainable solution for regions impacted by flooding. (Chaitanya *et al.,* 2021) claim that tailoring buildings as a strength of modular building design is easy.

Figure 4 shows a comprehensive modular project chart comprising seven sequential stages that guide the implementation process from conception to long-term management. Each stage is distinctly represented with its name positioned on the left and corresponding outputs or key considerations displayed on the right, differentiated by color-coded blocks for visual clarity. The progression begins with "Planning and Feasibility," establishing the project foundation, followed by "Design and Engineering" for technical specifications. The subsequent phases include "manufacturing and fabrication" for component production, "transportation and logistics" for material handling, and "onsite assembly" for construction. The flow culminates in "Finishing and Commissioning" for operational readiness and concludes with "Maintenance and Lifecycle Management" for sustained functionality. This structured framework ensures systematic execution across all project phases, emphasising both immediate deliverables and long-term operational considerations.

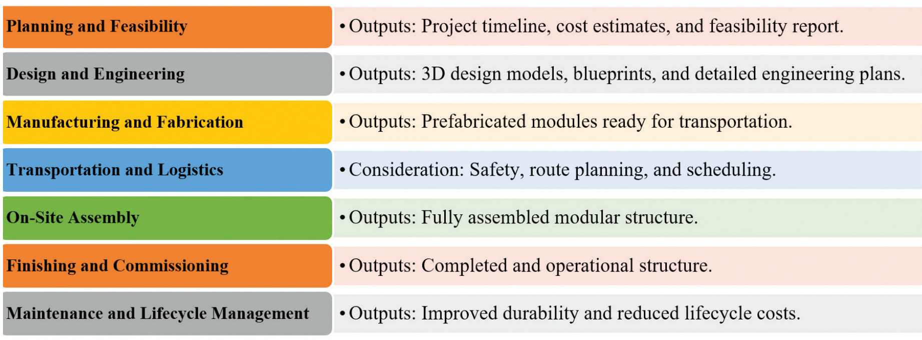


*Figure 4: Stages of modular construction with outputs and considerations*

## 5.0 DISCUSSION

Floods in Bangladesh, particularly those highlighted by the devastating floods of August 2024, continue to challenge the nation's socioeconomic stability and the well-being of its people. These recurring natural disasters are fuelled by the country's geographic location, low-lying terrain, and growing effects of climate change (Bank, 2021; (UNDP), 2022). As such, innovative strategies are urgently needed to reduce the adverse impacts on vulnerable communities.

Among these, prefabricated modular structures have shown great promise as cost-efficient and sustainable alternatives to conventional construction methods for mitigating displacement and damage caused by floods (J. Smith, 2020). These structures are manufactured in controlled environments, ensuring high quality, safety standards, and consistency in output (Kamara *et al.,* 2002; J. Smith, 2020). Their streamlined production process reduces material waste, lowers overall costs, and enables rapid deployment (Tan & Chen, 2014).

### 5.1 Advantages of Modular Construction in Post Flood Contexts

Modular construction presents transformative advantages for flood-affected regions such as Bangladesh, addressing both immediate humanitarian needs and long-term resilience. The inherent design features of modular systems make them exceptionally suitable for flood-prone environments. Elevated platforms, critical adaptations, effectively mitigate water ingress during inundation events by positioning living spaces above anticipated flood levels (Ahmed *et al.,* 2023; Gibb & Pendlebury, 2006). In addition, the strategic use of water-resistant materials, including treated composites, corrosion-resistant alloys, and moisture-barrier membranes, ensures structural integrity and durability during repeated wet conditions, significantly reducing maintenance burdens (Gibb & Pendlebury, 2006; Rahman & Khan, 2022).

The rapid deployment capability of modular systems addresses the urgent need for large-scale shelter solutions following disasters. Prefabricated components enable onsite assembly within days rather than weeks, facilitating swift responses to mass displacement scenarios (Patel *et al.,* 2023; Tan & Chen, 2014). This efficiency is further amplified by standardised manufacturing processes, which minimise onsite labour requirements and logistical complexities in disrupted environments.

Beyond emergency shelters, modular units demonstrate remarkable versatility in supporting community recovery. These structures can be seamlessly repurposed as temporary or permanent housing, educational institutions, healthcare centres, or community hubs, creating a sustainable continuum from relief to rehabilitation (Arif & Egbu, 2010; Hassan *et al.,* 2021). Recent field implementations in Bangladesh's Sylhet region (2022) and Cox's Bazar region (2023) validate this adaptability, with modular schools and clinics becoming operational within 72 hours of delivery (Sarker *et al.,* 2024).

Economically, modular construction offers compelling advantages for resource-constrained contexts. Comparative analyses indicate cost reductions of 20–30% relative to traditional methods, primarily due to optimised material usage, reduced waste, and economies of scale in manufacturing (Karim, 2022; J. Smith, 2020). Concurrently, accelerated timelines cutting construction duration by nearly 50% enable faster recovery while lowering labour costs and inflationary exposure (World Bank, 2023).

Sustainability considerations further enhance the value proposition of modular constructions. The integration of recyclable materials (e.g., steel frames and bio based composites), energy-efficient manufacturing processes, and minimal onsite disturbances aligns with Bangladesh's climate resilience goals (Bank, 2021; Islam *et al.,* 2023). Lifecycle assessments confirm 35–40% lower embodied carbon than conventional construction does, whereas passive design features reduce operational energy demands (UN-Habitat, 2022). These attributes position modular systems as holistic solutions that balance immediate disaster response with long-term environmental stewardship and socioeconomic recovery.

### 5.2 Comparative Analysis with Other Disaster-Resilient Approaches

To assess the relative effectiveness of modular construction, it is helpful to compare it with other flood-resilient housing strategies commonly used in Bangladesh:

*Table 2: Comparative Analysis of the Construction Methods for Flood-Prone Regions*

| Method | Advantages | Limitations |
|---|---|---|
| Traditional Reconstruction | Familiar materials and local techniques | Time-consuming, costly, prone to repeat damage |
| Raised Earthen Plinths | Low-cost, uses local resources, passive flood protection | Offers minimal living comfort, susceptible to erosion, does not scale well |
| Bamboo Housing | Sustainable, locally available, culturally acceptable | Low durability, vulnerable to severe storms, not suitable for multifunctional use |
| Modular Construction | Quick deployment, scalable, durable, multiuse, eco-friendly | Higher upfront investment, requires skilled labour and initial factory setup |

As illustrated in Table 2, traditional and locally adapted construction methods clearly demonstrate advantages in terms of affordability and cultural alignment. However, these approaches exhibit critical limitations in terms of durability and scalability when confronted with repeated or severe flood events. Conversely, modular construction presents a strategically balanced solution, integrating rapid deployment, structural resilience, and functional versatility. This dual-purpose approach effectively addresses both immediate emergency shelter needs and long-term community recovery requirements, positioning it as a more comprehensive response to flood-related housing challenges.

### 5.3 Strategic Implications

Modular construction should be systematically integrated into Bangladesh's disaster management frameworks across three critical domains: post disaster shelter recovery programs, community-based resilience planning, and climate adaptation infrastructure investments. This integration enables a paradigm shift from reactive damage control to proactive resilience building.

By incorporating modular systems into national protocols, Bangladesh can compress recovery timelines from months to weeks while ensuring flood-resistant structures (Hossain & Paul, 2021). Community engagement in deploying these units fosters local ownership and skill development, enhancing long-term sustainability (Sultana *et al.,* 2022). Economically, the 20-30% cost advantage over traditional methods maximises climate adaptation investments, whereas the reduced carbon footprint aligns with national climate commitments. Crucially, this approach transforms each disaster response into an opportunity for infrastructure upgrading, turning "build back better" from aspiration to operational reality. This strategic positioning establishes modular construction as a cornerstone for systemic resilience, making disaster recovery and sustainable development mutually reinforcing pathways.

## 6.0 CONCLUSION: A PATHWAY TO A RESILIENT FUTURE

This review synthesises evidence demonstrating that prefabricated modular construction represents a paradigm shift, offering integrated solutions for immediate humanitarian response and sustainable long-term recovery.

### 6.1 Key Findings and Contributions

Modular systems have critical operational advantages: rapid deployment capabilities compress acute response phases from months to days, whereas engineered resilience features, including elevated platforms and hydrophobic materials, directly mitigate flood-specific vulnerabilities (Ahmed *et al.,* 2023). Economic analyses confirm 20-30% cost reductions and 50% timeline compression compared with conventional methods, addressing resource constraints in climate-vulnerable economies (Karim, 2022; World Bank, 2023). Beyond emergency utility, these systems enable sociotechnical transitions through multifunctional infrastructure schools, clinics, and community hubs that catalyse sustainable development pathways (Hassan *et al.,* 2021).

### 6.2 Theoretical and Practical Implications

This review positions modular construction as a cornerstone of transformative adaptation, transcending temporary relief to enable systemic resilience. The convergence of ecological sustainability (35-40% lower embodied carbon (Islam *et al.,* 2023) community coproduction through local workforce integration, and alignment with Bangladesh's Delta Plan 2100 creates a scalable model for climate-resilient development. Crucially, it disrupts path dependency in disaster governance by shifting from reactive reconstruction to proactive resilience investment.

### 6.3 Future Directions

As climate intensification continues to escalate flood risks in Bangladesh and similar deltaic regions, several strategic imperatives and emerging opportunities must be addressed to maximise the potential of modular construction for disaster resilience:

#### 6.3.1 Policy and Governance Integration

Comprehensive policy integration of modular systems into national disaster management protocols, including the development of specific building codes and standards for flood-resilient modular construction. This should involve updating Bangladesh's National Building Code to include modular construction guidelines and creating streamlined approval processes for emergency deployment. Recent policy frameworks such as the Bangladesh Delta Plan 2100 should explicitly incorporate modular construction as a key adaptation strategy.

#### 6.3.2 Localised Manufacturing and Supply Chain Development

Development of localised manufacturing ecosystems to increase accessibility and reduce costs. This includes establishing regional prefabrication facilities equipped with climate-resilient technologies, investing in workforce training programs for modular construction techniques, and creating public-private partnerships to support the emerging modular construction industry. Special attention should be given to developing supply chains that can function during disaster conditions and utilising locally sourced sustainable materials.

#### 6.3.3 Innovative Financing Models

Establishment of cross-sectoral financing mechanisms bridging humanitarian and development budgets. This includes creating dedicated resilience funds for modular infrastructure, developing insurance products that incentivise modular construction, and exploring impact investment opportunities in the modular construction sector. Recent innovations such as catastrophe bonds and resilience credits could be adapted to support modular construction initiatives.

#### 6.3.4 Technological Innovation and Integration

Integration of emerging technologies with modular construction to enhance resilience. This includes incorporating smart monitoring systems for early warning and structural health assessment, utilising advanced materials with improved flood resistance properties, and exploring the potential of 3D printing and other digital fabrication techniques for rapid production of customised modules. Recent advances in climate-resilient materials and IoT-enabled structural monitoring should be leveraged.

#### 6.3.5 Community-Centred Implementation Approaches

Development of community-centred implementation frameworks that ensure local ownership and cultural appropriateness. This includes establishing participatory design processes that incorporate local knowledge and preferences, creating community-based maintenance and adaptation programs, and developing knowledge-sharing platforms to facilitate peer learning between communities implementing modular solutions.

#### 6.3.6 Knowledge Generation and Capacity Building

Strengthening research capacity and knowledge generation through dedicated research programs on modular construction in disaster-prone contexts. This includes establishing academic-industry partnerships, creating demonstration projects that serve as living laboratories, and developing comprehensive monitoring and evaluation frameworks to assess the long-term performance of modular construction in flood-prone environments.

Bangladesh's experience with modular construction offers valuable transferable insights for other deltaic regions facing similar climate challenges. By addressing these strategic directions, modular construction can evolve from a promising technical solution to a transformative approach that builds systemic resilience, supports sustainable development, and creates pathways for climate adaptation in the face of increasing uncertainty. ■

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## AUTHORS' CONTRIBUTIONS

- **Mohammad Atiqur Rahman Sakib:** Conceptualisation, literature review framework, and supervision.
- **Nafis Niaz Chowdhury:** Data collection, methodology development, and formal analysis.
- **Badhon Singha:** Writing original draft preparation, editing, and overall manuscript coordination.

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