Technology-Enabled Flood Disaster Management: Lessons from Malaysia and a Context-Aware Adaptation Framework for Sri Lanka

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***Abstract*—Flooding remains one of the most recurrent and socio-economically damaging natural hazards in South and Southeast Asia. Sri Lanka experiences frequent flood events, particularly in low-lying urban regions such as Colombo, where flood risk is intensified by wetland encroachment, drainage limitations, and fragmented institutional responsibilities. Malaysia, which faces similar monsoonal flood patterns, has developed comparatively mature flood disaster management practices integrating early warning systems, centralized coordination, and technology-enabled decision support. This paper presents a practitioner-oriented and technology-focused comparative analysis of flood disaster management approaches in Malaysia and Sri Lanka. Governance structures, early warning mechanisms, data integration, infrastructure maintenance, and public communication strategies are examined. Based on documented practices and limitations, the study extracts transferable lessons and proposes a multi-layered, technology-enabled adaptation framework tailored to Sri Lanka. The framework emphasizes decision support systems, real-time data integration, and community-aware communication mechanisms to enhance preparedness and response capabilities.**

***Index Terms*—Flood disaster management, decision support systems, early warning systems, GIS, comparative analysis**

I. Introduction

Flood disasters pose a growing threat to sustainable development, particularly in tropical developing countries. Sri Lanka is classified as having a high river flood hazard, with potentially damaging flood events expected at least once every decade [1]. Urban flood vulnerability is especially pronounced in the Colombo metropolitan region due to low elevation, Kelani River overflow, wetland loss, and unregulated land development [2], [3].

Despite substantial investments in flood mitigation infrastructure, post-project evaluations indicate persistent inundation caused by weak operation and maintenance practices, insufficient secondary drainage, and unclear institutional accountability [4]. As a result, flood response in Sri Lanka remains largely reactive, relying on informal community networks and ad-hoc information dissemination [5]. These limitations highlight the need for a more integrated, technology-enabled flood management approach.

Malaysia, which experiences comparable monsoonal flooding, has progressively strengthened its flood disaster management systems through centralized governance, real-time monitoring infrastructure, and decision-support-oriented information platforms. Analyzing Malaysia's experience offers valuable insights for strengthening flood resilience in Sri Lanka through information technology driven solutions.

II. Flood Disaster Management Practices in Malaysia

Malaysia adopts a structured, multi-tier flood governance model coordinated under the National Disaster Management Agency (NADMA). Disaster management responsibilities are distributed across federal, state, and district levels, enabling vertical coordination and centralized command during flood emergencies [7]. Flood risk management follows a comprehensive disaster cycle encompassing prevention, mitigation, preparedness, response, and recovery.

From a technological perspective, Malaysia has invested heavily in flood forecasting and monitoring infrastructure. The Department of Irrigation and Drainage operates extensive telemetric rainfall and river water-level monitoring stations, supporting real-time flood forecasting across multiple river basins [6]. These data streams are integrated into centralized platforms such as Infobanjir, which function as decision-support tools for authorities and information portals for the public.

However, recent studies reveal that technological sophistication does not necessarily guarantee effective public preparedness. Empirical evidence from Johor shows that a significant portion of the population remains unaware of official flood early warning systems and instead relies on social media and messaging applications for flood-related information [8]. This highlights the importance of aligning technical systems with human-centered communication practices.

https://doi.org/10.54389/ZZLW1030

III. Flood Disaster Management Context in Sri Lanka

Sri Lanka's flood risk management framework involves multiple institutions, including the Disaster Management Centre, local authorities, and sector-specific agencies. In urban areas such as Colombo, flood risk is exacerbated by the degradation of wetlands that previously acted as natural flood retention zones [2]. Policy enforcement challenges have allowed continued development within flood-prone areas [3].

Although major flood control projects have improved drainage capacity in selected locations, evaluation reports identify persistent weaknesses in secondary drainage networks and maintenance regimes [4]. Institutional fragmentation often results in unclear responsibility for operation and maintenance, reducing infrastructure effectiveness. Consequently, flood coping strategies in Sri Lanka rely heavily on community-based networks and informal organizational support, particularly during emergency response and recovery phases [5].

IV. Comparative Analysis

A comparative summary of flood disaster management practices in Malaysia and Sri Lanka is presented in Table I. The comparison highlights structural differences in governance, technology adoption, and operational practices.

TABLE I. Comparison of Flood Disaster Management Practices

Aspect	Malaysia	Sri Lanka
Governance	Centralized (NADMA)	Multi-agency, fragmented
Early warning	Real-time forecasting systems	Limited system integration
Decision support	GIS dashboards, portals	Mostly manual decision-making
Communication	Official + social media	Informal community channels
Maintenance	Defined O&M structures	Weak secondary drain O&M

To further quantify readiness, Table II presents a qualitative indicator-based assessment adapted from disaster management maturity models.

TABLE II. Indicative Technology and Institutional Readiness Comparison

Indicator	Malaysia	Sri Lanka
Real-time hydrological data availability	High	Medium
Centralized flood information portal	Yes	Partial
Decision support system usage	High	Low
Public alert digital reach	Medium	Medium
Community feedback integration	Low	Medium
O&M accountability clarity	Medium	Low

A. Reciprocal Lessons for Malaysia

While Malaysia demonstrates strengths in technological integration and centralized coordination, the comparative analysis also highlights practices from Sri Lanka that may offer reciprocal value. Sri Lanka's reliance on dense community and organizational networks during flood events highlights the potential role of social capital in strengthening disaster resilience. Informal community-based communication and mutual support mechanisms have proven effective in disseminating information and facilitating localized response, particularly in resource-constrained settings. Incorporating such community-centric engagement strategies into Malaysia's predominantly top-down flood management approach may enhance public trust, local participation, and the effectiveness of last-mile communication.

V. Technology-Enabled Adaptation Framework for Sri Lanka

Based on the comparative analysis of flood disaster management practices in Malaysia and Sri Lanka, a technology-enabled adaptation framework is proposed to strengthen flood preparedness, response, and coordination in the Sri Lankan context. The framework integrates information technology components with institutional workflows and community participation to support timely decision-making and effective risk communication.

The framework is conceptual and practitioner-oriented, synthesized from comparative analysis and documented best practices, and intended to guide future system design and implementation rather than represent a fully deployed system. Figure 1 presents the overall architecture of the proposed framework and the interaction among its key components.

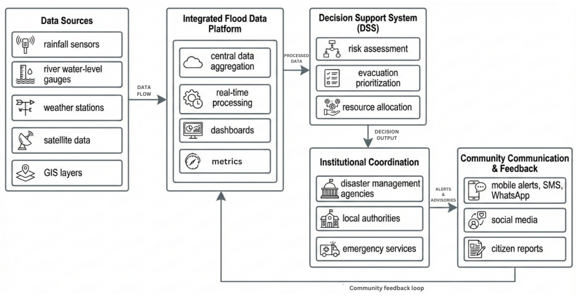

Fig. 1. Technology-enabled flood disaster management framework adapted from Malaysia's best practices for the Sri Lankan context

A. Data Sources and Sensing Layer

The data sources layer represents the foundational inputs required for flood monitoring and assessment. This layer integrates heterogeneous data streams, including rainfall sensors, river water-level gauges, weather stations, satellite observations, and geographic information system (GIS) layers. These data sources provide real-time and spatially referenced information essential for understanding evolving flood conditions and supporting downstream analytical processes.

B. Integrated Flood Data Platform

The integrated flood data platform functions as the central processing and aggregation layer of the framework. It is responsible for collecting incoming sensor and spatial data, performing real-time data processing, and maintaining key monitoring metrics. Visualization dashboards hosted on this platform enable disaster management authorities to obtain situational awareness, track flood dynamics, and access historical and real-time indicators in a unified environment.

C. Decision Support System (DSS)

Built on top of the integrated data platform, the decision support system (DSS) translates processed data into actionable insights. The DSS supports functions such as flood risk assessment, evacuation prioritization, and resource allocation. Rather than relying on computationally intensive AI-based predictive models, the DSS emphasizes rule-based reasoning, threshold-driven alerts, and visual analytics, making it suitable for operational use in resource-constrained and time-critical disaster management settings.

D. Institutional Coordination and Operational Response

The institutional coordination component represents the operational use of DSS outputs by disaster management agencies, local authorities, and emergency services. This layer facilitates coordinated decision-making, inter-agency communication, and execution of response actions, such as evacuation orders and deployment of emergency resources. Clear information flow from the DSS to institutional actors helps reduce fragmentation and delays commonly observed in flood response operations.

E. Community Communication and Feedback Loop

The community communication and feedback component focuses on disseminating timely alerts and advisories to the public through multiple digital channels [8], including mobile alerts, SMS, messaging applications, and social media platforms. In addition to one-way alerting, this component enables two-way communication by incorporating citizen reports and community feedback. Such feedback is routed back to the integrated data platform, creating a continuous feedback loop that enhances situational awareness and supports adaptive response during flood events.

F. Implementation Considerations

Although the proposed framework is conceptual, several implementation considerations are important for practical deployment. Interoperability among government agencies may require standardized data exchange protocols and centralized coordination mechanisms to ensure consistent real-time information sharing. The framework is intentionally designed using lightweight and modular components to improve scalability and suitability for resource-constrained environments. In addition, cybersecurity and communication resilience remain critical during disaster events, particularly when relying on cloud-based platforms and mobile communication channels. Therefore, secure data handling, backup communication pathways, and redundancy mechanisms should be considered in future implementations to improve operational reliability during extreme flood scenarios.

VI. Limitations and Future Work

This study is limited by its conceptual nature, as the proposed framework is derived from secondary sources and comparative analysis rather than empirical system deployment. Quantitative performance evaluation and real-time validation were beyond the scope of this work, and institutional and socio-political factors were considered only at a high level.

Future work will focus on pilot implementation in flood-prone urban areas, such as the Colombo metropolitan region. Planned extensions include integrating real-time sensor data, incorporating lightweight analytics within the decision support system, and conducting user-centered evaluations with practitioners and community stakeholders. Empirical validation using historical flood events and scenario-based simulations will also be explored.

VII. Conclusion

This paper presented a technology-oriented comparative analysis of flood disaster management practices in Malaysia and Sri Lanka. By identifying transferable lessons and contextual limitations, a multi-layered adaptation framework was proposed for Sri Lanka. The framework emphasizes integrated data platforms, decision support systems, and community-aware communication. Future work will focus on pilot deployments and empirical evaluation of the framework in urban flood-prone regions.

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