The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLIX-M-1-2026
47th Canadian Symposium on Remote Sensing (CSRS), 4–11 July 2026, Toronto, Canada

Toward a Unified Geospatial Intelligence Framework Utilizing Edge Computing, IoT, and Multimodal Generative AI for Climate Risk Mitigation and Adaptive Evacuation Planning

Truong Thanh Hung Nguyen[1], Hung Cao[1]

[1] Analytics Everywhere Lab, University of New Brunswick, Fredericton, Canada
{hung.ntt, hcao3}@unb.ca

Keywords: Geospatial Intelligence, Edge Computing, IoT, Multimodal GenAI, Climate Risk Mitigation, Evacuation Planning.

Abstract

The increasing frequency and complexity of climate-induced hazards demand new approaches to disaster management that go beyond traditional, centralized, and static systems. This paper presents a vision for a **Unified Geospatial Intelligence Framework (UGIF)** that integrates Internet of Things (IoT) sensing, edge computing, and Multimodal Generative Artificial Intelligence (GenAI) into a cohesive and distributed architecture for climate risk mitigation and adaptive evacuation planning. The proposed framework connects heterogeneous data sources, including remote sensing, sensors, mobile telemetry, and citizen-generated inputs—across the IoT–edge–cloud continuum to enable real-time situational awareness and predictive intelligence. At its core, the framework leverages Multimodal GenAI models for hazard detection, forecasting, and scenario simulation, while supporting human-centered communication and multi-agency coordination. As a position paper, we articulate key design principles, system components, and future research directions, highlighting the potential of decentralized intelligence, participatory sensing, and uncertainty-aware decision-making. We further discuss the practicality, challenges, and alternative perspectives associated with deploying such systems at scale. This work aims to provide a conceptual foundation for next-generation geospatial intelligence systems that are adaptive, resilient, and capable of supporting proactive disaster response in an increasingly uncertain climate landscape.

1. Introduction

The intensification of climate change has led to a marked increase in the frequency, severity, and unpredictability of natural hazards, including floods, wildfires, earthquakes, heatwaves, and coastal storm surges. These events are no longer isolated or slow to evolve. Instead, they exhibit complex spatiotemporal dynamics, cascading effects across infrastructures, and significant uncertainty. As a result, traditional disaster management systems, largely designed for static risk assessment and centralized decision-making, are increasingly inadequate for modern emergency response requirements.

Conventional geospatial intelligence systems rely heavily on periodic satellite observations, centralized data processing, and predefined hazard models (Al Shafian and Hu, 2024, Rolla et al., 2025). While these approaches provide valuable macro-level insights, they lack the spatiotemporal resolution and responsiveness needed to capture rapidly evolving events such as flash floods or wildfire spread (Yan et al., 2025). Furthermore, centralized architectures are vulnerable to communication failures, which are common during disasters, leading to delayed or incomplete situational awareness.

Recent advancements in Internet of Things (IoT) technologies have enabled the deployment of dense environmental sensing networks capable of capturing high-frequency, localized measurements (Zeng et al., 2023). These sensors provide critical ground-truth data, including hydrological, atmospheric, and geotechnical parameters (Saputra et al., 2025). However, many existing IoT-based systems operate in silos, lacking integration with higher-level geospatial analytics and predictive modeling frameworks. Consequently, their potential to support real-time decision-making and coordinated emergency response remains underexploited. Moreover, current edge-enabled solutions are typically task-specific and do not fully integrate with broader geospatial intelligence systems or multi-agency coordination platforms. Another critical aspect of disaster management is evacuation planning, which requires dynamic adaptation to changing environmental conditions, infrastructure constraints, and human behavior (Behrooz and Ilbeigi, 2024, Ternero et al., 2024). Traditional evacuation models rely on static maps or precomputed routes, which may quickly become obsolete during rapidly evolving emergencies. Integrating real-time hazard data with adaptive routing and mobility intelligence remains an open challenge.

In parallel, the rapid development of artificial intelligence (AI), particularly Multimodal Generative AI (GenAI), has introduced new capabilities for environmental modeling, scenario simulation, and decision support (Wang et al., 2024). Generative geospatial models, diffusion-based simulators, and multimodal large language models (MLLMs) can synthesize heterogeneous data sources and provide predictive insights into hazard evolution (Areerob et al., 2025). Despite these advances, existing AI-driven approaches are often confined to cloud-based environments and lack seamless integration with real-time sensor networks and operational emergency systems.

To address these limitations, this paper proposes a **Unified Geospatial Intelligence Framework (UGIF)** that integrates IoT sensing, edge computing, geospatial intelligence, and Multimodal GenAI into a cohesive, distributed architecture. The framework is designed to support real-time hazard detection, predictive modeling, adaptive evacuation planning, and coordinated emergency response. By extending the Intelligence Everywhere paradigm (Cao et al., 2023, Cao et al., 2019), the proposed system distributes intelligence across the IoT–edge–cloud continuum, enabling both localized autonomy and global coordination. By embedding intelligence throughout the sensing and processing stack, it enables agile, context-aware, and resilient emergency response. The archi-

This contribution has been peer-reviewed.
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tecture integrates satellite imagery, Unmanned Aerial Vehicle (UAV) observations, LiDAR (Light Detection and Ranging) data, mobile telemetry, vehicular Global Positioning System (GPS) traces, and high-frequency readings from distributed IoT sensors monitoring hydrological, atmospheric, and geotechnical conditions. Edge nodes positioned near sensor clusters or embedded in mobile platforms perform local processing to reduce latency, sustain functionality during network disruptions, and support immediate hazard detection. At its core, the system employs Multimodal GenAI models, including generative geospatial models, MLLMs, time series predictors, and diffusion-based simulation engines. It also incorporates a smart mobility subsystem for adaptive evacuation, a mobile safety application, and a central emergency management platform for coordinated multi-agency operations. This paper outlines the conceptual foundations, technical components, and operational interactions of this unified architecture with summarized contributions as follows:

- We present a vision for a Unified Geospatial Intelligence Framework (UGIF) that integrates IoT sensing, edge computing, and Multimodal GenAI into a distributed, adaptive system for climate risk mitigation and disaster response.
- We conceptualize an end-to-end, multimodal architecture that connects real-time sensing, predictive modeling, participatory human inputs, and coordinated emergency management, enabling continuous feedback between data, intelligence, and action.
- We outline future visions, practical considerations, system-level challenges, and alternative views, highlighting the roles of decentralized intelligence, uncertainty-aware decision-making, and human-centered design in building resilient, scalable disaster management systems.

2. Related Works

2.1 Multi-hazard Early Warning with Geospatial Decision Support

The development of multi-hazard early warning systems has become a central objective in global disaster risk reduction strategies. Frameworks such as the United Nations Office for Disaster Risk Reduction (UNDRR) and the World Meteorological Organization (WMO) Target G reporting emphasize MHEWS as a key measurable capability under the Sendai Framework (Rokhideh et al., 2025). These systems aim to provide timely, accurate, and actionable information across multiple hazard types, including hydrological, meteorological, and geological events.

Recent research in hazard management has moved beyond static risk assessment toward dynamic, data-driven approaches that integrate real-time observations with predictive modeling. Emerging paradigms, such as digital twins of urban and environmental systems, attempt to simulate hazard evolution and infrastructure response in near real time (Ghaffarian, 2025, Ge and Qin, 2025). Despite these advancements, existing early warning systems are often fragmented. Many systems remain siloed by hazard type, such as flood, wildfire, or seismic monitoring, and are typically managed by separate agencies with limited data sharing. Furthermore, they frequently lack a unified data model capable of integrating heterogeneous data sources, including real-time IoT sensor streams, remote sensing imagery, and mobility telemetry. This fragmentation limits their ability to provide comprehensive, real-time situational awareness and coordinated response capabilities (Gowda et al., 2024).

2.2 Evacuation Planning and Dynamic Routing under Hazard Uncertainty

Evacuation planning is another critical component of disaster response, requiring the coordination of infrastructure, human behavior, and evolving hazard conditions. Traditional approaches have relied on static evacuation plans and pre-computed routes, which are often insufficient in dynamic and uncertain environments.

Recent research has explored more adaptive approaches, including agent-based modeling (Takabatake et al., 2025) and dynamic routing techniques (Darvishan and Lim, 2021). Agent-based simulations enable the modeling of individual and collective behaviors during evacuations, providing insights into congestion patterns and system-level dynamics (Moradi et al., 2025). Systematic reviews highlight both the potential of these models and the challenges associated with their validation and calibration, particularly in real-world scenarios.

2.3 IoT Sensing, Edge Computing, and Resilient Analytics

Advances in IoT have enabled distributed sensing networks capable of high-fidelity environmental monitoring (Nguyen et al., 2025), yet many deployments remain isolated and lack unified predictive analytics (Nguyen et al., 2024a). Edge computing has improved resilience and reduced latency by processing data near sensor nodes, though integration with geospatial intelligence and emergency coordination remains limited (Das et al., 2021, Nguyen et al., 2024b). Progress in geospatial AI and remote sensing includes generative environmental models, LLM-based spatial reasoning, and diffusion models for hazard simulation. Evacuation research has yielded agent-based models, traffic flow analytics, and dynamic routing approaches (Zhang et al., 2024).

The primary motivations for edge computing include reducing latency, conserving bandwidth, and enhancing privacy (Shuiquan et al., 2025). Complementing this, the concept of fog computing extends computational capabilities into the network layer, enabling distributed analytics across heterogeneous environments. Standardization efforts such as Multi-access Edge Computing (MEC) further support this paradigm by promoting open, interoperable platforms for deploying applications at the network edge.

2.4 Multimodal GenAI for Geospatial Intelligence

Recent advances in AI have significantly enhanced the capabilities of geospatial data analysis. In particular, the emergence of geospatial foundation models has improved generalization across a wide range of Earth observation tasks (Vatsavai, 2024). Transformer-based architectures pretrained on large-scale multispectral imagery can be effectively fine-tuned for applications including flood mapping and wildfire damage assessment. Similarly, masked autoencoding is also used to learn robust representations from temporal and multispectral satellite data (Cong et al., 2022).

Beyond representation learning, the field is increasingly adopting generative modeling techniques for forecasting and scenario

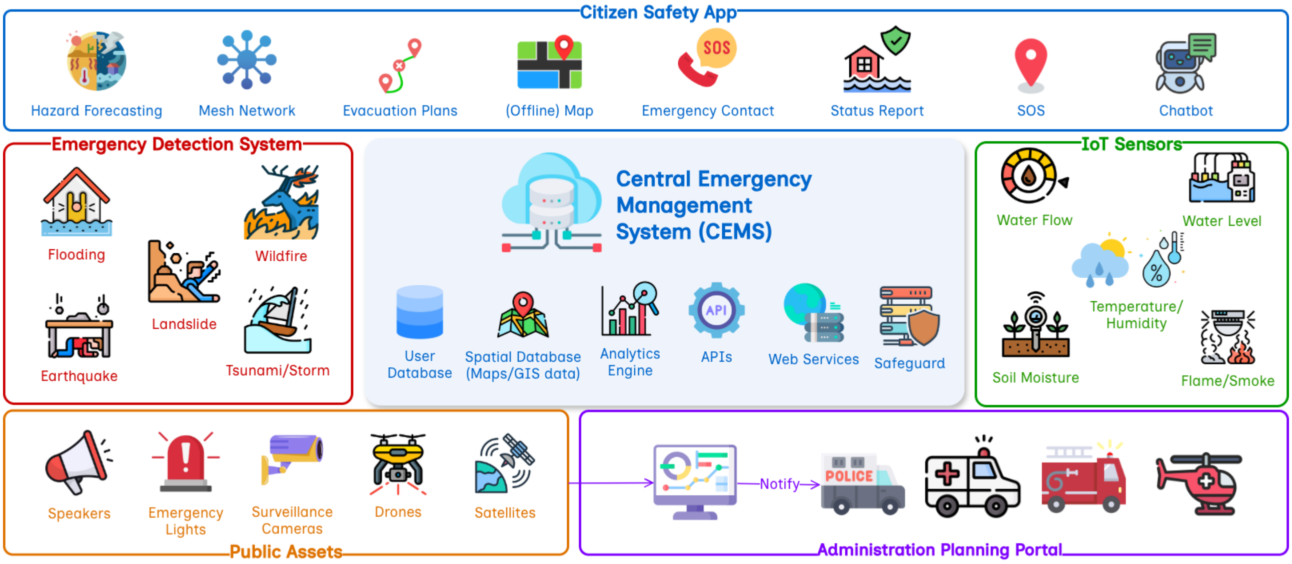

Figure 1. The Unified Geospatial Intelligence Framework (UGIF) Architecture.

simulation (Xiao et al., 2025). Diffusion-based models have been applied to spatiotemporal forecasting (Rühling Cachay et al., 2023), while generative models demonstrate potential in global medium-range weather prediction. In addition, deep generative models have shown substantial improvements in short-term forecasting tasks, such as precipitation nowcasting, offering more accurate and timely predictions (Ravuri et al., 2021, Wang et al., 2023).

Hence, our work advances towards a unified geospatial intelligence by integrating IoT sensing, edge inference, Multimodal GenAI, geospatial intelligence, adaptive evacuation routing, and coordinated emergency management into a single distributed architecture that supports pervasive intelligence, operational robustness, and multi-layered situational awareness.

3. Unified Geospatial Intelligence Framework (UGIF)

The proposed UGIF is designed as a distributed, multi-layered system that integrates sensing, computation, intelligence, and coordination across the IoT–edge–cloud continuum. Our framework establishes continuous feedback loops between data acquisition, predictive modeling, and operational response. A key design principle of the framework is distributed intelligence, where critical analytics are performed at multiple levels of the system. Edge nodes provide rapid, localized inference, while cloud-level systems enable large-scale data fusion and long-term forecasting. This hierarchical approach ensures robustness under network disruptions while maintaining global situational awareness. These components interact through standardized data pipelines and communication protocols, forming an integrated architecture that supports both localized autonomy and centralized coordination.

Figure 1 illustrates our proposed framework. Our UGIF framework consists of six modules: (i) the Central Emergency Management System, (ii) the Emergency Detection System, (iii) IoT Sensors and Edge Intelligence, (iv) the Citizen Safety Application, (v) Public Assets, and (vi) the Administration Planning Portal.

3.1 Central Emergency Management System (CEMS)

The Central Emergency Management System (CEMS) serves as the core intelligence and coordination hub of the framework, aggregating heterogeneous data sources, maintaining a unified geospatial representation of the environment, and supporting high-level decision-making, as shown in Figure 2.

CEMS integrates multiple data modalities, including static GIS layers, real-time IoT sensor streams, satellite imagery, UAV observations, infrastructure data, and user-generated inputs. These data are organized within a spatially indexed data infrastructure, enabling efficient querying and real-time updates. The system supports both streaming and batch data pipelines, allowing it to handle high-frequency sensor inputs alongside large-scale geospatial datasets.

CEMS incorporates Multimodal GenAI models, which include geospatial foundation models for feature extraction, time-series forecasting models for predicting hazard evolution, and diffusion-based models for scenario simulation. Together, these models enable the system to generate probabilistic forecasts, simulate alternative hazard trajectories, and quantify prediction uncertainty.

In addition, CEMS integrates MLLMs to provide natural language interfaces for decision-makers. This allows emergency operators to query the system, interpret complex outputs, and generate human-readable reports. Workflow orchestration mechanisms and APIs enable seamless communication with external agencies, ensuring coordinated response across different operational units.

3.2 Emergency Detection System

The Emergency Detection System is responsible for the early identification and continuous monitoring of hazards. It operates on multimodal data streams, combining observations from remote sensing platforms, in-situ sensors, and participatory inputs.

Several specialized deep learning models are employed to detect patterns associated with different types of hazards. Convolutional and transformer-based models process satellite and

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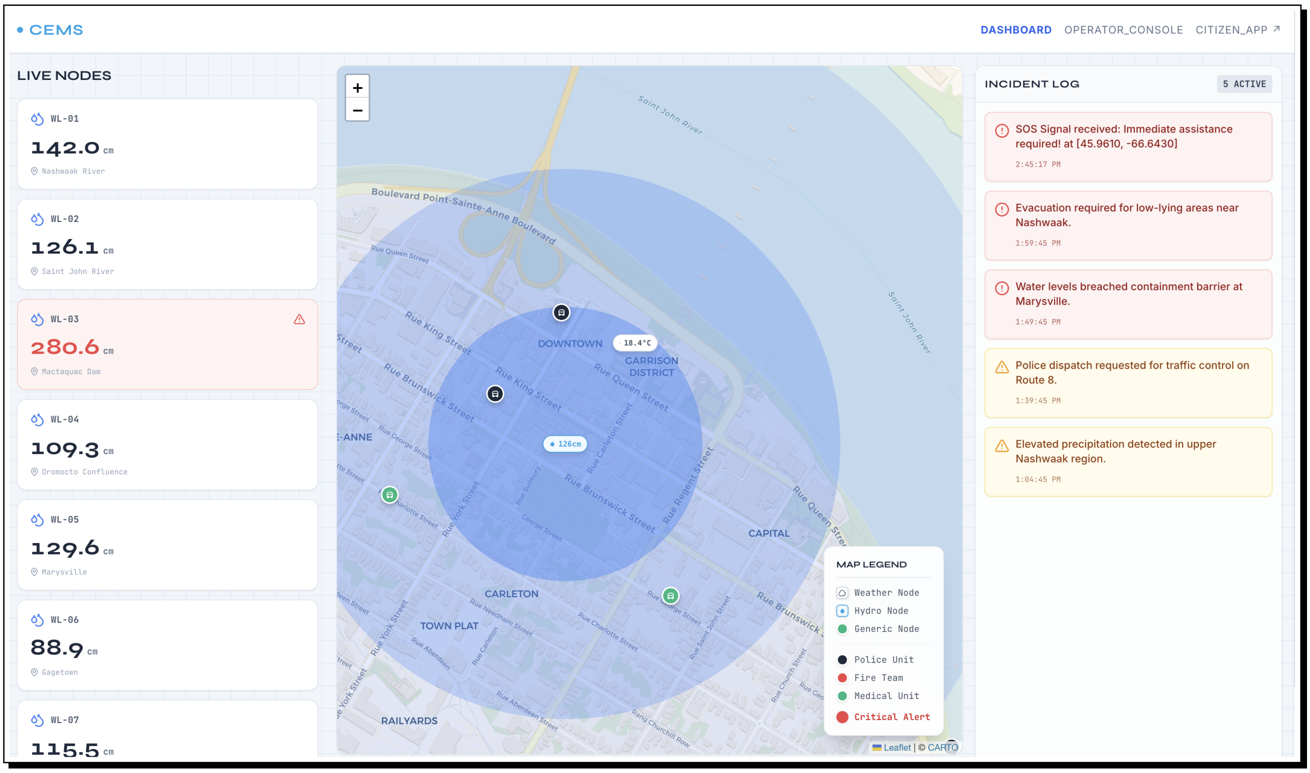


Figure 2. Administration Planning Portal Interface in Central Emergency Management System (CEMS).

UAV imagery to identify flood extents, wildfire boundaries, and infrastructure damage. Time-series models analyze sensor data to detect anomalies, such as sudden water-level rises or seismic activity. These models are designed to operate across both edge and cloud environments, ensuring timely detection even in scenarios with limited connectivity.

The system continuously updates hazard maps and generates alerts that are propagated to CEMS and downstream modules. Importantly, detection is not treated as a one-time event but as an ongoing process, with models continuously refining their outputs as new data becomes available. This enables the system to capture the dynamic evolution of hazards and provide up-to-date situational awareness.

3.3 IoT Sensors

IoT sensors form the primary data acquisition layer of the proposed framework, enabling continuous, high-resolution monitoring of both environmental processes and critical infrastructure states. The sensing layer is composed of heterogeneous field devices selected according to the hazard context. For hydrological monitoring, the framework can integrate ultrasonic and radar water-level sensors, pressure transducers, and acoustic Doppler flow meters to measure river stage, discharge, and flow velocity. For meteorological observations, compact weather stations equipped with temperature, relative humidity, barometric pressure, rainfall, and wind sensors provide localized atmospheric measurements. Soil-related conditions are captured using capacitive and time-domain reflectometry (TDR) soil-moisture probes, pore-water pressure sensors, and ground temperature sensors, which are particularly relevant for landslide and drought monitoring. In urban and industrial environments, air-quality nodes include electrochemical and optical sensors for CO_2, NO_2, $PM_{2.5}$, and other pollutants. Structural health monitoring is supported through MEMS accelerometers, strain gauges, tiltmeters, crack-width sensors, and vibration sensors installed on bridges, buildings, dams, and transportation assets.

Each sensor node consists of a sensing element, a low-power microcontroller or embedded processor, a communication module, and an energy subsystem. Hardware platforms include ESP32-based microcontroller units for lightweight sensing tasks, while more capable embedded boards such as Raspberry Pi, NVIDIA Jetson Nano, or industrial edge gateways are used for local analytics. Depending on the deployment scenario, communication can be established through LoRaWAN, LTE/5G, Wi-Fi, and satellite uplinks. Low-power wide-area technologies such as LoRaWAN are particularly suitable for geographically distributed hazard monitoring because they provide long-range connectivity with reduced energy consumption, whereas Wi-Fi and 5G are better suited for high-bandwidth applications such as image transmission or dense urban sensing.

To address latency, bandwidth, and reliability constraints, the framework incorporates edge computing units colocated with sensor clusters or gateway nodes. These edge devices perform on-site preprocessing operations such as signal denoising, temporal smoothing, calibration correction, missing-data imputation, feature extraction, and data aggregation. For example, raw water-level signals can be filtered to remove noise caused by turbulence, and accelerometer streams can be transformed into spectral features for vibration-based structural anomaly assessment. Lightweight machine learning models or compressed neural networks are deployed at the edge for rapid event detection and classification. This allows the system to identify anomalies such as sudden river-stage rise, abnormal bridge vibration, smoke concentration spikes, or slope instability indicators without continuously transmitting full raw data streams to centralized servers.

Edge intelligence also improves operational resilience under degraded network conditions. During communication outages, edge nodes continue to execute local inference, trigger threshold-based alarms, buffer time-stamped observations, and support decentralized decision-making for nearby emergency units. This is particularly important in disaster scenarios where backhaul connectivity may be intermittent or completely unavailable. Once communication links are restored, the buffered observations, inferred events, and system logs are synchronized with the central CEMS, ensuring consistency between local and global situational awareness layers.

To support geospatial fusion, every sensor observation is associated with spatial metadata, including geographic coordinates, elevation, sensor orientation, deployment context, and timestamp. GNSS modules and surveyed fixed coordinates are used for geolocation, while spatial indexing methods such as geohashing, R-trees, and grid-based tiling enable efficient storage and retrieval within geospatial databases. This georeferenced sensor stream can then be integrated with satellite imagery, UAV observations, digital elevation models, land-use maps, transportation networks, and hazard zonation layers. Such multimodal fusion enables fine-grained spatial analysis, improves the calibration of predictive models, and supports near-real-time mapping of hazard evolution and infrastructure exposure.

3.4 Citizen Safety Application

The Citizen Safety Application provides a direct interface between the framework and the public, enabling two-way communication and participatory sensing, as shown in Figure 3. It is designed to deliver timely information while also collecting valuable situational data from users.

The application offers features such as real-time hazard alerts, evacuation guidance, offline maps, and emergency communication tools. Mesh networking capabilities allow devices to communicate directly with each other, ensuring connectivity even when traditional communication infrastructure is compromised.

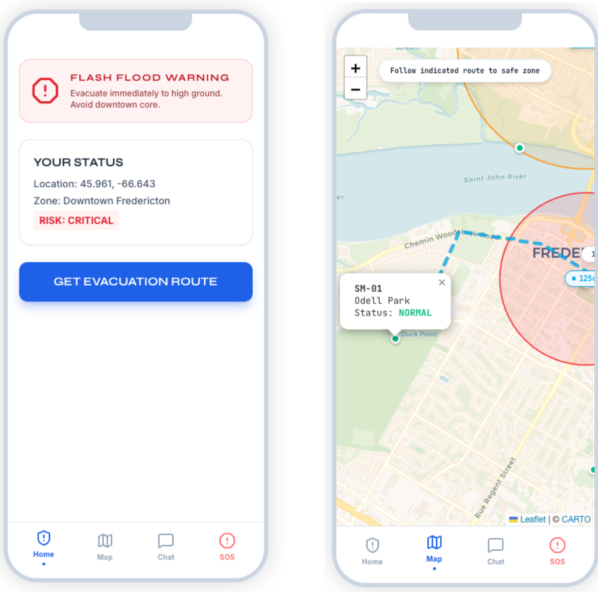
Beyond information dissemination, the application functions as a distributed sensing node. Users can report observations, share location data, and provide status updates, thereby contributing to richer, more comprehensive situational awareness. This human-in-the-loop approach enhances the system's ability to capture on-the-ground conditions that may not be fully observable through sensors or remote sensing.

The integration of AI-powered chat interfaces further supports user interaction, enabling personalized guidance and contextual decision support during emergencies.

3.5 Public Assets

Public assets, including drones, surveillance systems, and emergency communication devices, provide critical support for field-level operations. These assets act as both sensing and actuation components within the framework.

UAVs are deployed to capture high-resolution imagery for tasks such as flood mapping, wildfire monitoring, and infrastructure inspection. Surveillance cameras and environmental monitoring stations provide continuous data streams that complement other sensing modalities. Public communication systems, such as speakers and digital signage, are used to disseminate alerts and instructions to affected populations.



(a) Hazard Alert and Status (b) Evacuation Map

Figure 3. Citizen Safety Application Interface for Real-Time Hazard Awareness and Adaptive Evacuation.

These assets are dynamically coordinated through CEMS, enabling adaptive deployment in response to evolving conditions. For example, drones can be redirected to areas of interest identified by predictive models, while communication systems can be updated with real-time evacuation instructions.

3.6 Administration Planning Portal

The Administration Planning Portal serves as the primary interface for emergency managers and decision-makers. It provides a comprehensive operational view of the system, integrating real-time data, predictive analytics, and communication tools.

The portal includes interactive dashboards that display hazard maps, sensor data, and system alerts. Decision-makers can use these tools to monitor incident progression, allocate resources, and coordinate response efforts across multiple agencies. Scenario simulation capabilities allow operators to explore potential outcomes and evaluate different response strategies.

The portal also supports workflow management, enabling coordination of tasks such as issuing evacuation orders, deploying resources, and inter-agency communication. By providing a unified operational picture, the portal enhances situational awareness and supports informed decision-making under uncertainty.

4. Future Vision, Practicality and Alternative Views

4.1 Vision 1: Real-Time Geospatial Digital Twins for Predictive Disaster Management

A central vision of this work is the *emergence of real-time geospatial digital twins that continuously replicate and simulate the physical world*. By integrating streaming data from IoT sensors, satellite imagery, UAV observations, and citizen inputs, these digital twins can maintain a live representation of environmental and infrastructural states. When combined with

Multimodal GenAI, such systems can generate multiple plausible future scenarios, enabling authorities to anticipate hazard evolution and proactively plan interventions rather than react after events unfold.

Practicality. Advances in cloud computing, geospatial data platforms, and AI modeling make this vision increasingly feasible. Existing efforts in smart cities and environmental monitoring already demonstrate partial implementations of digital twins. The integration of foundation models and scalable data infrastructures suggests that real-time simulation at regional scales is within reach in the near future.

Alternative Views and Challenges. However, achieving fully operational digital twins at scale remains challenging. Continuous data integration from heterogeneous sources requires robust standardization and synchronization mechanisms (Ranatunga et al., 2024). The computational demands of real-time simulation and scenario generation are substantial, particularly when uncertainty is incorporated. Moreover, the assumption of complete and accurate data may not hold in disaster contexts, where sensor failures and data gaps are common (Ghaffarian, 2025). An alternative perspective suggests that simplified or domain-specific "partial twins" may be more practical than fully unified, high-fidelity replicas.

4.2 Vision 2: Decentralized and Autonomous Edge Intelligence for Disaster Response

Another key vision is the *transition toward decentralized, edge-driven intelligence, where decision-making capabilities are distributed across the network rather than concentrated in centralized systems*. In this paradigm, edge nodes embedded within IoT infrastructures, mobile devices, and public assets can perform real-time analysis and initiate localized actions. For instance, edge systems could autonomously detect hazards, trigger alerts, or adjust traffic signals to facilitate evacuation without requiring cloud connectivity.

Practicality. This vision is supported by rapid advancements in edge computing, lightweight AI models, and standardized platforms such as MEC. In many cases, edge deployment is already feasible for tasks such as anomaly detection and localized prediction. The ability to operate under network disruptions makes this approach particularly valuable in disaster scenarios.

Alternative Views and Challenges. Despite its advantages, decentralized intelligence introduces new complexities. Ensuring consistency and coordination across distributed nodes is non-trivial, especially when decisions must be aligned across jurisdictions and agencies. There are also challenges related to resource constraints, as edge devices have limited computational capacity compared to cloud systems (Bhaskaran and Muthuraman, 2025). An alternative view argues for hybrid architectures, where critical decisions remain centralized while edge systems provide support, rather than fully autonomous operation.

4.3 Vision 3: Human-Centered Participatory Intelligence Ecosystems

The framework also envisions *a human-centered, participatory intelligence ecosystem in which citizens actively contribute to situational awareness and decision-making*. Through mobile applications, wearable devices, and social sensing platforms, individuals can provide real-time observations, validate system outputs, and receive personalized guidance. This transforms citizens from passive recipients of information into active participants in disaster management.

Practicality. The widespread adoption of smartphones and mobile connectivity provides a strong foundation for participatory sensing. Existing applications already support crowdsourced data collection and emergency communication (Erokhin and Komendantova, 2024, Kangana et al., 2024). Integrating these capabilities with AI-driven systems can significantly enhance data richness and responsiveness.

Alternative Views and Challenges. However, this vision raises important concerns regarding privacy, data reliability, and inclusivity (Sezaki et al., 2016). Additionally, not all populations have equal access to digital technologies, potentially leading to uneven participation and benefits (Kangana et al., 2024). Some alternative approaches emphasize the continued importance of institutional data sources and expert-driven analysis, suggesting that participatory systems should complement rather than replace traditional methods.

4.4 Vision 4: Adaptive and Uncertainty-Aware Evacuation Intelligence

A further vision is the *development of adaptive evacuation systems that dynamically respond to evolving hazards using real-time data and predictive modeling*. By integrating multimodal sensing with AI-driven forecasting, these systems can continuously update evacuation routes, optimize traffic flows, and provide personalized guidance to individuals. Importantly, they incorporate uncertainty-aware predictions, enabling decision-makers to evaluate multiple possible scenarios and select robust strategies.

Practicality. Advances in data-driven routing, reinforcement learning, and real-time traffic analytics make adaptive evacuation increasingly achievable. Integration with navigation systems and mobile applications allows for direct dissemination of updated routes to users. Simulation tools and digital infrastructure further support scenario-based planning.

Alternative Views and Challenges. Nevertheless, the effectiveness of such systems depends on reliable data availability and user compliance. Rapidly changing conditions, infrastructure damage, and communication disruptions can limit the accuracy of routing recommendations (Lessan and Kim, 2022). Additionally, uncertainty in hazard predictions complicates decision-making, as overly conservative or aggressive strategies may have unintended consequences (Aldahlawi et al., 2024). Some perspectives advocate for simpler, rule-based evacuation strategies that are easier to implement and communicate, particularly in high-stress situations.

4.5 Vision 5: Toward a Unified and Interoperable Geospatial Intelligence Ecosystem

Ultimately, the overarching vision is to realize a *fully unified and interoperable geospatial intelligence ecosystem that seamlessly integrates sensing, analytics, and decision-making across multiple domains and stakeholders*. Such a system would enable continuous data exchange between agencies, standardized workflows, and coordinated responses at local, regional, and global scales.

Practicality. Efforts toward standardization, open data platforms, and interoperable APIs provide a pathway toward this vision. Increasing collaboration between academia, industry, and government agencies further supports the development of integrated systems.

Alternative Views and Challenges. However, achieving full unification may not always be practical or desirable. Organizational, political, and regulatory barriers can hinder data sharing and system integration (Gelagay, 2017, Schröter et al., 2025). In some cases, modular or loosely coupled systems may offer greater flexibility and adaptability. Additionally, governance issues, including data ownership and accountability, must be carefully addressed to ensure trust and sustainability.

5. Conclusion and Future Works

This paper presents the Unified Geospatial Intelligence Framework (UGIF), which integrates IoT sensing, edge computing, Multimodal GenAI, and geospatial intelligence into a cohesive, distributed architecture for climate risk mitigation and adaptive evacuation planning. By enabling continuous feedback between sensing, prediction, and action across the IoT–edge–cloud continuum, the framework shifts disaster management from reactive, centralized approaches to proactive, adaptive, and resilient systems. While the proposed vision highlights the potential of multimodal data fusion, decentralized intelligence, and human-centered participation, its realization requires addressing key challenges, including scalability, interoperability, uncertainty, and ethical considerations. Future work will focus on developing practical implementations, standardizing data and system integration, advancing lightweight, uncertainty-aware AI models, and validating the framework in real-world scenarios, ultimately contributing to the development of robust, inclusive geospatial intelligence systems for next-generation disaster response.

Acknowledgement

This work has been supported by NSERC Discovery Grant No RGPIN-2025-04478.

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