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Geospatial Information Integration for Comprehensive Disaster Management: GIIADM-i

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Abstract:

Disasters, unforeseen occurrences causing abrupt disruptions in normal life and resulting in significant human, material, economic, and environmental losses, can sometimes surpass a community's capacity to manage using its own resources. Safeguarding lives and resources becomes a critical necessity, requiring effective organization and utilization of available resources as a core aspect of disaster management. Disaster Management aims to efficiently organize and employ available resources sustainably to minimize risks and losses within society.

Comprehensive planning strategies need to be developed, encompassing a complete understanding of the disaster management life cycle and its interconnected components. By thoroughly evaluating challenges and opportunities across the four functional phases of the disaster management life cycle—mitigation, preparedness, response, and recovery—a holistic Disaster Management planning strategy can be devised. Each phase of the disaster management life cycle demands accurate, pertinent locational and temporal data to identify problem areas, comprehend vulnerabilities, analyse potential risk reductions, and identify gaps in implementation. Coordinated implementation of Disaster Management Strategies, with public participation in policy execution, is essential. Informed coordination at every phase of the

disaster management life cycle enhances efficiency and minimizes gaps between policy formulation and implementation

Geographic Information System (GIS) can play a pivotal role in establishing a well-coordinated disaster management system by ensuring updated data flow, real-time data analysis, and dissemination of information to decision-makers and the public for prompt responses. Geospatial Information Infrastructure (GII) acts as a structured mechanism for effective geospatial data access. GII defines an Access Network, data policies, and standards to connect individuals with data. It establishes a system architecture that links components like Infoware (information), Orgaware (organizational/institutional framework), Technoware (Technology), and Humanware (Human). The success of any management system hinges on the reliability, availability, interoperability, and accuracy of data and information. In the context of a Disaster Management system, GIS holds immense potential as a system integrator, connecting all components across different functional phases of its life cycle. In a country like India, with a vast population, a stable, adaptable, and comprehensive system could significantly contribute to reducing losses during disaster events.

'GII Assisted Disaster Management Interface (GIIADM-i)' is a proposed solution, allowing various users to generate, share, access, and utilize geographic information in disaster management. It sets technical standards, institutional structures, and financial allocations for geospatial data sharing and integration, benefiting diverse stakeholders. GIIADM-i is envisioned as a system integrator intended to deliver diverse information across multiple levels to various audiences involved in disaster management.

Keywords: Disaster management, Disaster prevention measures, Spatial planning, Location Intelligence, Geospatial technology, Community participation, Public Information System

Introduction

A disaster is a naturally occurring or human-induced disruption that disturbs the prevailing equilibrium. The United Nations International Strategy for Disaster Reduction (UNISDR) offers a comprehensive definition, describing it as "A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources." (NDMP, 2016, p7). In the context of India, the Disaster Management Act of 2005 defines a disaster as " a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or manmade causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property, or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area."

Disaster Management envelops purposeful human intervention designed to address disasters through comprehensive planning, coordination, and implementation. This approach integrates various strategies aimed at minimizing resource losses, encompassing prevention and mitigation, well-coordinated preparedness, integrated response, and swift recovery. The Sendai Framework for Disaster Risk Reduction 2015-2030, adopted by UN Member States during the Third UN World Conference on Disaster Risk Reduction in Sendai, Japan, provides global guidance for reducing disaster risks and minimizing losses in lives, livelihoods, and health worldwide. The Sendai Framework prioritizes four key areas: understanding disaster risk, strengthening disaster risk governance, investing in disaster risk reduction for resilience, and enhancing disaster preparedness to "Build Back Better (BBB)" in recovery, rehabilitation, and reconstruction. Strengthening governance to manage risk is closely tied to investing in disaster risk reduction through both structural and non-structural measures to enhance resilience. India formulated the National Disaster Management Plan (NDMP, 2016) in pursuance of the Sendai Framework with five thematic areas for action – Understanding risk, Inter-agency coordination, investing in DRR –Structural Measures, investing in DRR Non–Structural Measures, Capacity Development

Structural measures involve constructing disaster-resilient structures such as dams, reservoirs, embankments, and channel improvements. On the other hand, non-structural measures focus on

developing an integrated system that connects different stakeholders to act in a coordinated manner.

Disaster Risk Reduction (DRR) has emerged as a crucial humanitarian action-based approach aimed at mitigating the severity of disasters. As defined by Kemp (2008), DRR efforts involve the engagement of local communities to explore risk factors and implement methods, practices, and cultural changes that reduce the probability of natural hazards resulting in severe disasters.

Technology has provided advanced tools for data collection, analysis, and communication, enhancing the efficiency and effectiveness of disaster risk reduction and response efforts. Satellite imagery, geographic information systems (GIS), and real-time communication platforms have empowered disaster management authorities to make informed decisions promptly. Moreover,Crowdsourced Geographical Information (CGI) fromsocial media and mobile applications plays a vital role in disseminating timely information and mobilizing communities during emergencies.

In parallel, the inclusion of community-based participation ensures that local knowledge, cultural insights, and on-the-ground experiences are integrated into disaster management plans.Involving the local communities in the planning and decision-making processes not only enhances the relevance of strategies but also promotes community resilience.The combination of technology-driven solutions, and community-based participation creates a dynamic and effective framework for Disaster Management.

2. Literature Review

2.1 GIS for Disaster Management

The popularization of Geographic Information Systems (GIS) marked a significant paradigm shift in Geography, as highlighted by Goodchild (1988). Defined as integrated computer systems

for spatially referenced data, GIS owes its origins to the development of the Canada Geographic Information System in the early 1960s.

In the realm of Disaster Management, Tomlinson (1988) positions GIS as a crucial 'tool,' emphasizing its capacity to store, analyze, and visualize geographic data. This fundamental concept set the stage for further exploration of spatial data handling and analysis, paving the way for GIS applications in disaster risk assessment, emergency response planning, vulnerability mapping, and the integration of diverse datasets.

Building on this, Wright et al. (1997) define 'GISci' as concerned with the geographic concepts used to describe, analyze, model, reason about, and make decisions on phenomena distributed on the earth's surface.

Harish Karnatak (2012) further delve into the critical role of GIS in various phases of disaster management, including preparedness, response, and recovery. They stress GIS's comprehensive framework for handling spatial and non-spatial data throughout the disaster life cycle. Miller, Engemann & Yager (2006) highlight GIS as an enabler in disaster management, emphasizing its effective role in formulating plans by ensuring adequate information and establishing communication links.

Lynn Usery et al (2009) emphasizes the versatile role of GIS in disaster scenarios as an integrator and analyst, offering effective visualizations critical for decision-making. Discussing its implementation in emergency management, Usery underscores GIS's role in situational awareness, resource allocation, and coordination among response agencies during disasters, highlighting its importance in real-time data collection, mapping affected areas, identifying vulnerable populations, and optimizing response efforts. Collectively, these perspectives underscore GIS as an indispensable tool in enhancing disaster management strategies and outcomes.

2.2 Community-Based Disaster Risk Management

Disaster Risk Reduction is recognized as a comprehensive framework aimed at safeguarding communities by actively involving them in reducing disaster risk. Efficient management assumes a pivotal role within the Community-Based Disaster Risk Management (CBDRM) framework, binding grassroots populations into the system to ensure transparent and good governance. This approach addresses management issues, such as delays, insufficient public data, ambiguous technical guidelines, material scarcity, and dispersed operational zones, which can impede progress. The backing of the community hinges on accessible data, sharing standards, understanding rights, and aid availability. Zubir and Amiroll (2011) emphasize the need for the effective role of Volunteer Involving Organizations (VIO) at different administrative levels in Malaysia, illustrating that a well-defined regulatory structure in the government encourages expressions of volunteerism and norms of social reciprocity during natural disasters.

The scope of utilizing Geographic Information Systems (GIS) in CBDRM has been widely advocated by researchers, practitioners, and organizations involved in disaster risk reduction and management. Scholars in the field of disaster studies, disaster management experts, humanitarian organizations, and entities like the United Nations Office for Disaster Risk Reduction (UNDRR) have highlighted the significance of GIS in CBDRM initiatives.

The concept of Participatory Disaster Risk Assessment (PDRA) (Pelling, 2007) promotes a 'bottom-up' knowledge-based approach, emphasizing community involvement in various stages of the assessment process. Randall B. Kemp (2008) builds upon this concept with the design of Public Participatory GIS (PPGIS), incorporating ICT support to involve the public in data collection and organization. This empowers local communities to assess their natural hazard proclivities. Public Participatory GIS (PPGIS) stands as an exemplary method within the framework of 'GISci' to implement community-based disaster risk reduction.

The necessity of integrating Geographic Information Systems (GIS) with local-level indigenous knowledge is discussed to leverage existing human and technical resources, fostering robust partnerships between Vietnamese local communities and both local and national institutions (Phong Tran et al., 2009).

Capineri et al. (2016) advocate for Crowdsourced Geographic Information (CGI) in disaster management, citing its immense potential showcased during the earthquake in Haiti in 2010. CGI, sourced from social media, crowd sensing, and collaborative mapping, improves 'situation awareness' and 'monitors unfolded events,' providing first-hand information as an alternative source to conventional information for disaster management agencies.

2.3 Disaster Management in India

In India, the robust institutional setup for Disaster Management includes organizations such as the National Disaster Management Authority (NDMA) with state, district and local level authorities established to implement the Disaster Management Plan of 2005 down to the grassroots level. The National Institute of Disaster Management (NIDM) is a premier institute for training and capacity development programs for managing natural disasters in India, on a national as well as regional basis. The nation has adopted a multifaceted approach, incorporating both structural and non-structural measures to enhance its disaster resilience.

Structural measures involve the development of disaster-resilient infrastructures, cyclone shelters, river embankments, and retrofitting vulnerable buildings to withstand earthquakes. These initiatives aim to fortify the country's physical foundations against various natural calamities.

Non-structural measures have been equally emphasized, with a focus on leveraging powerful early warning systems and flood monitoring systems developed at different administrative levels. These systems enhance the nation's capacity to anticipate and respond effectively to impending disasters.

Recognizing the community as the first respondent, the Community-Based Disaster Management (CBDM) program ensures that urgent or emergencies are dealt with promptly and in a well-prepared manner at the community level. This proactive approach at the grassroots level ensures mitigating the potential escalation of such situations into full-blown disasters.

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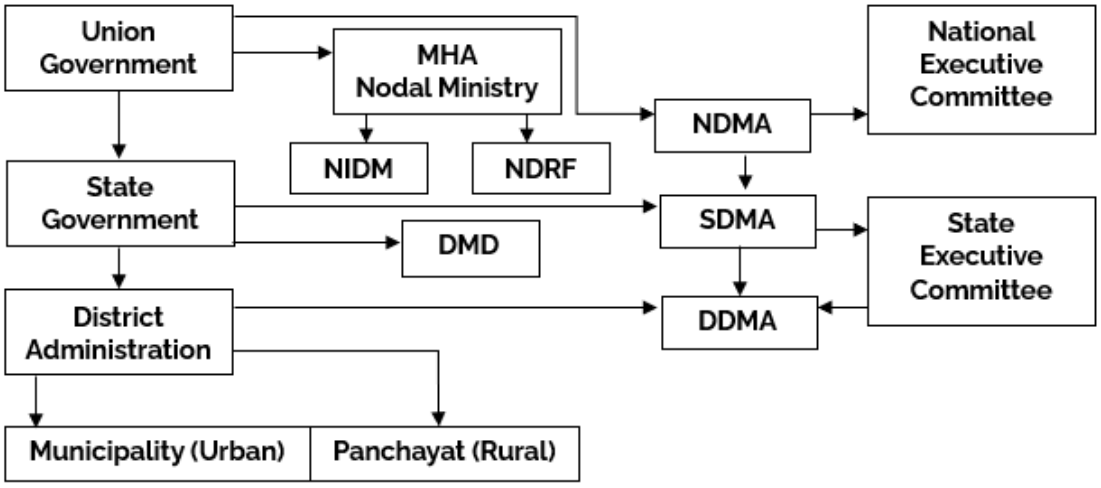

Figure 1: Legal –Institutional Framework of DM Act 2005

3. Objectives

1. Transform Disaster Management into a responsive and well-informed system integrating data and technology
2. Enhance Disaster Management inclusivity by actively involving the local community in the decision-making process
3. Establish effective integration of all stakeholders through a unified information system, streamlining communication via a single window.

4. Methodology

The Geographical Information Infrastructure-based Prototype Application, known as 'GII Assisted Disaster Management Interface (GIIADM-i)', aims to emulate a comprehensive framework. It connects stakeholders and their interlinked operations, designed to address diverse phases of disaster management. This prototype application utilizes Census 2011 data for demographics and referenced Hazard Zonation Maps of Odisha State Disaster Management Authority (OSDMA), as publicly available. These maps were used as sample maps to visualise

the risk scenario and not true to scale. The geospatial layers in this application contain simulated disaster locations, facility points, and shelter locations, serving as sample data. Administrative details such as State and District Boundaries are incorporated using OpenStreetMap Base Layers. GIIADM-i serves as a demonstration platform, showcasing the functionalities and connections among different disaster management components within a unified interface.

4.1GIIADM-i:ADisaster Management System solution powered by support of Geospatial Technology

Technology serves as the linchpin in coordinating disaster management systems by integrating data, enabling communication, and aiding in predictive analysis. It consolidates information from diverse sources, standardise, facilitates real-time communication among responders, and visualizes critical data for better planning. Through predictive models and early warning systems, it forewarns and prepares communities. Additionally, technology assists in resource management, aids rescue efforts, engages communities, and supports post-disaster recovery and reconstruction. In essence, it acts as a central force, amalgamating different elements of disaster management for improved readiness and response.

Geospatial Information Infrastructure (GII) acts as a pivotal system integrator in disaster management by amalgamating diverse data sources, technologies, and stakeholders to create a cohesive framework consisting of advantages of data integration, interoperability through a unified platform and standardise data handling methods. It facilitates Live Data visualisation, monitoring and analysis, resource allocation and coordination, acts as a decision support system in all phases of the disaster management lifecycle.

GIIADM-i represents a Geospatial Information Infrastructure-based architecture designed to boost Disaster Management Systems. It's tailored to harness geospatial and location-based data concerning disaster occurrences, demographic details, and socio-cultural characteristics. This data is pivotal in assessing vulnerability during the pre-disaster phase, crucial for effective preparedness. This platform serves as a dynamic tool, enabling the formulation of rescue plans during disasters and aiding in mitigation efforts. Moreover, it facilitates the creation of

restoration plans by leveraging real-time assessments and past experiences, aiming to contribute to the 'build-back-better' approach.

GIIADM-i stands as a proposed interface that integrates all stakeholders into a unified platform. It offers comprehensive insights into disaster risk factors, vulnerability assessments based on historical data and collective expertise, and simulations projecting potential future risks. This collaborative approach involves contributions from both the community and scientists/researchers.

Leveraging the experiences of task force personnel and relief agencies, GIIADM-i identifies gaps in existing strategies, thereby fortifying future disaster management plans. It's envisioned as a readily accessible resource for decision-makers, providing the necessary information for rational and informed decision-making in crisis situations.

4.2GIIADM-i: A platform to integrate community participation in Disaster Management

The proposed interface can integrate community actions/reactions as part of disaster management activities.

Formulation of Community Based Disaster ManagementPlan (CBDMP) is widely accepted worldwide. In India, the huge population baseis a challenge in terms of vulnerability, but technical assistance has the potential to translate the challenge intoa resource base for planning and execution of Disaster Management initiatives. National Disaster Management Plan (NDMP) has been well provisioned to integrate the local population [NDMP, 2016, P 2].The traditional view of Disaster Management considers disaster as a physical event, but the aspect of ‘humanitarian action’ to manage disaster has been popularized in recent years. Scholars found instances of worse management undermining the importance of social capital and lack of coordination.

The National Disaster Management Plan (NDMP) of 2016 in India is a comprehensive framework that outlines strategies, guidelines, and actions for all phases of disaster management: prevention, mitigation, preparedness, response, and recovery. In this plan, community

participation is a central tenet across various aspects like community-driven assessment, empowering through capacity building, public awareness and education initiatives, community-based Disaster Risk Reduction efforts and Collaborative Early Warning Systems.

Through these concerted efforts, the NDMP underscores the indispensable role of community participation in disaster management. By engaging and empowering local communities, the plan aims to cultivate resilience and ensure more effective disaster response and recovery measures at the grassroots level.

The proposed web-based platform offers an integration of humanware and technoware of GII components, ensuring community participation in various aspects like

1. Community-DrivenRisk Assessment: Engaging local communities to identify and comprehend risks in their areas. Utilizing community insights and experiences to shape a Comprehensive Disaster Management Plan, including evacuation routes and shelter locations. The GIIADM-i platform enables citizen contribution, standardizes crowd-sourced information, and keeps it updated
2. Empowerment through Capacity Building: Equipping communities with training, resources, and skills for swift emergency response. Highlighting success stories of capacity-building activities on a common platform to encourage greater community involvement.
3. Public awareness and Education Initiatives:Conduct targeted campaigns to educate communities about hazards, safety protocols, evacuation procedures, and emergency contacts. Displaying information about awareness campaigns on a virtual notice board with registration links and sending messages through the platform.

4. Community-based Disaster Risk Reduction efforts:Encouraging and supporting community-led initiatives to minimize risks. GIIADM-iassists in efforts to improve infrastructure resilience, organize practice drills, and promote sustainable practices for risk mitigation. Sharing updated global disaster resilience practices through the platform to inform and empower communities
5. Collaborative Early Warning Systems: Involving communities in establishing and managing early warning systems. Ensuring comprehension of alerts and appropriate responses for swift actions. Integrating local volunteers and NGOs into the Disaster Management system for active participation.
6. Inclusivity and support for vulnerable groups: Integrating marginalized and vulnerable groups into disaster plans. Tailoring support mechanisms to address their specific needs. Identifying and educating vulnerable groups like the elderly, women, children, and specially-abled individuals on appropriate disaster response behaviour.

4.3GIIADM-i: A solution to interagency coordination in disaster management

Geographical Information Infrastructure (GII) as a system integrator involves the coordination and integration of various components within the geospatial domain to create a cohesive and functional system

As a comprehensive system integrator, GII encompasses all facets of disaster management:

i. Data Sources:

GII consolidates information from various spatial and non-spatial sources. It combines geographic data with non-spatial attributes like demographics and

infrastructure details, enabling a comprehensive understanding of disaster-prone areas for informed decision-making.

ii. Technology Platforms:

GII facilitates seamless integration among platforms, creating a network where outputs from one system feed into others. This interconnected ecosystem ensures a dynamic flow of information and resources.

iii. Standardization:

Ensuring conformity to established standards and protocols, GII promotes data standardization and modelling. This guarantees compatibility across different systems, fostering smooth data exchange and interoperability.

iv. Analysis and Applications:

GII incorporates tools for data visualization, analysis and modelling, to assist in disaster management. It enables the extraction of valuable insights and the development of applications for planning, emergency response, and recovery.

v. Policy Frameworks

Integration of policies and guidelines governs data sharing, privacy, security, and ethical use within GII. This ensures compliance and proper governance of geospatial information.

vi. Human Expertise

Skilled professionals within GII manage and interpret geospatial data effectively, enhancing the system's utilization and functionality

GIIADM-iis a GII-based proposed platformto operate as a system integrator, combining diverse geospatial data sources, technologies like GIS and GPS, standardization protocols, analysis tools, policies, and human expertise into a cohesive framework of Disaster Management. In the administrative and socio-cultural setup of India,this platformaims to act as an integrated system that facilitates seamless data exchange, multi-level integration, real-time analysis and application

across various fields like urban planning, disaster management, and environmental monitoring, enabling efficient decision-making and management processes.

Throughout these phases, GII acts as an investigative tool, leveraging geospatial data, analysis, and visualization to enhance decision-making, coordination, and resource management in disaster situations. Its ability to integrate various data sources and technologies significantly contributes to more effective and efficient disaster management lifecycles.

5. Discussion:

GIIADM-i is a GII empowered and strategically structured mechanism to provide effective access to geospatial data. GII defines Access Network, data policy and data standards to connect the people with the data. GII defines the system architecture establishing the connections between the components like Infoware (information), Orgaware (organisation /institutional framework), Technoware (Technology) and Humanware (Human). GII consists of dynamic conditions and possibilities to offer different users to generate, share, access and use geographic information. GII defines technical standards, institutional structure, and financial outlay for geospatial data sharing and integration to extend the benefit to different stakeholders.

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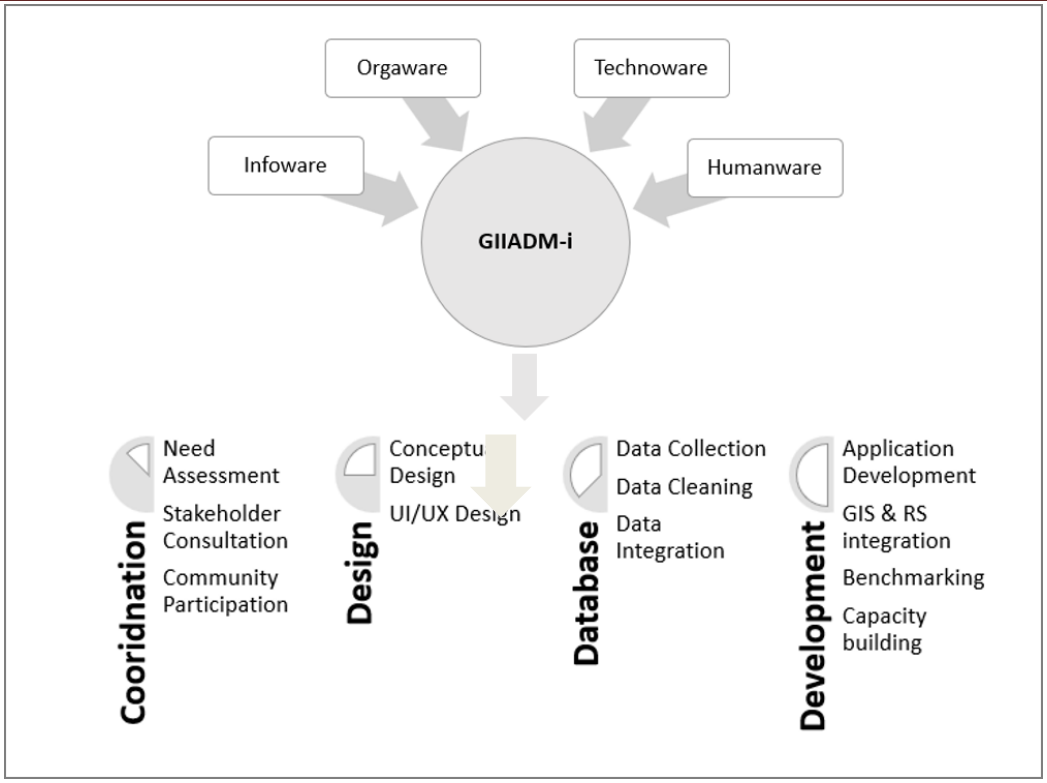

Figure 1: Conceptual Data Model of GIIADM-i

GIIADM-i is a proposed technical solution to assist in disaster risk reduction efforts and disaster management strategies. The blueprint of the product is designed considering the Indian scenario of disaster management policies, administrative setup with hierarchy-based functional responsibilities, human resources in terms of citizens, field personnel, volunteers and decision makers and their functional abilities in view of varied understanding of disaster risks. Due to high population pressure, In India perception towards disaster risk varied across the socio-economic-political stratum. The proposed solution is to integrate people with the system in a coordinated manner through established functional nodes.

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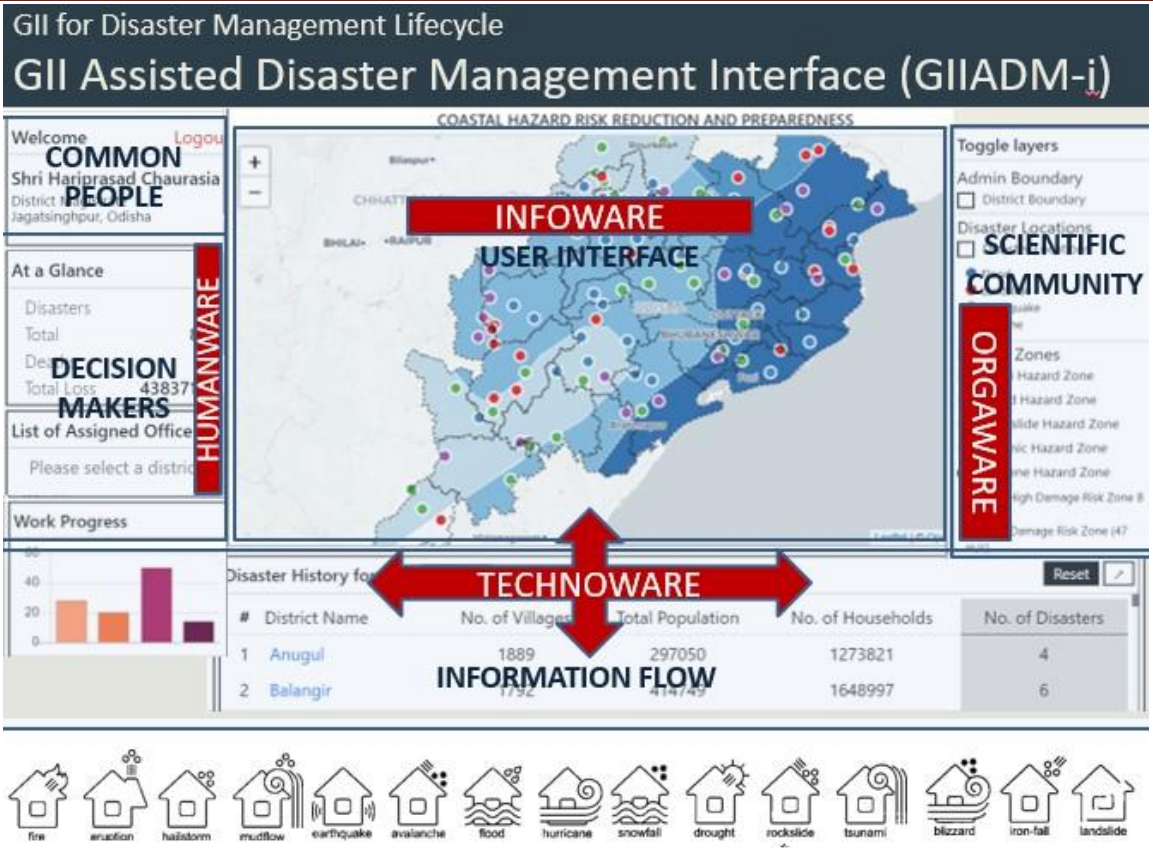

Figure 2: Blue Print of GIIADM-i

GIIAM-i is composed of four basic components – (i) Human-ware to include Decision Makers, Disaster Relief Personnel and People; (ii) Orgaware consisting of institutional strength and hierarchy, research organisations; (iii) Technoware to establish the link between information collection, organization and dissemination and (iv) Infoware to provide processed, analysed information in the form of the interface to utilize in actions and decision making.

GIIADM-i is proposed to act like a system integrator to cater to multi-level information to different audiences. The system is designed with the concept that different stakeholders like common people, relief forces, decision makers, and researchers need not the same information to initiate 'action' for their end. At the time of Disaster common people are generally in need of information like evacuation routes, location of shelters, distribution centers and local area contacts. On the other side Decision makers are more concerned with the estimated risks in pre-

disaster situations, status of relief, rescue and rehabilitation in post-disaster period. Research Organisation and Scientific Community promptly give their technical assistance to create visuals of the situation in view of estimated risk, vulnerabilities, magnitude of loss etc. The total system is established stable linkage connecting individual components.

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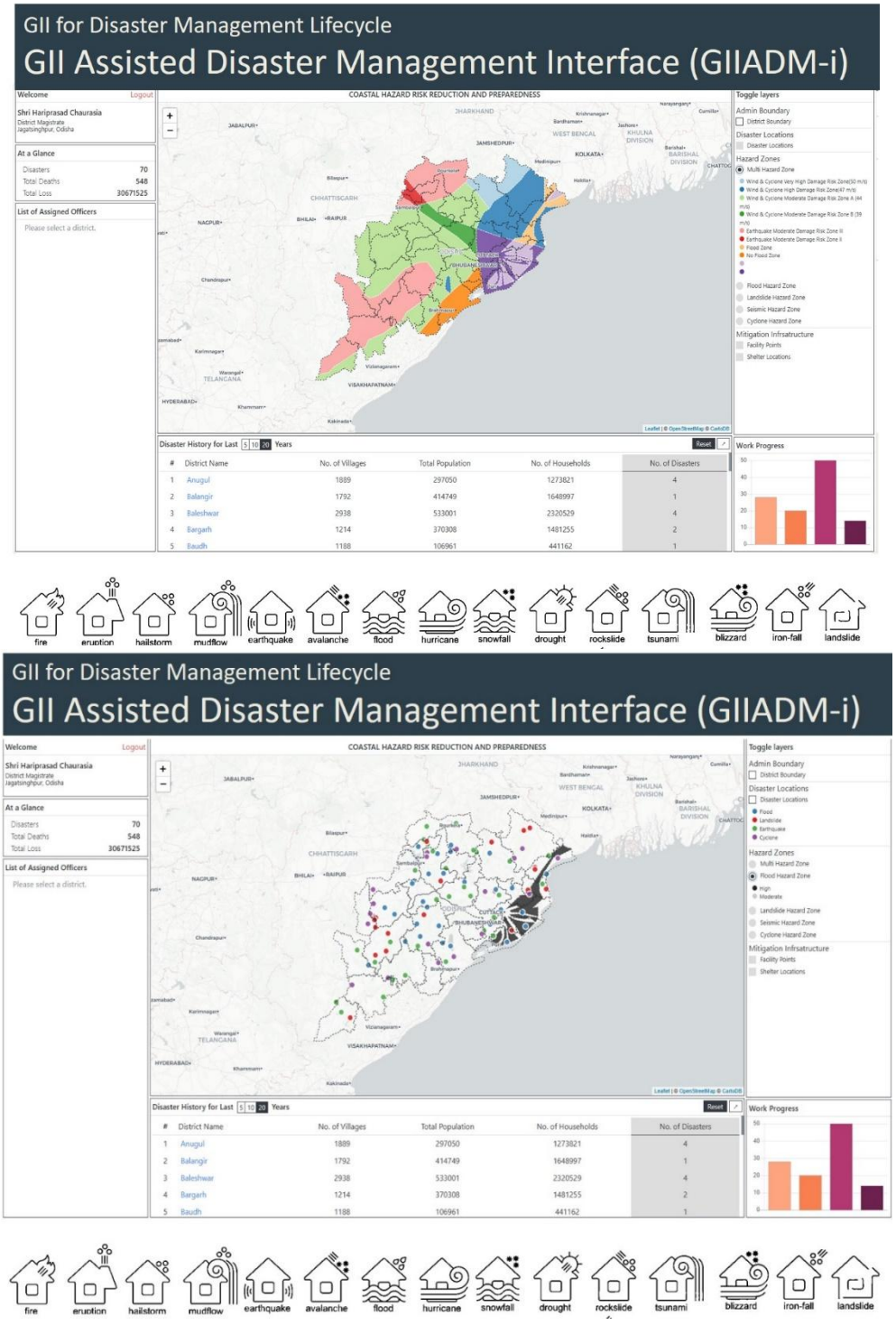

Figure 3: Efficient Information Dissemination via Location-Aware Query Capabilities

The GIIADM-i application customizes user access based on specific roles for effective contribution, retrieval, and analysis of information across various phases of disaster management lifecycle. Different stakeholders, such as common citizens, VIO/NGOs, district and central government officials, scientific communities, and researchers—have distinct information needs.

During the pre-disaster phase, the scientific community can offer valuable input by assessing disaster risks through vulnerability analysis and modelling. This scientific data enables Decision Makers to visualize risks, strategize, and implement preventive measures. Additionally, local community insights, shared via the app, empower policymakers to devise relevant strategies. For example, in Figure 3 Shelter A was pre-assigned shelter to a family living in location X, but based on feedback received from public/authority that after disaster hit the connecting roads are inaccessible alternative shelter B was assigned to the respective family.

Administrative departments access these details through unique logins, providing them with a clear view of relief/rescue operations, nodal officers, and hierarchical structures. Furthermore, on-ground Relief and Rescue Personnel can update live data via the app, facilitating real-time risk assessments. Decision makers leverage this information for swift adjustments in disaster management strategies, including manpower reallocation and duty reassignment. The well integrated platform facilitates intra-agency and inter-agency communications, information transmission occurs in real-time, preventing delays and ensuring effective disaster management.

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Figure 4: Real-time reallocation of Shelters based on feedback received from ground

Conclusion:

In conclusion, the development of a unified Disaster Management system is a complex endeavor marked by challenges such as integrating diverse stakeholders, standardizing data, and fostering coordination. Resource constraints, varying disaster complexities, and cultural differences add further layers of complexity, compounded by political, bureaucratic, and technological hurdles. Overcoming these challenges demands concerted efforts in consensus-building, stakeholder collaboration, infrastructure investment, and continuous adaptation to evolving circumstances and technologies.

In the context of Disaster Management in India, these challenges are particularly pronounced due to the country's diverse geography, high population density, and vulnerability to a range of natural and human-made disasters. While technology serves as an integrating tool, existing technological and information gaps pose challenges to the successful implementation of the Disaster Management Plan in India. The challenges primarily stem from insufficient integration and coordination among stakeholders, shortcomings in data sharing, and the lack of centralized

information dissemination through a unified system. These issues lead to redundant efforts and a prevailing, isolated approach among agencies, involved in disaster management in the country, that operate independently.

The GIIADM-i system is strategically designed to address these challenges by providing a comprehensive framework. It serves as an integrator between agencies, facilitating resource management, information dissemination, and coordination. Acting as a coordinator, GIIADM-i establishes links between nodes and implements a public-private partnership model in disaster management. As a tool for informed decision-making, it helps in integrating and analysing data to bridge existing gaps. This multifaceted approach, utilizing Geographical Information Infrastructure (GII), offers a holistic solution to disaster risk management. It enhances coordination, promotes good governance, encourages prompt community participation, and contributes to the successful implementation of the National Disaster Management Plan by leveraging the capabilities of Information Technology and the locational intelligence of geospatial technology.

GIIADM-i is designed to provide a comprehensive framework, to act as an integrator between agencies, to manage and deploy resources and disseminate information, to perform as a coordinator establishinga link between nodes andimplement Public-Private-Partnership model in disaster management, to analyse as a decision maker to fill the gap.This multifaceted approach of 'GIIADM-i' is designed to install functionalities and utilities of Geographical Information Infrastructure (GII) to offer a complete solution to disaster risk management. It offers improved coordination, good governance,prompt community participation and help in the successful implementation of the National Disaster Management Plan utilizing capabilities of Information Technology and locational intelligence of geospatial technology.

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