

Transdisciplinary Research Strategy On Crisis Management And Resilience Of Population

The Case Of Tourism Destinations In South-East Asia

Caroline Rizza (Ed.)



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Foreword

As France and Indonesia celebrate this year the 75th anniversary of the establishment of their diplomatic relations, President Emmanuel Macron's State visit to Indonesia in May 2025 and President Prabowo Subianto's visit to Paris in July 2025 as Guest of Honor for France's National Day celebrations marked significant milestones in the strengthening and diversification of our bilateral relationship.

On 28th May, 2025, in Jakarta, our two Presidents adopted a joint declaration entitled "Horizon 2050", identifying the priorities for the development of our strategic partnership for the next 25 years. In this statement, [France and Indonesia reaffirmed their commitment to expand their cooperation in the fields of research, new technologies, and sustainable development.](#)

Supported by the French Ministry for Europe and Foreign Affairs, the *Strategic Transdisciplinary Research for Crisis Management and Community Resilience* (or STraP) project is a very concrete example of this type of cooperation.

This trilateral project, [bringing together France, Indonesia, notably through the BNPB, and Vietnam](#), embodies the strength of collaborative research in addressing global challenges. Through the joint elaboration of a strategic roadmap, it offers both a scientific foundation and an operational vision for improving risk governance, enhancing communication in times of crisis, and strengthening the resilience of local communities, particularly in vulnerable and fast-developing tourist areas such as Labuan Bajo in Indonesia.

Of particular note is the [community-centered and transdisciplinary approach](#) that has guided the work from the start. By bringing together researchers, civil protection teams, and local actors, the project has made it possible to move beyond academic silos and toward collective problem-solving.

The STraP project is also a clear illustration of the [French strategy in the Indopacific, where our commitment to disaster preparedness is longstanding and multifaceted](#), with investments in risk reduction, inclusive governance, and the protection of key populations, notably women and children. Our cooperation spans bilateral and multi-lateral frameworks, including within ASEAN, and is fully aligned with the goals of the 2030 Agenda for Sustainable Development.

I would like to express my sincere appreciation to all the partners, researchers, and practitioners who made this project a success. This roadmap is also a [call to further action](#) – to turn knowledge into resilience, and cooperation into long-term impact.

Fabien Penone

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Transdisciplinary research strategy on crisis management and resilience of population

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A fast-paced project year

Indonesia and Vietnam are countries subject to a wide range of risks. The Archipelago already has a culture of preparedness and response, through its National Agency for Disaster Management (Badan Nasional Penanggulangan Bencana, BNPB). In Vietnam, the permanent structure is the Vietnam Disaster Management Authority (VNDMA), which reports to the Ministry of Agriculture and Rural Development (MARD). France is currently providing both countries with its knowledge of hazards (seismic, volcanic, but also climate change and forest fires) through its operators and research centers as well as the Directorate for Security and Defense Cooperation, in a dispersed manner.

At the time the project was submitted, BNPB wanted to strengthen its “actionable” knowledge base through a collaboration with France and around a vision combining governance and resilience in a growing tourism destination. From their side, the French embassies in Indonesia and Vietnam were both concerned about the risks to which tourists are exposed in these countries.

The “Transdisciplinary research strategy on crisis management and resilience of population” ‘STRAP’ project has been funded as part of the Fonds Equipe France (FEF). It aims to bring together teaching, research and civil protection teams to improve the safety and resilience of populations about the issue of risk prevention and crisis management. It has two main objectives:

▶ The structuring of a 5-year roadmap, aimed at BNPB, for the implementation of transdisciplinary Franco-Indonesian research (researchers/practitioners) and including a Vietnamese and/or ASEAN dimension;

▶ The implementation of two transdisciplinary pilot projects on “resilience of population and digital technology” in the rapidly developing tourist areas of Labuan Bajo in Indonesia and the Province of Quanh Binh in Vietnam.

To do so, a community-centered approach has been adopted in the implementation of both objectives.

This book presents and gathers the roadmap and its constitutive topics. It has been collaboratively realized from July 2024 to April 2025:

From July to October 2024, Indonesian, Vietnamese and French research teams have been reached to contribute to this roadmap and characterize the existing and future areas of collaboration. Once the project and its main stakes were presented, each team has been asked to propose a topic or challenge. Based on this first pool of research teams, **a first hybrid workshop took place in December 2024**, where each team presented their area of expertise and the challenge(s) they were willing to address in the road map.

Based on this first workshop, teams representing at least two countries have been proposed to address a specific challenge and foster their cooperation.

Each teams met at least once online in order to discuss and prepare the content of the constitutive challenge(s) of the roadmap presented during a second workshop in March 2025. This second workshop gave a first overview of the roadmap, completed by two additional on-going Franco-Indonesian projects in Lampung and Semarang. Feedbacks have been formulated, specifically by BNPB, in order to support the teams to finalize the roadmap. Also, a call for independent contributions from research teams and/or from the Asia Pacific area have been opened through the ISCRAM community network to complement the roadmap.

The final hybrid workshop of presentation of the roadmap by team took place the 24th of April 2025. It included the contextualization of the project and its transdisciplinary stakes (see the following Introduction by Udrech), the results of the collaboration between Indonesian, Vietnamese and French teams (see Part 1), the independent proposals as well as the first insights of the both pilot-surveys conducted in the Province of Quang Binh (Vietnam) and in Labuan Bajo (Indonesia) (see Part 2).

A state of the art

The study of crises and their management has been the subject of research for many years. Already Morin (1976) was calling for a theory of crisis, a common basis for sectoral, multi-sectoral or interdisciplinary research. While the Anglo-Saxon literature indiscriminately uses emergency, crisis and disaster (Hiltz *et al.*, 2014), global warming, as a latent crisis whose local manifestations are increasingly recurrent and violent, leads us to return to the distinction between crisis and disaster, in the sense of major events (Thom, 1976), to better rethink its processes as a concept and its occurrences in the field, as objects of empirical study. In France, the fires in the summer of 2022 in previously unaffected areas and the difficulty of containing them, as well as the occurrence of extreme weather events and their consequences for populations (such as the floods in the North of France and the Pas de Calais in 2023–2024, or more recently the violence of cyclone Chido in Mayotte), are illustrations of risks described as emerging by civil security actors. In South-East Asia, such as Indonesia and Vietnam, meteorological events (typhoons, floods) are also leading these countries to rethink risk prevention and crisis communication.

In this context, the recurrence and violence of this type of risks, exacerbated by global warming, require to work on both 'breaking within risk and crisis management' and adapting professional and public practices to deal with it. In response to this societal challenge, our STRAP project has been closely defined and implemented in collaboration with the French embassies in Indonesia and Vietnam, the National Agency for Disaster Management (BNPB)

without which access to the Indonesian field and meetings with local authorities and civil society would not have been possible, and the support of the SILDARO expert in crisis management. In order to conduct a community-centered approach, our aim was to study the system of actors involved in crisis management (including civil society) to support more collaborative practices and to encourage the development of (new) dynamics in the face of the disruption scenarios envisaged in the areas. Indeed, among the methodologies proposed by official institutions, taking account of "territoriality" and using scenarios to carry out assessments on a local scale, inform decision-making and thus improve the resilience of communities and territories are now favored in the face of global warming (Commission Européenne, 2023; UNISDR, 2015).

Info-communication research on risk and crisis management

Thinking crisis management as a continuum from prevention to recovery makes it possible to involve all the actors in civil society in the implementation of policies, plans and standards relating to global warming and associated emerging risks, as well as to restore the trust between institutions and citizens that is necessary for them to work together (Courant *et al.*, 2021; UNISDR, 2015). Research highlights the contributions of citizens and expert communities to crisis management and the contribution of digital devices (Palen *et al.*, 2020; Reuter & Kaufhol, 2018), particularly at the local level often embodied by civil protection agencies (Batard, 2021; Rizza, 2022). While

the inclusion of citizens in crisis management seems to be progressing with the recognition and support of expert communities such as the Virtual Operations Support Teams (VOST¹), the literature still deplors the breakdown in trust between citizens and institutions, who are not used to cooperating, leading to frustration and misunderstandings during a major event (Boin, 2009; Reuter *et al.*, 2016; Scanlon *et al.*, 2014).

From simulation to living-lab as a methodology for understanding and more create collaborative practices

To overcome this difficulty, simulation experience enables actors to manipulate and acquire a certain sense of activity which facilitates the development of relevant responses and knowledge, supporting business, technical or procedural clarifications (Morand *et al.*, 2022; Morand, Larribau, Safin, & Rizza, 2023; Morand, Larribau, Safin, Soichet, *et al.*, 2023). In crisis management, simulations are used to reproduce emergency situations, enabling experimentation in a semi-realistic context while preserving the complexity of the situations (Gerhold *et al.*, 2020; Yao *et al.*, 2010).

Following the work of Fayeton, we do not consider the civil protection exercise as a simple training exercise for crisis units, but as a place (during its preparation, during the exercise itself and at its sidelines) for redefining the dynamics between the actors, their missions and perspectives in particular. In our transdisciplinary approach, the exercise, its scenario and its implementation become the point of entry for an object whose scope is wider and consequent: the interactions between the actors outside the exercise, a means of putting these interactions up for discussion, or even redefining them through methodologies such as participative workshops.

1. <https://vosteuropa.org/>

In this framework, two previous projects (i.e. “Combining digital technology and living lab approach for a rescuer-citizen” and “Resilience of population in the face of global emerging risks on a territory: towards an actor citizen of the operational chain of crisis management”) have demonstrated the efficiency of living-laboratories (living-labs) as an alternative to civil protection’s exercises and as a relevant approach to make several diverse “worlds” or systems of actors to meet and share their visions, beliefs, practices. At the light of their results, living-labs foster collaboration between citizens and official institutions in charge of emergency or crisis management and support elaboration of collaborative practices.

The living lab is a method developed in the 1990s at the Massachusetts Institute of Technology, which aims to provide a meeting place for all the stakeholders involved in a situation to test a technological innovation (Johnsen & Bolle, 2008; Mentler *et al.*, 2017). This method allows a test in a situation close to reality and makes it possible to identify and confront the real constraints even before reaching a more advanced development process. It also provides opportunities for different populations, varying in their level of familiarity, to interact and collaborate (Morand, Larribau, Safin, Pages, *et al.*, 2023). Moreover, living laboratories offer the opportunity to use a diverse set of complementary methodologies. For life-threatening emergencies, simulation seems to be the most appropriate setting. The use of simulations with scenarios in a semi-real context seems adequate and can genuinely benefit the participants in moments of emergency or crisis (Fledderus *et al.*, 2014; Leminen *et al.*, 2012). Experiencing the simulations together contributes to the creation of a discourse and a common frame of reference allowing for a more efficient cooperation later (Leitner *et al.*, 2007; Leminen *et al.*, 2012).

Faced with global warming: a scenario-based approach to the territory and its risks

In 2015 the United Nations, meeting in Sendai, established a framework for action for disaster risk reduction to 2015-2030 (UNISDR, 2015). This framework for action is structured around four priorities: Understanding disaster risk; Strengthening disaster risk governance to better manage disaster risk; Investing in disaster risk resilience to build resilience; and Improving preparedness for effective response and to 'do better and build back better'. The measures proposed include the integration of social media as a means of communication action, the importance of taking 'territoriality' into account to 'ensure that traditional, indigenous and local knowledge and practices complement, as appropriate, scientific knowledge in disaster risk assessment and facilitate the development and implementation of policies, strategies, plans and programs in specific sectors, based on a cross-sectoral approach, which should take into account local realities and context' as well as the mobilization of scenarios for evaluating the strategies thus defined at regional level.

In 2023, the European Commission in its 'European Union Disaster Resilience Goals: Acting together to deal with future emergencies' insists on drawing up scenarios to strengthen the resilience of a territory, whether national, transnational or international. It stresses the need to act both in the prevention and crisis response phases, as well as on the cooperation of a certain number of actors in society with civil protection to strengthen resilience (Commission Européenne, 2023).

The resilience of an area and its communities

The concept of resilience comes from Holling (1973) who describes it as the capacity of an ecological system to absorb an external shock. Moatty & Reghezza-Zitt (2018) present two conceptions of resilience, depending on whether it is the antonym of vulnerability – improving the resistance of a system mechanically reduces its vulnerability, or whether it is more encompassing by focusing on both the territorial system and its (infrastructure) network – resilience becomes a capacity to maintain activity during a crisis and to recover post-crisis according to a mechanical link between the resilience of technical networks and the resilience of the territorial system. The authors

emphasize that territorial resilience makes it possible to broaden the technical approach to network vulnerability by considering 'the importance of organizational vulnerabilities at all scales'. Dufty (2012, 2013) highlights the multitude of definitions of 'disaster resilience' and clarifies the two meanings of the term: while the original notion of resilience, from the Latin word *resilio*, means 'jumping back' or 'bouncing back' (i.e. resuming normal functioning), a second meaning encourages consideration of the new post-disaster reality and its possibilities. Thus, the definition of community resilience emphasizes the human aspect of the system. It can be defined as 'the existence, development and commitment of community resources to manage change and uncertainty' (Becker *et al.*, 2019) and can be measured by 'the success of civil protection authorities and communities in improving their capabilities and adapting to cope with possible adverse events in the future' (Eklund *et al.*, 2023). For Dufty (2012), community resilience involves three dimensions that digital communication tools, and more specifically in his case social media, can improve: risk reduction (by providing new media for information, discussion, coordination and feedback); emergency management (by enabling non-professional communities to contribute to the resolution of a crisis); and community development and collaboration. Risk culture is an essential element in understanding the resilience of a community in a given area. Courant *et al.*, (2021) define it as an awareness of risk and of all the knowledge that enables actors and citizens to anticipate the impact of a situation and to adopt adaptive behavior in the event of a disaster. More specifically, the knowledge they mention covers the interactions between nature and land-use planning choices, as well as past or even actual experience of the hazard in the area, which enables them to make their own progress. This knowledge becomes culture, in the sense that it is inscribed geographically and temporally through its transmission over time. In this way, the culture of risk(s) is territorially specific.

About tourism resilience

In the context of tourism, resilience also refers to the ability of tourist systems, destinations, and communities to adapt, recover, and rebuild more effectively in response to various challenges and disruptions,

including natural disasters. The concept is crucial for the anticipated sustainability and success of tourism-related initiatives (Gottschalk *et al.*, 2022; Ketter, 2022; Nguyen *et al.*, 2023). An essential component of tourism resilience is the social support from stakeholders and local communities, since it fosters collaboration and collective responsibility in addressing the impacts of tourism (Sheppard & Williams, 2016). Again, a crucial aspect is community resilience, also defined as the ability of local communities to maintain and restore their socioeconomic and cultural structures against challenges associated with tourism (Cornejo Ortega & Chávez Dagostino, 2023; Saarinen & Gill, 2019).

Enhancing infrastructures, promoting community development and engagement, and improving sustainable tourism practices constitute a comprehensive implementation of resilience methods in destination management at the local level (Della Corte *et al.*, 2021; Luong *et al.*, 2025).

Information and communication technologies for risk and crisis communication

During times of crisis, information and communication technologies (ICTs), including social media

platforms (e.g., Twitter/X, Facebook, and Instagram), enable the rapid dissemination of alerts and information during emergencies, effectively reaching large audiences in real-time (Kar & Cochran, 2019; Rizza & Pereira, 2014). ICT enables real-time, interactive communication for the public, which is crucial for swift response and effective management. More specifically, social media provides a platform for real-time updates and engagement with tourists, rendering it an essential instrument for risk and crisis communication. This facilitates crisis management by regulating the narrative and addressing tourists' concerns (Alba-María Martínez-Sala *et al.*, 2024; Barbe & Pennington-Gray, 2022; Park *et al.*, 2019). Social media platforms facilitate interpersonal interaction and instantaneous information sharing, hence enhancing situational awareness and coordination (Rizza, 2023a; Schroeder *et al.*, 2013). Nevertheless, ICTs and specifically social media also present challenges, including the proliferation of misinformation, digital inequities, trust deficits, and the complexity of managing varied information channels. Efficient handling of these aspects is crucial to maximizing the advantages of ICT in crisis scenarios (Rizza, 2023b).

Conclusion and transdisciplinary prospects

Global warming and its impact on specific territories call for developing the notion of 'emerging risks', understood and defined as "a natural risk, possibly pre-existing in an area, but whose increased recurrence and intensity puts into tension the management methods (processes and interactions) previously defined and implemented to prevent and respond to it" based on the transdisciplinary work conducted with practitioners and experts (Rizza, 2025). We then prefer a definition focused on the 'exceptional' dimension of a risk when it occurs instead of the unprecedented nature of the risk, because new to a territory. Indeed, embracing such a broader and more inclusive definition of "emerging risk" enables both to understand and define the occurrence of new phenomena in an area and the processes and interactions needed to prevent and respond to them, as well as to adapt existing processes and interactions to risks whose exceptional occurrence makes them 'emerging'. We hope

that our forthcoming transdisciplinary research projects will bring new elements to discuss and challenge this notion.

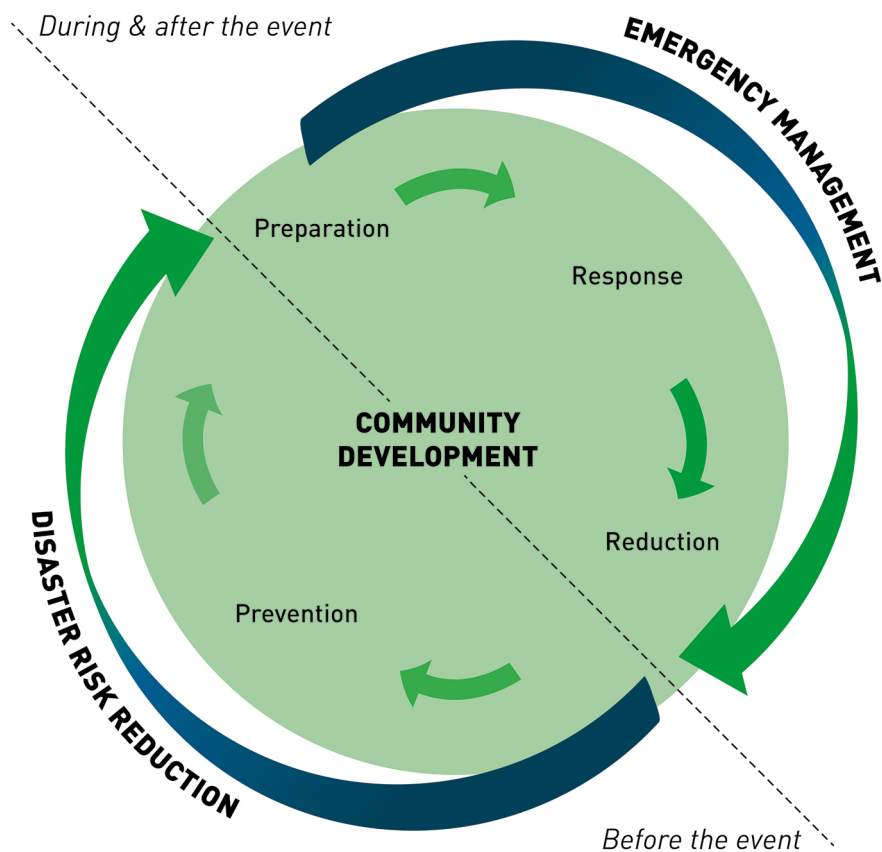
Proposing a transdisciplinary approach centered on local communities also leads to extend the usual technical approach to resilience (in terms of network vulnerability) by focusing on both the territorial system (infrastructure networks) and its network of actors (Moatty & Reghezza-Zitt, 2018; Rizza, 2025). The following figure superimposes the three dimensions of the resilience of a population (Dufty, 2012) in a territory onto the traditional crisis management cycle – prevention, preparation, response and recovery. In a simplified and schematic way, it illustrates the challenge of improving the networks of actors and their collaboration in order to cope with a risk, which may be emerging, and its occurrence in an area: on the one hand, it places at the center of the crisis management cycle the de-

velopment of the community (and its processes and interactions between actors) which becomes transversal to the four phases of the cycle; on the other hand, and consequently, it underlines the challenge of bringing the prevention phase closer to the event management phase.

Improving territorial resilience implies developing a resilient local community. This involves co-constructing processes and setting up interactions between actors during the prevention phases and in response to the emerging risk, taking into account both the plurality of actors known and to be identified, as well as the plurality of actions to be defined in addition to the common bases of knowledge and skills. Coordination between local actors (public authorities/crisis managers, local actors, private actors, civil society, etc.) is thus considered and implemented during each phase of the crisis management cycle, without differentiating between disaster risk reduction (prevention) and event management. From a methodological point of view, we believe that transdisciplinary approaches, and more specifically, the adaptation and implementation of new ways of simulating situations and fostering collaboration such as the P-ARDI methodology « Problem Actors Resources Dynamics Interactions » (Etienne *et al.*, 2008, 2011)

constitute new opportunities for institutional actors to think and rephrase their processes in order to include local citizens or communities. This methodology has been implemented through a practitioners' workshop led by SILDARO in the frame of the STRAP project. The workshop gathered twelve actors from tourist sector, local and national crisis management agencies (forthcoming results). Same methodology will be implemented in the Province of Quang Binh (Vietnam) in the frame of a new FEF project led by the IRD.

Last but not least, the two pilot surveys have shed light on recurring questions regarding the opportunities and challenges raised by ICTs in terms of preventing risks, communicating about a major event as well as building resilient local communities. These questions are addressed in this roadmap through three main and transversal dimensions: informational when it comes to alert, to counter or verify the veracity of information circulating online, as well as to build an accurate operational common picture of the event; communicational in terms of temporality and expectations of population (e.g., digital culture); and organizational when it comes to respond to the event, to monitor civil society's initiatives and to integrate some of them.



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Strengthening Safety Tourism in Labuan Bajo: Toward a Resilient and Sustainable Archipelagic Development

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Labuan Bajo, located in the eastern Indonesian archipelago, is one of Indonesia's designated Super Priority Tourism Destinations and a gateway to the Komodo National Park. Its stunning biodiversity, coastal landscapes, and cultural richness position it as a global tourism magnet. However, Labuan Bajo's geographical setting in a hazard-prone, ecologically sensitive region presents substantial challenges. The increasing number of tourists visiting marine-based sites such as Padar Hill and Komodo dragon habitats poses safety concerns for both visitors and host communities.

To ensure the sustainability and resilience of this destination, this paper argues for a risk-informed, science-based, and community-centered development approach. By promoting tourism safety as a key enabler of sustainable development, we propose a resilience roadmap for Labuan Bajo that integrates early warning systems, participatory planning, and adaptive governance aligned with international frameworks such as the Sendai Framework for Disaster Risk Reduction (SFDRR) and the United Nations Ocean Decade.

Theoretical Framework: Understanding Resilience in Tourism Systems

Resilience in the context of tourism and disaster risk management refers to the capacity of communities and systems to absorb disturbances, adapt to adverse conditions, and transform through crises without losing their essential functions. Drawing from (Maguire & Hagan, 2007) and contemporary global definitions (UNDRR, DFID, OECD), resilience is viewed as a dynamic property characterized by:

► **Threshold:** The tipping point beyond which a system cannot recover. In tourism, this reflects environmental carrying capacities or institutional fragilities that, if exceeded, cause irreversible impacts.

► **Recovery Time:** The pace and depth of recovery after disruption. A destination may physically rebuild quickly, yet struggle with long-term livelihood or reputational recovery.

► **Transformation:** The opportunity to evolve through crisis. Disasters can accelerate reforms, stimulate innovation, and bring long-term improvements in governance, infrastructure, and technology.

By applying this framework, tourism resilience becomes measurable and actionable, forming a bridge between vulnerability and sustainable development.

Vision: Safe Tourism and Safe Ocean

To achieve a truly sustainable and adaptive tourism system, the concept of resilience must be embedded as a guiding principle. Resilience, in this context, is not merely the ability to recover from crises, but also to anticipate risks, absorb shocks, reorganize systems, and transform in the face of adversity.

Drawing from theoretical foundations such as those of Maguire & Hagan (2007), resilience includes three interrelated dimensions:

► **Threshold:** The maximum level of pressure or disturbance a system can endure without losing its essential structure or function. In tourism, this relates to environmental carrying capacity and socio-economic vulnerability.

► **Recovery Time:** The speed and depth of recovery after disruption. Superficial recovery (e.g., restored infrastructure) may mask deeper issues (e.g., lost livelihoods, community trauma).

► **Transformation:** The capacity to emerge stronger, through innovation, reform, and integration of lessons learned. Post-disaster settings offer unique opportunities for advancing governance, technology, and institutional learning.

By operationalizing resilience through planning and investment, destinations like Labuan Bajo can shift from reactive to anticipatory systems – ensuring not only safety, but long-term viability and adaptability.

The vision for Labuan Bajo is to become a globally recognized, resilient tourism destination that upholds the integrity of its marine and terrestrial eco-

systems. The concept of a “Safe Ocean” emphasizes the protection of marine-based tourism through:

- Enhanced multi-hazard early warning systems (especially in marine areas);
- Risk-informed zoning for diving, boating, and wildlife interaction;
- Capacity building for local coastal communities and guides;
- Integration of oceanographic and meteorological data into safety protocols.

This vision is closely aligned with UN Ocean Decade Challenge 6: Increasing Community Resilience to Ocean Hazards. The challenge highlights the need for:

► **People-centered early warning systems** that combine scientific and local knowledge;

► **Community-based education and capacity building** to ensure local populations are informed and capable of responding to marine risks;

► **Inclusive governance** that places community voices at the center of risk planning and ocean hazard management;

► **Integration with SDG frameworks**, especially SDG 11 and SDG 13, which advocate for disaster-resilient infrastructure and climate-responsive actions.

For Labuan Bajo, adopting Challenge 6 as a framework strengthens the commitment to build safety tourism not only for tourists but also for the surrounding coastal communities. This integration will support the development of a destination that is not only economically attractive but also resilient, inclusive, and capable of withstanding diverse ocean-related hazards.

Identifying Key Issues and Strategic Pathways

To achieve the above vision, it is essential to diagnose current barriers and design feasible interventions grounded in resilience. The next sections of this paper present a progressive analysis – starting with a review of present-day constraints, followed by a SWOT framework to assess internal capacities and external opportunities. Building on this foundation,

we outline a phased roadmap to guide strategic planning and implementation.

This narrative structure ensures a logical flow from problem identification to solution-building, allowing the reader to understand how resilience-based tourism can evolve from vision to actionable reality in Labuan Bajo.

Current Challenges

The development of tourism in Labuan Bajo faces multiple constraints:

- ▶ **Tourism Risks:** Activities in high-risk zones such as Komodo dragon habitats, Padar Hill, and marine channels with strong currents lack sufficient risk controls;
- ▶ **Infrastructure Gaps:** Evacuation routes, emergency services, and safety signage are not adequately developed;

▶ **Human Resource Limitations:** There is a shortage of trained safety personnel and local guides with disaster awareness;

▶ **Community Gaps:** Limited community engagement in planning, preparedness, and benefit-sharing;

▶ **Policy Fragmentation:** Weak coordination between tourism, environmental, and disaster management agencies.

SWOT analysis

We conducted a Strengths Weaknesses Opportunities and Threats (SWOT) analysis of Labuan Bajo as one of Indonesia’s Super Priority Tourism Desti-

nations, guided by the vision of promoting safety tourism, as follows:

Strengths	Weaknesses
<ul style="list-style-type: none"> • Unique biodiversity and landscape • Government support as Super Priority Destination • Existing transport access and branding 	<ul style="list-style-type: none"> • Insufficient emergency infrastructure • Low community participation in safety protocols • Limited human resources for safety tourism
Opportunities	Threats
<ul style="list-style-type: none"> • Growing global demand for safe and sustainable tourism • Advances in safety tech and monitoring • International cooperation and funding 	<ul style="list-style-type: none"> • Earthquakes, tsunamis, extreme weather • Climate-related degradation of marine environments • Reputation risks from safety incidents

Roadmap for Safety and Resilience (2025–2030)

Building on the resilience framework outlined earlier, the following roadmap is designed not only to reduce immediate risks but also to foster long-term adaptive capacity and transformation. Each phase of the roadmap corresponds to one or more dimensions of resilience:

▶ **Threshold** is addressed through hazard and vulnerability mapping in 2025, aiming to understand the limits of existing systems and anticipate pressure points;

▶ **Recovery Time** is integrated through scenario modeling in 2026 and the development of rapid-response decision-support tools in 2027, designed to reduce lag in post-disaster reactions;

▶ **Transformation** is pursued through regulatory integration, institutional reform, and impact evaluation from 2028 onward, creating opportunities to embed innovation, inclusiveness, and learning into governance systems.

This alignment ensures that resilience is not treated as a theoretical ideal, but as a practical, measurable pathway embedded within Labuan Bajo's tourism development strategy.

The proposed roadmap includes seven years of phased implementation:

- **2025:** Hazard and vulnerability data improvement; participatory risk mapping
- **2026:** Cascading hazard modeling and scenario building
- **2027:** Development of a Multi-Hazard Tourism Safety Dashboard

- **2028:** Integration of risk metrics into tourism regulation and spatial plans
- **2029:** Evaluation of implementation and institutional reforms
- **2030:** Consolidation and scaling to other tourism clusters

This roadmap draws from co-produced research between Indonesian and French institutions and is guided by international frameworks such as the SFDRR.

Key Considerations

To ensure successful implementation, three cross-cutting issues must be addressed:

- ▶ **From Planning to Execution:** Institutional clarity is essential. Stakeholder mapping and role definition are needed to ensure leadership, coordination, and accountability;
- ▶ **Community Integration:** Risk perception, local knowledge, and civic participation must be em-

bedded from the beginning. Training, simulation exercises, and community-led monitoring are recommended;

- ▶ **Resilience as Transformation:** Safety should not only reduce risk but also drive wider reforms in governance, innovation, and inclusivity. Indicators of transformation may include digital adoption, diversified livelihoods, and ecosystem restoration.

Conclusion

The future of Labuan Bajo as a world-class eco-tourism destination depends on its ability to manage risk intelligently and inclusively. Tourism safety is not a separate sectoral concern but an enabling condition for development. The roadmap presented in this paper outlines a replicable and scalable model for

resilience-building in small island and archipelagic contexts.

Investing in disaster risk reduction, institutional coordination, and local empowerment will transform Labuan Bajo from a high-risk tourism hotspot into a resilient, inclusive, and globally trusted destination.

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Part 1

Roadmap on Crisis Management and Tourism Resilience in South-East Asia

Transdisciplinary perspectives
and approaches

Building resilient island infrastructure in the face of future changes and transitions

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Introduction

Islands exhibit distinct characteristics that fundamentally shape their development and functioning. Due to their geographical isolation and bounded nature, islands face unique challenges in resource management, infrastructure development, and economic sustainability. These spatial constraints, characterized by limited land mass and population size, create specific operational conditions that differ significantly from continental settings (Baldacchino, 2006; Grydehøj, 2020). Modern understanding emphasizes that these insular characteristics are not limiting factors but dynamic features that interact with technological, social, and environmental systems. Islands' relationship with surrounding waters and nearby mainlands creates both opportunities and vulnerabilities, particularly in resource dependency, climate resilience, and infrastructure needs (Foley *et al.*, 2023). Their position within extensive maritime networks and their responses to environmental challenges demonstrate how island communities adapt to and transform these inherent characteristics, revealing the complex interplay between geographical constraints and human adaptation (Nel *et al.*, 2021).

The inherent characteristics of islands present unique challenges in disaster management. Their limited spatial extent and bounded nature concentrate hazard exposure while constraining evacuation options and emergency response capabilities (Kelman, 2020; Méheux *et al.*, 2019). Physical isolation, restricted resources, and often singular critical infrastructure systems amplify vulnerability to natural disasters, particularly climate change-induced events such as storms, flooding, and sea-level rise (Nunn & Kumar, 2019). However, island communities frequently demonstrate remarkable resilience through traditional knowledge systems and adaptive social networks (Campbell, 2018). This paradox between heightened vulnerability and enhanced adaptive capacity illustrates how islandness shapes disaster risk and community response mechanisms. The interconnected nature of island systems means that disruptions to critical infrastructure or supply chains can produce cascading effects across multiple sectors, necessitating integrated approaches to

disaster risk reduction that acknowledge both the constraints and opportunities of insular contexts (Duvat *et al.*, 2021; Petzold & Magnan, 2019).

Within this context, actions supporting disaster resilience constitute a fundamental element for the sustainability and development of island tourism. Destinations that integrate proactive resilience measures show better recovery capacity following disruptive events (Orchiston, 2013). Investment in infrastructure and emergency plans represents a determining factor for tourism resilience in the face of disasters (Filimonau & De Coteau, 2020). The adoption of strategic and holistic approaches in crisis management is essential for the tourism sector confronting increasing risks (Ritchie, 2008). Furthermore, the development of adaptive capacities within tourism communities constitutes a crucial element for sector resilience, enabling destinations to better anticipate and respond to disruptions (Prayag, 2018). These integrated approaches recognize that island tourism systems must balance vulnerability with the inherent adaptability found in island communities.

This paper presents the foundation of a research that aims to analyze how transitions, particularly climate change and geohazards, affect Indonesia's island infrastructure through the lens of Hazards, Vulnerability, and Resilience. This study will generate data from prospective scenarios and statistical analyses to inform long-term infrastructure planning and decision-making processes. The resilience of Indonesia's island infrastructure is a critical issue due to the country's extreme vulnerability to climate change, natural disasters, and socio-economic challenges. As the world's largest archipelagic nation, Indonesia faces rising sea levels, land subsidence, and increasing disaster risks that threaten millions of coastal residents. Many small islands may become uninhabitable without adequate adaptation measures, displacing communities and disrupting local economies. The first part of the article presents the context of the resilience of Indonesia's island infrastructure. A state-of-the-art presents Indonesia's strategy for resilient infrastructures. Finally, a research agenda is provided.

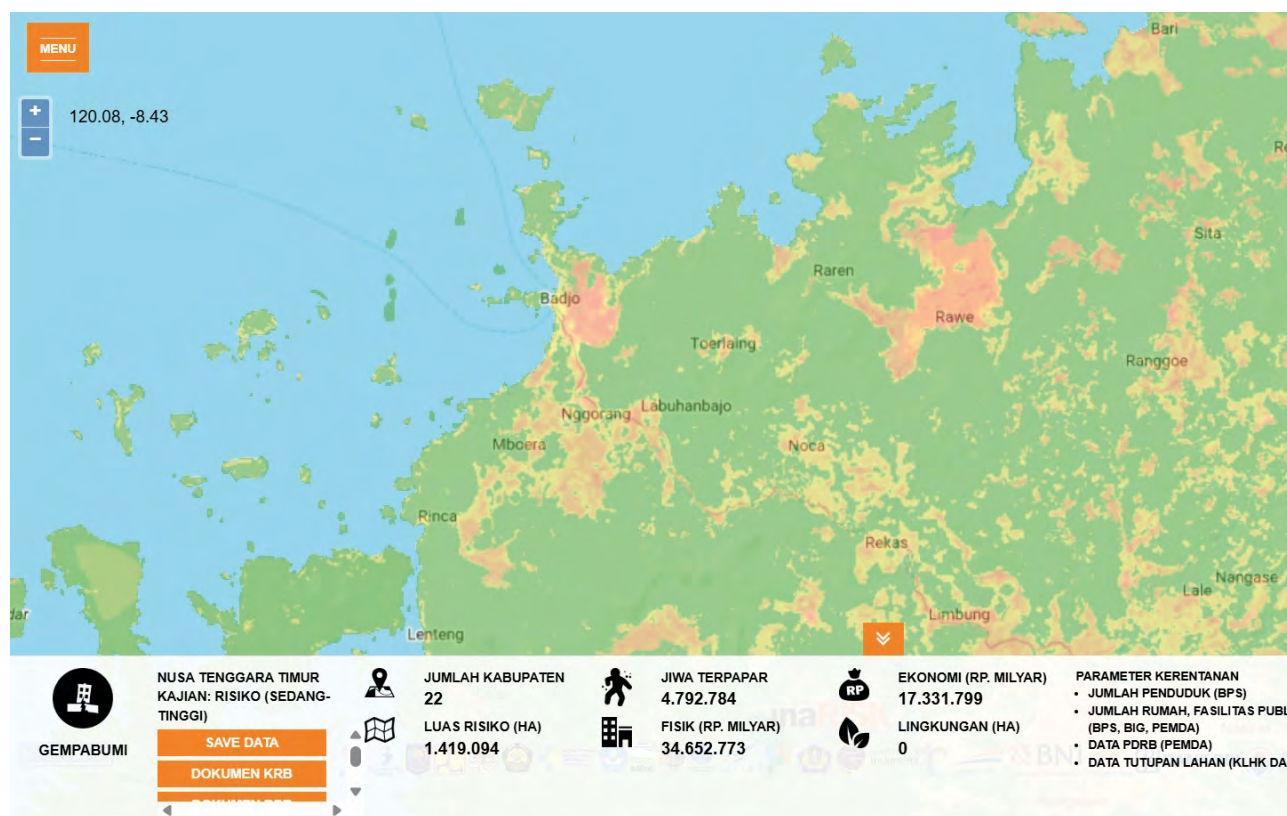
Context

As the world’s largest archipelagic state, Indonesia presents a compelling case for examining hazards, vulnerability, and resilience in island and remote-setting infrastructure. With over 17,000 islands, Indonesia faces diverse environmental risks and infrastructural disparities. While major islands like Java, Bali, and Sumatra benefit from vast developing infrastructure and advanced disaster response, remote islands and islets – such as Mentawai, Maluku, Nusa Tenggara, and the outermost Riau and Natuna islands – grapple with limited access to emergency services, fragmented supply chains, and weaker adaptive capacities (Djalante, 2017). These smaller, isolated islands are particularly vulnerable to coastal erosion, freshwater scarcity, and extreme weather events, with longer recovery times due to their distance and challenges in

transporting supports from logistical hubs (Hasan, 2020). Climate change exacerbates the impact of disasters such as landslides and floods, resulting in major damage to transportation infrastructure with floods causing 65% of road damage, and earthquakes and tsunamis more than 30% (Gupta *et al.*, 2023). Sea level rise of up to 52-115 cm in Indonesia by the end of the century risks damaging roads, bridges and critical transportation assets in coastal areas. This damage weakens infrastructure, disrupts transportation services, hampers the economy and increases the risk of community isolation (Nicholls *et al.*, 2007).

Labuan Bajo, as one of the main tourist destinations in Indonesia, has significant potential geological threats. The region is located in an active tectonic

Figure 1
Earthquake Hazard Index Map of Labuan Bajo and its Surroundings¹

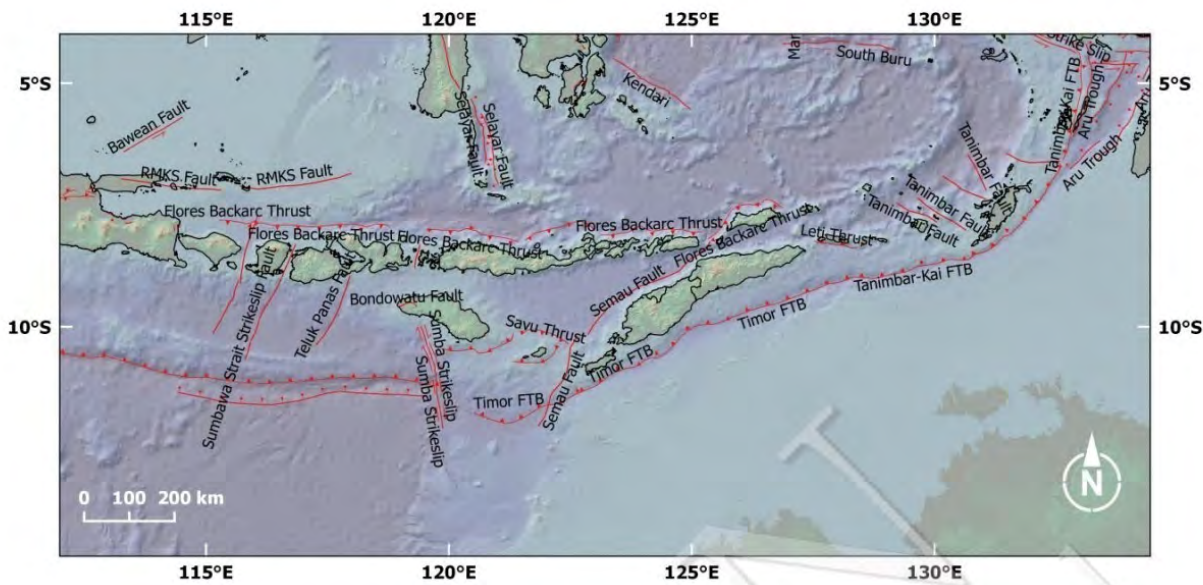


1. Data related to earthquake risk, threat, capacity, and vulnerability from the <https://inarisk.bnppb.go.id/> link and data related to earthquake sources from https://drive.google.com/file/d/1xYrYWWAcxxDNrqrTmb_NUTP9yLZWCLBX/view link

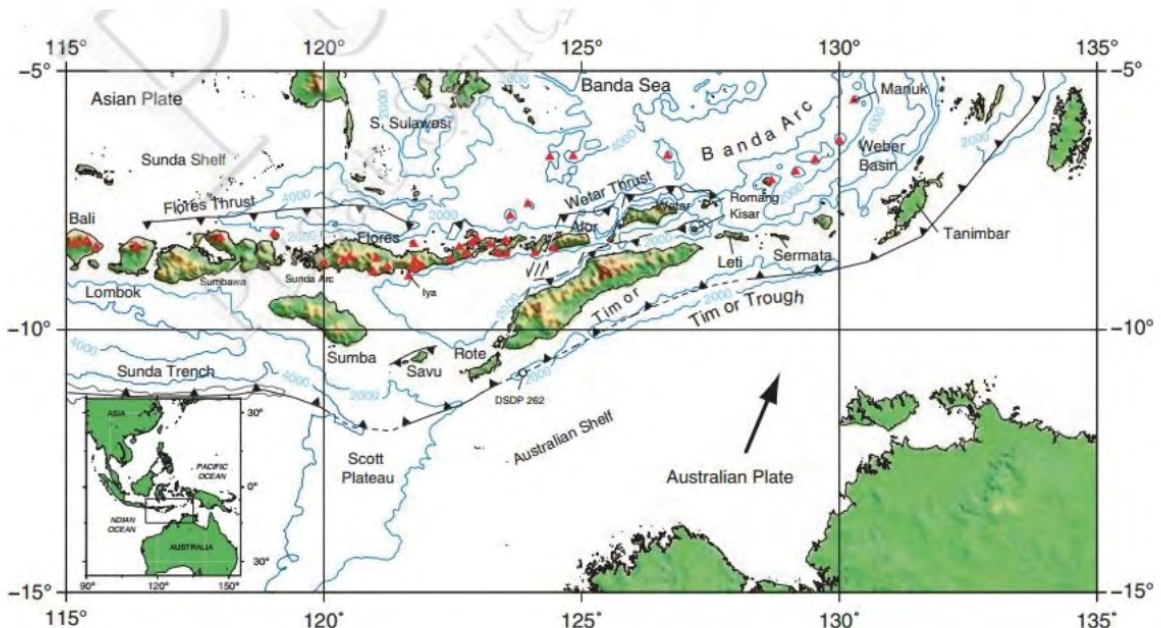
zone that is prone to various natural disasters such as earthquakes, tsunamis, floods and landslides (Wibowo, 2022). Complex geologic and climatologic factors make this region need special attention in infrastructure planning and management. One of the main hazards is earthquakes, which can be seen

from the earthquake hazard index map of InaRisk earthquake threat index map Figure 1 (Badan Nasional Penanggulangan Bencana, 2025). It can be seen from the figure that the Labuan Bajo area has a red zone spectrum, which means that the earthquake hazard index is in the high level. Earthquakes

Figure 2
Maps of Fault and Subduction zone of Labuan Bajo and Surrounding areas



Gambar II-28. Sesar Aktif Daerah Bali-Nusa Tenggara-Banda yang Terangkum Dalam Peta Gempa Nasional 2017



Gambar II-27. Konfigurasi daerah Bali - Nusa Tenggara dan Banda (Harris, 2011)

that occur in the region can be caused by tectonic activity along the subduction zone between the Indo-Australian Plate and the Eurasian Plate and the presence of several faults around the Labuan Bajo area as presented in Figure 2. These earthquake sources can cause significant structural damage to buildings and public infrastructure. In addition, the potential for tsunamis caused by submarine earthquakes also poses a serious threat to coastal communities, especially given the high level of marine tourism activity in the region.

In addition to hazards from tectonic activity, Labuan Bajo also faces hydrometeorological risks such as flooding and landslides. Heavy rainfall, especially during the rainy season, often triggers flooding in low-lying areas and landslides in hilly areas. Environmental degradation due to land conversion and deforestation exacerbates these risks, causing soil erosion and reduced water absorption by the

soil. Given these geohazards, effective mitigation measures are needed to reduce disaster risk and improve infrastructure resilience in Labuan Bajo. The development of earthquake-resistant infrastructure, tsunami early warning systems, improved drainage to reduce flood risk, and environmental rehabilitation to prevent landslides are some of the solutions that must be prioritized. With a holistic approach and based on risk mitigation, Labuan Bajo can continue to develop as a safe and sustainable tourist destination for the community and tourists (Fatina *et al.*, 2023). Beyond environmental concerns, weak infrastructure limits access to essential services such as clean water, energy, and transportation, particularly in remote islands. Many rely on costly, unsustainable diesel energy and lack proper waste management, further degrading their ecosystems. Addressing these issues is crucial to ensuring long-term economic stability, food security, and sustainable development.

State of the art

Indonesia's unique archipelagic context of over 17,000 islands has fostered specialized approaches to infrastructure resilience across eight strategic domains.

Climate-Resilient Infrastructure and Geological Hazards

Research by Triana and Wahyudi (2020) documents how rising sea levels disrupt river outflow in coastal areas. The Great Garuda sea wall project exemplifies integrated approaches that work "in tandem with natural restoration." Studies in Labuan Bajo by Taris and Rastika (2025) identify how "incomplete drainage infrastructure" exacerbates flooding during high tides, proposing retarding basins and sustainable drainage solutions. Tetteh *et al.* (2025) further recommend real-time monitoring systems and geo-technical techniques for landslide risk reduction.

Affordable and Community-Based Solutions

Current approaches prioritize accessible technologies for remote islands that are still dependent on "expensive and polluting diesel generators." The Cirata Floating Solar Plant demonstrates scalable

renewable solutions, while hybrid energy systems combining solar with bioenergy from agricultural waste offer a 24/7 electricity supply. These approaches reduce fossil fuel dependence while creating locally manageable infrastructure.

Nature-Based Solutions

Nehren *et al.* (2023) highlight the effectiveness of ecosystem-based approaches, particularly "utilizing mangrove forests as natural protection against tsunamis." Research shows that these solutions provide sustainable protection while preserving biodiversity. Integrating ecosystem-based design principles supports "harmony with environmental sustainability" while engaging communities in implementation.

Water Security and Management

Water management research addresses comprehensive needs from "provision and distribution of clean water" to "maintenance of water infrastructure." Studies emphasize rainwater harvesting systems, solar-powered desalination, and greywater recycling for agriculture. Watershed and groundwater protection through reforestation and controlled land use emerges as essential for long-term water security.

Disaster Preparedness and Early Warning Systems

Given Indonesia's exposure to "tsunamis, cyclones, and earthquakes," research prioritizes low-cost early warning systems incorporating indigenous knowledge. Studies recommend improved evacuation plans and designated shelters, particularly for remote areas where "external aid may be delayed." Strengthened telecommunications and satellite-based communication networks ensure vital connections during disasters.

Practical and Low-Cost Transportation Solutions

Transportation resilience prioritizes "improving ferry connectivity" and "maintaining small-scale fishing ports" over costly electrification. Research emphasizes durable road infrastructure using "locally available materials like compacted gravel or stabilized earth." Strengthened river and coastal transport systems help connect small islands to larger economic centers.

Circular Economy and Waste Management

The research addresses "waste accumulation in Indonesia's islands" through community-led recycling,

plastic repurposing, and composting programs. Waste-to-energy solutions, particularly biogas generation from organic waste, provide dual benefits. Studies emphasize marine pollution law enforcement to protect coastal ecosystems critical to island resilience.

Policy and Governance for Long-Term Resilience

Governance frameworks emphasize "locally-led planning with active community involvement" in decision-making. Research recommends optimizing "village funds (Dana Desa)" for infrastructure resilience while strengthening public-private partnerships. Integrating disaster risk reduction into local land-use planning ensures sustainable development aligned with community needs and environmental constraints.

This balanced approach reflects Indonesia's distinctive infrastructure resilience paradigm, combining technical innovation, ecosystem-based solutions, and community engagement to address the complex challenges of island territories.

Prospective insight design for infrastructure resilience

The following outlines a comprehensive research program applying a four-phase methodology (Cue González *et al.*, 2023, 2024, 2025) to address Indonesia's infrastructure resilience challenges.

Phase 1: Problem Definition

The research begins by formalizing the problem using the canonical formulation: "Will climate change and geological hazard-driven evolution of the physical and systemic risks significantly affect the operational performance of coastal infrastructure located in Indonesian archipelagic regions within the next 30 years?" This precise framing guides structured data collection across four key dimensions. Hazards and exposure assessment will document climate-related threats like sea level rise affecting coastal infrastructure as identified by Triana and Wahyudi

(2020), alongside geological hazards prevalent in Indonesia's seismically active regions. Absorptive capacity will be evaluated through a detailed analysis of infrastructure condition, maintenance history, and response to past disruptions, particularly in vulnerable locations like Labuan Bajo that experienced flooding in early 2025. Infrastructure characteristics, including age, materials, design standards, and network criticality, will be cataloged. Territorial context analysis will examine socio-economic factors, governance structures, and community dependency on specific infrastructure systems. This comprehensive data collection enables identifying and characterizing key parameter classes with their associated conditions, creating a foundation for subsequent analysis.

Phase 2: Scenario Building

The second phase employs General Morphological Analysis to construct comprehensive future scenarios. Using the data collected in Phase 1, a morphological box will represent the universe of possible scenarios by mapping key parameters and their potential states. Parameters will include climate projections, geological activity patterns, infrastructure deterioration rates, maintenance regimes, governance capacity, and resource availability. Cross-consistency assessment will refine this universe of possibilities by evaluating parameter interactions and eliminating contradictory combinations. This process identifies a solution space of feasible context scenarios representing plausible futures for Indonesian infrastructure. This refined set selects representative scenarios for detailed analysis, focusing on high-priority infrastructure in vulnerable regions like coastal urban centers, tourism-dependent islands, including the Komodo National Park area, and critical transportation links between islands. These scenarios form the analytical foundation for resilience assessment and adaptation planning.

Phase 3: Resilience Assessment

The third phase leverages the context scenarios to assess critical infrastructure resilience through iterative modeling. Models will examine how disaster risks affect infrastructure throughout its lifespan, incorporating degradation patterns, failure thresholds, and interconnected system dynamics. The assessment will evaluate how infrastructure like coastal protection systems, water management facilities, transportation networks, and energy systems respond to disruptions under different climate and geological hazard scenarios. Various maintenance decision alternatives will be modeled, from reactive approaches to proactive resilience enhancement strategies, such as the nature-based solutions high-

lighted by Nehren *et al.* (2023) and the drainage solutions proposed by Taris and Rastika (2025). The analysis will account for resource constraints, implementation timeframes, and cross-sectoral impacts. This phase produces decision scenarios that reflect different adaptation strategies, providing a quantitative basis for comparing infrastructure investment options across multiple futures.

Phase 4: Decision Support Development

The final phase translates decision scenarios into actionable insights for infrastructure planning and management in Indonesia's island context. Research results are integrated with performance assessment frameworks that evaluate technical effectiveness, economic efficiency, social equity, and environmental sustainability. For each decision scenario, key performance indicators are calculated to assess effectiveness in reducing infrastructure vulnerability, feasibility within resource constraints, and long-term impacts on development goals. The assessment will specifically address the eight strategic domains identified in the state of the art, evaluating how proposed interventions address climate-resilient infrastructure needs, community-based solutions, nature-based approaches, water security, disaster preparedness, transportation resilience, waste management, and governance requirements. This comprehensive evaluation supports evidence-based decision-making by providing quantitative and qualitative data on trade-offs between different adaptation options, ultimately informing Indonesia's national infrastructure resilience strategy with scientifically robust recommendations.

This four-phase methodology creates a systematic approach to enhancing Indonesia's infrastructure resilience. It translates scientific analysis into practical adaptation strategies that address the unique challenges of the world's largest archipelagic nation.

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Integrating Multi-Hazard Risk Analysis into Spatial Planning for Ecotourism Destination in Archipelago Countries: Case Study of Labuan Bajo

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Introduction

Ecotourism destinations in archipelago countries, such as Indonesia, are highly vulnerable to multiple natural hazards, including earthquakes, tsunamis, landslides, and coastal flooding. Labuan Bajo, a key tourism hub in Indonesia, exemplifies these challenges, as its rapid development must balance environmental conservation, local economic benefits, and disaster risk management. Integrating multi-hazard risk analysis into spatial planning is crucial to ensuring sustainable and resilient development in such high-risk areas. It's also an imperative requirement to uphold an image of safety and trust, which is essential to foresting international ecotourism.

Integrating multi-hazard risk analysis into spatial planning necessitates the use of comprehensive risk assessment systems, dynamic models, socio-economic-environmental-infrastructure data integration, and advanced decision support systems (Chang *et al.*, 2023). These approaches ensure that spatial design is informed by a complete aware-

ness of multi-hazard hazards, resulting in long-term development and disaster resilience. However, using multi-hazard risk analysis in spatial planning at a comprehensive level involves some substantial problems.

Despite its importance, implementing multi-hazard risk analysis within spatial planning presents significant challenges, including methodological complexities, data limitations, and practical issues (Buck & Summers, 2020; Hadianti *et al.*, 2021; Kappescet *et al.*, 2012). These challenges are further amplified in developing nations with limited resources and institutional capacities. Understanding how to overcome these barriers in places like Labuan Bajo can provide valuable insights for other ecotourism destinations in archipelagic settings. This study explores the integration of multi-hazard risk analysis into spatial planning for Labuan Bajo, highlighting the potential strategies, benefits, and obstacles in achieving sustainable ecotourism development.

Context

Since the establishment of Labuan Bajo (Indonesia) as a Super Priority Tourism Destination (Destinasi Pariwisata Super Prioritas, DPSP) Labuan Bajo has experienced rapid development in multiple aspects. This strategic status, granted by the Government of Indonesia, has catalyzed investment in tourism, transport, and hospitality infrastructure, positioning Labuan Bajo as a gateway to the Komodo National Park and a global ecotourism icon. Yet, this rapid development trajectory brings heightened exposure to socio-environmental vulnerabilities, particularly given the region's geographic and ecological fragility. Furthermore, the area has geographical challenges (archipelago), limited regional carrying capacity, and a high risk of disaster (BNPB, 2023; Sejati *et al.*, 2023).

Labuan Bajo is situated within an archipelagic and seismically active zone, characterized by a mosaic of small islands, steep terrain, and limited infrastructure redundancy. These topographical and geomorphological conditions, combined with high-intensity rainfall patterns and tectonic insta-

bility, render the area highly susceptible to a range of natural hazards – such as earthquakes, landslides, tsunamis, and coastal flooding (BNPB, 2023; Sejati *et al.*, 2023). Moreover, the increasing concentration of tourism assets and population in hazard-prone zones has intensified both exposure and vulnerability, straining local environmental carrying capacity and service delivery systems.

However, Indonesia (including Labuan Bajo) has made progress in integrating multi-hazard risk analysis into spatial planning, structural obstacles such as data fragmentation and governance gaps. The availability of disaggregated, real-time risk data and its translation into spatial and regulatory instruments is still inconsistent across sub-national jurisdictions. Discrepancy in data management systems, overlapping institutional mandates, and limited inter-agency coordination continue to hinder effective risk mainstreaming at the local level (Djalante *et al.*, 2019; UNDP, 2020). To protect its expanding population and accomplish sustainable development, it will be essential to give priority to technology-

driven, adaptable, and participative techniques. Success depends on promoting cross-sector cooperation and coordinating national policies with local context (Labuan Bajo).

Given these challenges, advancing a risk-informed development agenda in Labuan Bajo will require a transition toward technology-driven, adaptive, and participatory spatial governance models. This implies leveraging innovations in remote sensing, geospatial analytics, and early warning systems to build predictive and interactive risk platforms. More importantly, these technical solutions must be embedded within institutional frameworks that prioritize inter-sectoral collaboration and iterative learning.

Cross-sector collaboration – particularly between local governments, national planning bodies, tourism authorities, and disaster risk management (DRM) agencies – is a critical enabler of this agenda. Currently, institutional siloing often leads to fragmented planning outcomes where tourism growth and risk reduction strategies are misaligned. Therefore, fostering integrated planning platforms and multi-level governance arrangements will be essential to ensure that resilience considerations are embedded within the spatial and economic blueprint of the DPSP program (Pardede *et al.*, 2022).

Equally vital is the alignment of national DRM policies and development priorities with local contexts.

The success of spatial risk integration in Labuan Bajo hinges on translating national resilience objectives – such as those articulated in Indonesia’s RPJMN (Rencana Pembangunan Jangka Menengah Nasional, National Medium-Term Development Plan) – into structured planning instruments that customized to the region’s distinct ecological, cultural, and socio-economic dynamics.

Furthermore, inclusive decision-making processes must be institutionalized. Inclusive decision-making means ensuring that local community voices, including those of marginalized and indigenous populations, are reflected within the spatial strategies. Participatory planning approaches not only improve the relevance and acceptance of risk-informed policies but also contribute to social capital formation and collective resilience. Organisations, whether local, national or international, all have a crucial role to play in supporting these processes and ensuring that the voices of the most vulnerable communities are heard and included.

In sum, the path forward for Labuan Bajo lies in constructing a locally grounded, technologically enhanced, and governance-sensitive approach to multi-hazard risk integration. By strategically aligning policy, practice, and community engagement, the region can chart a development trajectory that safeguards both its populations and its ecotourism potential—positioning itself as a model of sustainable and resilient development in Southeast Asia.

State of the art

The development of comprehensive multi-hazard risk frameworks is a consistent theme, reflecting the need for holistic approaches to disaster risk management (Zhou & Zhai, 2023). These frameworks aim to integrate various risk factors and provide a unified methodology for assessing and mitigating risks.

Current research places a strong emphasis on data-driven, interactive, and comprehensive methods for integrating multi-hazard resilience into spatial planning (Maragno *et al.*, 2023; Senevirathne *et al.*, 2024). Interoperable data platforms for decision support systems and adaptable governance frameworks are essential for future research and development.

Recent advancements in research emphasize the incorporation of data-driven, interactive, and real-time methods for embedding resilience within spatial planning systems. Technologies such as remote sensing, geographic information systems (GIS), machine learning (ML), and sensor-based hazard detection have considerably enhanced the granularity and timeliness of risk assessments (Maragno *et al.*, 2023). For example, ML algorithms have been applied to landslide susceptibility mapping in tropical and subtropical environments, offering predictive capacity based on dynamic environmental indicators (Hong *et al.*, 2021). Similarly, real-time flood monitoring systems have enabled predictive urban drainage planning and early warning deploy-

ment in coastal urban centres (Senevirathne *et al.*, 2024).

A parallel development in this domain is the creation of interoperable data platforms that support dynamic decision-making under uncertainty. These platforms enable multi-stakeholder access to real-time hazard, exposure, and vulnerability data and have proven instrumental in coordinating cross-agency responses. Notably, platforms such as InaRISK in Indonesia demonstrate how risk data integration can be institutionalized into national disaster planning protocols (BNPB, 2021). The integration of such systems into local planning processes is critical for ensuring that hazard and vulnerability assessments influence zoning, infrastructure development, and contingency planning.

Equally significant is the focus on governance and institutional adaptability. Effective implementation of multi-hazard frameworks depends on adaptive governance systems that are capable of iterative learning, cross-sectoral coordination, and responsive policy adjustments. Research suggests that rigid institutional structures often fail to accommodate evolving hazard landscapes, particularly under conditions of compound and cascading risks (Djalante *et al.*, 2019). Consequently, emerging governance models emphasize decentralisation, polycentricity, and participatory approaches, wherein local stakeholders, including community-based organisations and indigenous groups, are embedded in decision-making processes (Pahl-Wostl, 2019).

Preparation and inter-organizational coordination are crucial elements in effectively managing large-scale disasters (Björck *et al.*, 2024). The effective implementation of multi-hazard frameworks directly contributes to the establishment of crisis management capabilities and the resilience of organizations and territories. Considering the multi-hazards framework as an interorganizational collaborative framework, three interoperability pillars need to be considered: interoperability in terms of technical systems, organizational systems, and social

systems. A lack of interoperability will hamper the capacity to rapidly respond to the disaster's immediate and long term consequences (Johansson *et al.*, 2024).

This adaptive governance paradigm is particularly relevant for tourist destinations in archipelagic contexts, such as Labuan Bajo in East Nusa Tenggara, where environmental fragility intersects with rapid development. The influx of tourism-related infrastructure development poses risks of maladaptation, especially when not aligned with hazard-prone landscapes and community resilience capacities. There is growing advocacy for place-based decision-support tools that incorporate local socio-ecological dynamics into scenario modelling and planning (Thomalla *et al.*, 2018). These tools should also facilitate participatory planning methods that integrate indigenous knowledge systems with scientific assessments, ensuring greater legitimacy and sustainability of interventions.

Looking forward, research is increasingly converging around three priority areas. First, the enhancement of data interoperability and standardisation across national and local agencies to streamline multi-hazard assessments. Second, the co-production of knowledge with communities, integrating citizen science, participatory GIS, and mobile data collection to ensure that risk assessments reflect lived experiences. Third, the development of robust, transparent, and adaptive decision-support systems tailored for use in ecotourism and conservation-sensitive regions. These systems should not only improve operational response but also inform long-term land use and development planning.

In conclusion, the state of the art in multi-hazard risk frameworks reveals a maturing convergence of technological innovation, institutional reform, and participatory methodologies. As climate-related and socio-environmental risks intensify, particularly in vulnerable tourism-dependent areas, future research and policy must continue to promote integrative and context-sensitive resilience planning.

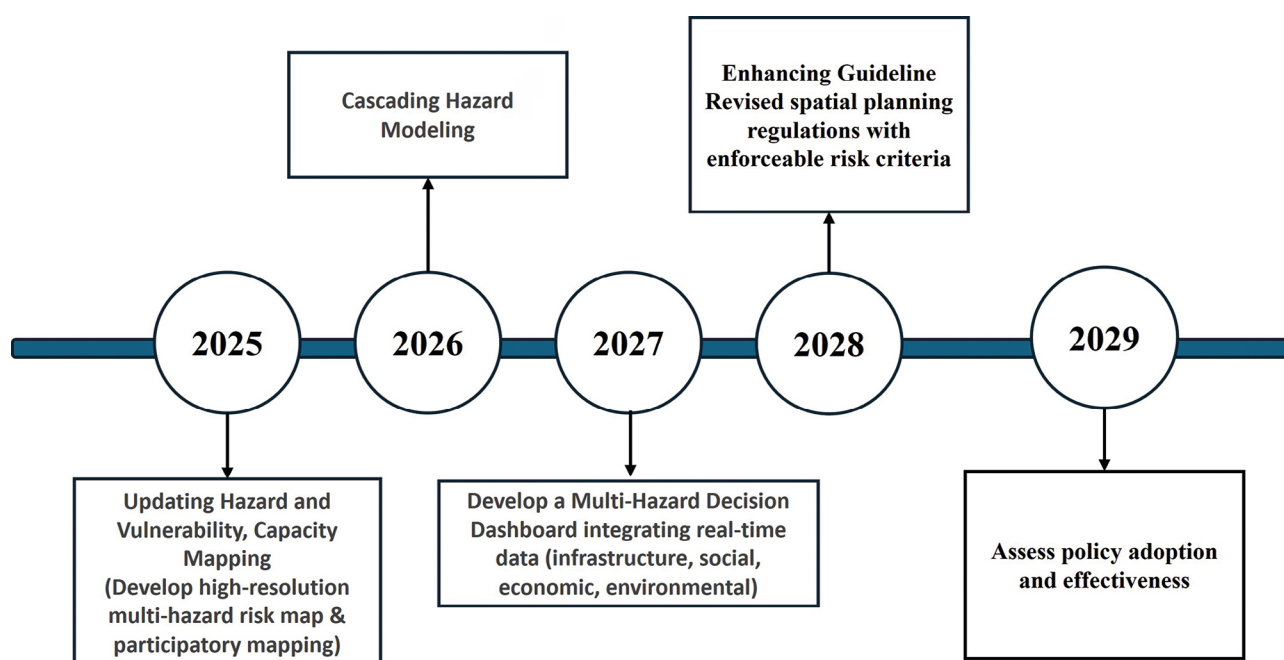
Strategic roadmap for integrating multi-hazard risk analysis into spatial planning for Labuan Bajo (2025–2029)

The strategic roadmap for integrating multi-hazard risk analysis into spatial planning for Labuan Bajo (2025–2029) presented in Figure 3 underscores a phased and adaptive framework, built upon institutional learning, participatory governance, and data-

ta-enhanced decision-making. This roadmap aligns with Indonesia's national disaster risk reduction priorities under the Sendai Framework and reflects an applied research-practice continuum that is critical for risk-sensitive tourism development in the region.

Figure 3

The strategic roadmap for integrating multi-hazard risk analysis into spatial planning for Labuan Bajo (2025–2029)



2025 – Hazard and Vulnerability Data Enhancement

The foundational year of 2025 is centered on advancing the resolution, reliability, and relevance of hazard and vulnerability mapping. Current limitations in spatial and temporal data granularity present a critical bottleneck for localized risk assessments. Therefore, a core research and practitioner priority is the co-development of high-resolution multi-hazard risk maps that integrate both historical data and real-time inputs, including topography, hydrology, land use, and socio-demo-

graphic vulnerability (Maragno *et al.*, 2023; BNPB, 2021).

Participatory risk mapping will also be foregrounded, ensuring local knowledge is captured through structured stakeholder engagement with communities, tourism operators, and local government units. Such participatory geospatial methodologies enhance the legitimacy and contextualization of scientific data (Gaillard & Mercer, 2013). Moreover, this stage necessitates investment in technical capacity building to enable local actors to operate geospatial and risk mapping tools independently.

2026 – Cascading Hazard Modelling and Scenario Analysis

In 2026, the focus will pivot to the development of cascading hazard models that simulate interdependencies and trigger mechanisms between geophysical and climate-related hazards. In the context of Labuan Bajo, potential scenarios include earthquake-induced landslides and tsunami sequences, exacerbated by coastal development and topographic constraints.

These models must account for compound hazards – an area still underexplored in Southeast Asian contexts (Gill & Malamud, 2014) – through stochastic simulation and scenario-based planning methods. A significant research challenge lies in quantifying uncertainties and inter-hazard feedback loops within these models. Practitioners, meanwhile, will require usable interfaces to translate technical outputs into actionable spatial plans, hazard zoning, and building code revisions.

2027 – Multi-Hazard Decision Dashboard Implementation

The 2027 milestone involves the operationalization of a Multi-Hazard Decision Dashboard. This decision-support system (DSS) will integrate real-time data streams– including meteorological, seismic, infrastructure, and socio-economic indicators – into a centralized platform to assist planning authorities and emergency managers in dynamic risk appraisal and land-use decision-making.

Research questions in this phase include: how can DSS tools be calibrated to local decision-making needs and cognitive frames? How can uncertainty be visualized for non-technical users? Practitioner concerns will center on system interoperability, institutional uptake, and the digital governance capacity to sustain the dashboard’s functions. Lessons from similar systems, such as Japan’s Disaster Information Management System (DIMS), may offer transferable design and governance models (UN-DRR, 2020).

2028 – Regulatory and Institutional Reforms

By 2028, regulatory integration becomes the focal area. Spatial planning laws, environmental licensing, and tourism development controls will be reviewed and revised to include enforceable disaster risk metrics. Research will need to assess the effectiveness of existing risk regulations and identify policy gaps in hazard-sensitive development control.

On the practitioner front, this phase will require institutional coordination among the Ministry of Agrarian Affairs and Spatial Planning (ATR/BPN), BNPB, and regional planning agencies (Bappeda). Regulatory harmonization, standard operating procedures, and risk-informed spatial planning guidelines must be embedded in statutory instruments and local ordinances. Attention must also be paid to land tenure complexities and the rights of indigenous and coastal communities.

2029 – Policy Evaluation and Strategic Recalibration

The final year, 2029, is dedicated to assessing the outcomes of prior interventions. This includes evaluating the effectiveness of regulatory frameworks, stakeholder adoption of risk tools, and measurable improvements in resilience metrics. Mixed-methods evaluations – combining spatial impact assessments, policy analysis, and community perception surveys –will be essential to triangulate performance across sectors.

This phase also opens new research frontiers: how have tourism development pathways shifted in response to risk-sensitive planning? Are there observable reductions in exposure and vulnerability? Such findings will inform strategic recalibrations for the next planning cycle and institutionalize a feedback loop in spatial governance. A key issue at stake will be embedding resilience monitoring as a permanent function within local governance mechanisms.

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Risk Communication Approach for Safety Tourism

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Introduction

Comprising over 17,000 islands, Indonesia provides amazing travel spots worldwide. The risk information for specific use in tourism activities is already there at some point. However, it is not yet fully formulated for overall tourism activities, such as over-tourism in some specific areas in Indonesia. For instance, Labuan Bajo in East Nusa Tenggara is a stunning tourist destination vulnerable to geological, hydrological, and meteorological risks. Nearly 42 disaster events, including extreme weather, floods, landslides, wildfires, and volcanic eruptions, have been reported in East Nusa Tenggara by the National Disaster Management Agency since February 2024. There were 27 fatalities, 66 injuries, 454 house collapses, 11,015 inundations, and eight essential infrastructures damaged as a result of the incident. Typhoons and floods are the most common disasters in the region, according to InaRisk BNPB, but landslides and droughts have also been prevalent since 2009¹. The national and provincial governments have produced a general risk map for the region because it is exposed to various threats. However, the distribution of risk information is limited only to its evacuation mechanism during emergencies.

The most productive industries in East Nusa Tenggara, with a population of 5,452,547, are agriculture and fishing (26.7%)². While several significant national destinations, tourism and services also form a substantial portion of the regional economy. East Nusa Tenggara's abundance of fantastic tourist destinations enables them to prepare their local setting for consumption by people worldwide. The influx of visitors presents an over-tourism problem

1. <https://gis.bnpb.go.id>

2. <https://ntt.bps.go.id/id>

for the localities. Over tourism typically demonstrates two sides of a coin phenomenon: on the one hand, it helps to strengthen economic sectors, while on the other, it has adverse environmental effects. In addition to being exposed to several risks, East Nusa Tenggara is a vulnerable place for its residents.

As an archipelago, the local dwellers, who are also vulnerable groups, generate a culture of preparedness and response that are specific and unique. When we discuss the local dwellers, we are sure their local experience and contexts are prominent in describing the culture of resilience they performed. Now, we also deal with several tourists from across the globe who experience East Nusa Tenggara.

Labuan Bajo, such as a tourist destination, travelers may not expect or pay attention to the potential risks surrounding them. Travelers may view specific tourist locations as a safe space for enjoyable activities, in contrast to anticipated or perceived threats. According to Mair *et al.* (2016), risk communication with tourists is not considered enough in the literature on tourism risk management. The government must develop appropriate tourism-oriented communication strategies considering the diversity of stakeholder characteristics.

According to other research (Liu-Lastres, B *et al.* 2019, Wang, J *et al.* 2019), numerous tourist locations lack tourist-oriented risk communication techniques, which mainly focus on locals' information processing and search. On the other hand, there hasn't been enough discussion of how visitors seek and interpret risk information. Tourists frequently live in unfamiliar places, lack readily available support systems during crises, and lack the knowledge to comprehend communication information.

Context

A resilient community is expected to be able to withstand, recover, and rebuild towards sustainable livelihood post-disaster occurrence. Risk communication is a means, process, and result of a resilient community. Information exchange, collecting opinions, and advice sharing involve multiple par-

ties, from the local community to the government (WHO). The process presents parts of communicating and transferring knowledge in correlation with hazards, vulnerability, capacity, and risk within a time frame context.

Communicating risk faces challenges in effectively engaging people to minimize risk and distrust (Fathollahzadeh *et al.*, 2024), potentially due to a lack of precise or accurate information in correlation with communication mechanisms. The early warning system is an essential means to bridge in-

formation between scientists and the local people or community at disaster-prone areas, where the government also plays the authority to mobilize resources to minimize risk.

In terms of the research context, Table 1 describes the research matrix.

Table 1
Research Matrix

Goals	Approach	Indicators	Expected Result
Understanding characteristics of existing risk communication in the research area (UGM)	Qualitative Research	Available risk information; Source of information; Mechanism of transmission for the information	Descriptive Model
Examining the potential framework for developing effective risk communication for the research area (UGM)	Mix Qualitative & Quantitative	Ancillary data on historical occurrence, available infrastructure for disaster mitigation, early warning system (EWS), Risk Map; Another possible planning document for disaster management, government budget	Matrix on enabling environment and supporting tools
		Local perception of disaster; Local understanding of disaster mitigation; Local capacity for disaster reduction; Social modalities	Matrix on knowledge structure to risk communication
To understand the risk perception from local dweller and tourist in the research area (UI)	Mix Qualitative & Quantitative	Local dweller and tourist perception on disaster risk, practice they do to figure out the disaster risk	Descriptive Model

State of the art

The risk communication for safety tourism is somewhat challenging. At one tipping point, it is crucial to strengthen awareness, while at the other continuum, it relates to social concerns, even social riots that may appeal during the spread of information. The Figure 4 indicates shifting paradigms, approaches, and mechanisms in dealing with risk information.

The shifting paradigm from disaster management to disaster risk reduction highlights its latest imple-

mentation. In the disaster management paradigm, most of the attention is responding to any emergency situation. Meanwhile, disaster risk management has notably put insight into the importance of precautionary principles, even in emergencies (UNDRR, 2019b, 2019a, 2024).

During the earlier days, disaster information was available in times of disaster or post-disaster to tackle disaster impacts. Meanwhile, the risk information is supposedly available far before the predicted oc-

Figure 4
 Maps of Fault and Subduction zone of Labuan Bajo and Surrounding areas



currence (called hazard or threat potentials). The hazard information is equipped with vulnerability information whereas we claimed that these potential elements will be subjected to hazard if not doing any precaution, adaptation or mitigation (Widyarako & Hizbaron, 2020). The information on hazard and vulnerability generally overlaid into risk information comprising the information upon the potential of loss, damage, and destruction in monetary units. This risk information is often equipped with a list of things that can be carried out under any emergency, which is called preparedness (Agustin & Marta, 2019). The proposed intermediate framework is to pursue disaster resilience, which put much focus upon the community to withstand, recover, and rebuild towards sustainable livelihood post disaster occurrence especially in the tourism sector.

In the most recent development, the risk information is not only formulated using technocratic approach by scientists or authorities, it can also carry

out using participatory approach (Agustin & Marta, 2019; Shaw *et al.*, 2009). The civic society is well taken to join the whole process of data collection, data analysis even decision-making process using early warning mechanism, precautionary tools in a format of Citizen Science. The technocratic approach leaves a very critical point where the civic society as the user of the information generally being left out and concern about the result of the information, also possible to cause stir and questioning to the information. Meanwhile, the participatory approach brings much softer approach whereas the civic society are also able to be engaged at the very early stage of information gathering, so that they are part of the information making itself.

Here, among much of the changes, the risk information also facing so much transformation due to the supporting infrastructure such as internet. Before the social media strongly and globally influence internet-based civilization, risk information was diffi-

cult to access due to its sensitive-value. The non-value-free information is limited to only authority and or scientific community to access the data. Therefore, the rights to understand the risk information is often regulate in top-down manners, whereas the civic society only able to follow the instruction during emergency situation and or during preparedness. After the Covid-19 pandemic, the global use to internet has been significantly increasing, which cause stir to global use to social media as well. The overcrowded data put so much pressure to assure which one is right or wrong? Here, the openness of the information is opening widely through the social media and websites. The limited data transcend into open access data, with abundant source of data called big data come into surface (Pang *et al.*, n.d.; Ruz *et al.*, 2020a, 2020b; Widyanarko & Hizbaron,

2020). Data acquisition using script algorithm has been carried out widely to transfer its meaning using sentiment analysis, or any other semantic analytics (Salsabilla & Hizbaron, 2021; Widyanarko & Hizbaron, 2020). The data originated from diverse source is not yet an information if it is not validated by the authorities. The civic society are able to access any kind of data, which also led to lots of opinion, rumors even false information. Thus, current challenge to develop a risk information framework to create safer tourism will requires not only the use of classical data but also need to also rethinking on the use of abundant “big data” with validated and curated analytics for public information. The fundamental information often influences mitigation and adaptation strategies using verified big data and participatory Decision Support Systems.

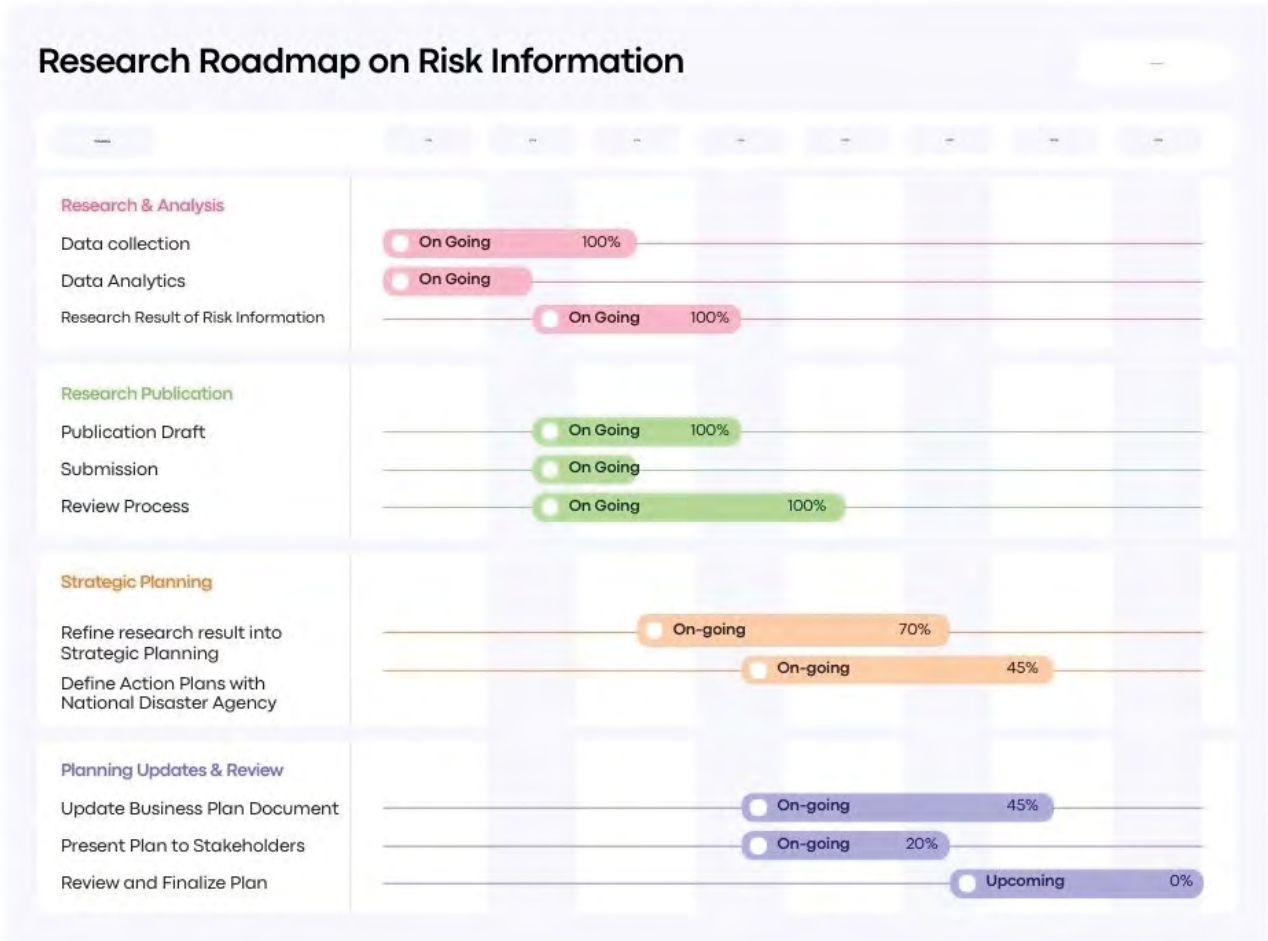
Developing safer tourism using risk-based information survey in the five forthcoming years

The fundamental basis for developing safer tourism using risk-based information has recently gained much attention. The idea is to integrate risk-based management into all sectors, including tourism. The global mandate to sustain all development sectors also puts more homework on each local to the national government to pursue the availability of risk information infrastructure, guidelines, regulations, and its implementation.

The research team has formulated a roadmap to conduct research and produce scientific evidence to support the science-policy process in the long run (1-5 years) in the [Figure 5](#) below.

The roadmap of the research indicated that during the year 2025–2026 the research will focus to develop spatial-statistic and participatory model to effective risk information and communication for the research area. In further milestone, yea 2026–2027 the research aimed to generate science-based policy based on the scientific publication which fundamental to be verified at the policy level. The strategic planning of current disaster management in the area needs to be evaluated during 2027–2028 in order to see the gap with the proposed model of risk information and communication that has been formulated. Hence, in 2028–2029, the research team tries to formulate review to the existing planning in general so that the implementation of the risk information and communication are feasible for the area.

Figure 5
 Research Roadmap on Risk Information



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Digital Tools for Disaster Preparedness: Evaluating Messaging vs. Application Approaches for Hazard-Specific and Territory-Focused Devices

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Introduction

Natural hazards pose significant risks to local populations and tourists, which can be mitigated through Information Technology (IT-based) solutions for timely communication and coordination. Modern technologies such as Geographic Information Systems (GIS) and remote sensing enable real-time flood monitoring and damage assessment, which are critical for directing evacuation efforts and resource allocation (Singkran, 2017). Platforms like the United Nations Virtual OSOCC have demonstrated how centralized ICT systems improve inter-agency coordination during disasters (Bjerge *et al.*, 2016). Social media analytics further enhance situational awareness by allowing authorities to identify affected areas through geotagged posts and sentiment analysis (Suhaimin *et al.*, 2023). However, linguistic and technological barriers remain significant challenges, particularly for tourists unfamiliar with local warning systems. Studies on travelers' attitudes toward machine translation suggest that effective tools, such as multilingual mobile alerts and AI-driven translators, can help overcome these obstacles and improve the overall travel experience (Carvalho *et al.*, 2023).

Current IT-based hazard management tools vary in their approach, with some focusing on a specific hazard (e.g., earthquakes, tsunamis) and others covering an entire geographic area (e.g., islands, cities). Hazard-specific systems like flood risk mapping using multi-criteria GIS analysis achieve 95% accuracy in predicting vulnerable zones but lack adaptability to other disaster types (Ahmed *et al.*, 2024). Conversely, territory-specific frameworks such as the urban hazard information system in Sulawesi, Indonesia, integrate various hazard data to support sustainable regional development, although the proposed system is constrained by the availability of high-quality data at the local level (Hizbaron *et al.*, 2024). The Global Disaster Alert and Coordination System (GDACS) serves as a prominent example of a multi-hazard platform; however, its overall effectiveness is contingent upon the integration of localized vulnerability assessments, highlighting the need to incorporate region-specific data to enhance disaster risk management efforts (Schoepfer *et al.*, 2024).

This study explores the trade-offs between hazard-specific and territory-specific IT tools, as well as the role of applications versus messaging systems in ensuring effective adoption and response. While unified platforms like Virtual OSOCC reduce coordination costs (Bjerge *et al.*, 2016), case studies show disaster-specific apps achieve higher user retention during crises compared to general-purpose systems (Aliperti & Cruz, 2020). The analysis reveals that tourist populations require simplified messaging interfaces with visual alerts, whereas residents benefit from detailed GIS-based preparedness apps (Chelariu *et al.*, 2022). A hybrid approach that combines Twitter data and official response has evolved from passive information gathering to actively supporting victim rescue efforts, offering enhanced communication and coordination during disasters (Aldamen & Hacimic, 2023).

The exploration of digital technologies for disaster anticipation in this study is structured within the context of a case study in Indonesia, specifically in Labuan Bajo. The discussion of the state of the art includes an integrated perspective across several advanced domains: Multi-Hazard Early Warning Systems (EWS), Disaster Management Systems with mobile and web-based integration, and the application of Artificial Intelligence and Machine Learning for disaster response and impact assessment. It also examines the role of Cloud Computing and Big Data in enabling scalable and efficient disaster management solutions, along with the potential of crowdsourcing and community-based approaches in building disaster resilience at the local level. Finally, the authors present challenges and visions for the coming years based on the relevance of these technologies to the regional disaster landscape and the need for adaptive, inclusive, and data-driven solutions that can support both local governments and communities in enhancing disaster preparedness and response capabilities. The vision for the next five years for digital tools in disaster preparedness is presented from the perspectives of Indonesia and Vietnam.

Assessing IT Solutions for Disaster Risk Management in Ecotourism Destinations: The Case of Labuan Bajo

Leveraging digital technologies for disaster risk reduction can enhance the efficiency and speed of disaster response, particularly in low-income communities (Müller *et al.*, 2024). In line with this, a case study in Labuan Bajo, an ecotourism area prone to natural hazards, was conducted to examine the appropriate implementation of IT tools for hazard and disaster management. The study highlights the potential of context-specific digital solutions to strengthen early warning systems, support local coordination, and enhance resilience in tourism-dependent and archipelago countries. Labuan Bajo, located on the western tip of Flores, Indonesia, is a rapidly growing ecotourism destination known for its proximity to Komodo National Park. However, the region is exposed to multiple natural hazards due to its geographic and tectonic setting. The region lies within a tectonically active zone, making it susceptible to frequent seismic activities that pose risks to infrastructure and human safety. For example, the Flores Back-Arc Thrust has been identified as a major source of earthquake and tsunami risk in the area (Sianipar *et al.*, 2022). In addition to tectonic hazards, the region frequently experiences heavy monsoonal rainfall that leads to flash floods and landslides, especially in its hilly terrain (Rumambi & Sari, 2023). These recurring threats highlight the urgent need for robust disaster anticipation strategies tailored to the region's unique environmental and social context. As a tourist hub, Labuan Bajo's hazard management efforts must account for the transient nature of visitors, many of whom are unfamiliar with local risks and emergency procedures.

Currently, several national and local disaster information systems are available to be applied in Labuan Bajo, though their reach and effectiveness vary significantly. One of the primary tools is the Early Warning System (EWS) operated by Indonesia's Meteorological, Climatological, and Geophysical Agency (Badan Meteorologi, Klimatologi, dan Geofisika [BMKG]), which includes the Indonesian Tsunami Early Warning System (InaTEWS)³. This system uses real-time seismic and sea-level monitoring

to issue alerts for potential earthquake and tsunami events (BMKG, 2012). While robust in its technical capacity, the delivery of these alerts remains limited by infrastructure constraints and user accessibility, particularly among non-Indonesian speakers. Another important platform is InaRISK⁴, developed by the National Disaster Management Agency (Badan Nasional Penanggulangan Bencana [BNPB]). InaRISK offers a public-facing portal and mobile app that provides detailed hazard maps, risk indices, and recommended mitigation actions for various types of hazards, including floods, landslides, and earthquakes (Suharini *et al.*, 2023). However, the interface and communication are designed mainly for Indonesian residents and stakeholders, with limited features to support the specific needs of foreign tourists, such as multilingual support or travel-specific advisories.

On a more grassroots level, local communities and businesses in Lombok, an island located near Labuan Bajo, have adopted informal mechanisms such as WhatsApp groups or Instagram to circulate emergency updates and weather warnings. These channels, while fast and widely used, lack official verification and central coordination, raising concerns about the accuracy and consistency of the shared information (Nurjanah, 2023). Although BMKG has established official WhatsApp broadcasting services at the national level, there is no guarantee that residents or tourists are subscribed or aware of them, especially given the diversity of languages and the transient nature of tourist populations. Additionally, physical signage and evacuation maps are often the only source of hazard information available to tourists upon arrival. These are typically found in hotels, airports, and seaports. While useful in static conditions, such materials are not always updated to reflect real-time hazards or evolving risk levels during an ongoing event (Putera *et al.*, 2025). Moreover, these maps and signs often lack contextual instructions or multilingual content, limiting their effectiveness in guiding international visitors during emergencies.

3. <https://inatews.bmkg.go.id>

4. <https://inarisk.bnpb.go.id>

Despite the presence of these tools, several critical challenges remain in ensuring effective disaster communication in Labuan Bajo. These include inconsistent integration across platforms, lack of real-time localization for tourist itineraries, language barriers, and limited connectivity in remote or off-

shore areas. There is a growing need to unify official alert systems, local channels, and multilingual interfaces into a more cohesive, user-centered early warning ecosystem to improve disaster preparedness in tourism hotspots like Labuan Bajo.

State of The Art: Digital Tools and Supports for Disaster Preparedness

In the field of disaster preparedness, digital tools play a pivotal role in enhancing early warning systems, response coordination, and community resilience. These tools can be broadly categorized into messaging-based systems and application-based platforms, each tailored to address specific hazards or designed for comprehensive territorial coverage. Understanding the functionalities and implementations of these tools is crucial for optimizing their adoption and effectiveness.

Multi-Hazard Early Warning Systems (EWS)

Advancements in EWS have integrated technologies such as the Internet of Things (IoT), machine learning, and cloud-based data processing to detect and alert various hazards, including earthquakes, tsunamis, floods, and extreme weather events. For instance, the ShakeAlert system⁵ developed by the U.S. Geological Survey (USGS), utilizes seismic sensors to detect earthquakes and provide alerts before significant shaking occurs, thereby mitigating potential damages and casualties (McGuire *et al.*, 2025). Similarly, Google's Flood Hub⁶ employs satellite imagery and AI-based hydrological models to predict and warn about floods in real-time, particularly benefiting regions susceptible to sudden inundations (Google Research, n.d.). These systems exemplify hazard-specific applications that deliver targeted alerts to populations at risk. Nonetheless, their coverage remains limited primarily to major urban centers. For instance, as of April 10, 2025, no flooding data was available for Labuan Bajo, indicating the area is currently unsupported.

5. <https://www.shakealert.org>

6. <https://sites.research.google/floods>

Disaster Management Systems with Mobile and Web Integration

Mobile and web-based platforms have become indispensable in managing disasters by leveraging Geographic Information Systems (GIS), big data, and cloud computing mixed with national policy to enhance response coordination. Indonesia's InaRISK web-based platform, for example, provides hazard maps, mitigation recommendations, and preparedness guidelines for multiple disaster types, serving as a comprehensive tool for both authorities and the public (Suharini *et al.*, 2023). In the United States, the Federal Emergency Management Agency (FEMA) offers a mobile app⁷ that delivers real-time emergency alerts, disaster preparedness information, and localized hazard notifications, facilitating timely and informed decision-making during crises. These platforms represent territory-focused applications designed to cater to the disaster management needs of specific regions.

Artificial Intelligence (AI) and Machine Learning for Disaster Response and Impact Assessment

The integration of AI and machine learning has significantly advanced disaster management capabilities by enabling predictive modeling, automated risk assessment, and real-time damage evaluation. AI-driven models can predict earthquake aftershocks, tsunami wave propagation, storm intensity, and flood risks by analyzing real-time sensor data, thereby enhancing preparedness and response strategies (Norisugi *et al.*, 2024). Additionally, AI-enhanced satellite imagery analysis is employed to estimate infrastructure damage and map affected areas post-disaster, facilitating efficient allocation

7. <https://www.fema.gov/about/news-multimedia/mobile-products>

of resources and recovery efforts (Singh & Hoskere, 2023). Furthermore, AI-powered chatbots and virtual assistants, such as ERMES, provide automated guidance to affected populations, assisting them in accessing shelters, emergency contacts, and first aid instructions during emergencies (Urbanelli *et al.*, 2024). Similarly, the American Red Cross introduced Clara⁸, a disaster response chatbot designed to guide disaster survivors to assistance and resources, including locating shelters and obtaining financial aid. Clara operates in both English and Spanish, demonstrating the importance of multilingual support in emergency response. Moreover, with the advancement of Large Language Models (LLMs) and Retrieval-Augmented Generation (RAG) techniques, it is now possible to develop more sophisticated and context-aware virtual assistants that can deliver tailored information based on national policies, local regulations, and indigenous knowledge.

Cloud Computing and Big Data for Scalable Disaster Response

The utilization of cloud computing and big data has enabled large-scale disaster monitoring and response coordination. Platforms like Google Crisis Response⁹ integrate crowdsourced reports, government alerts, and AI-driven analytics to provide a comprehensive overview of disaster situations, aiding in informed decision-making and resource deployment. Similarly, IBM's initiatives leverage AI-powered predictive modeling to optimize emergency response, logistics, and resource allocation based on disaster impact simulations, demonstrating the potential of cloud-based solutions in enhancing disaster resilience (Talley, 2020). Open Data Initiatives for disaster management have also enabled researchers to contribute more effectively to scalable disaster response efforts. For example, government and humanitarian organi-

8. <https://www.redcross.org/get-help/disaster-relief-and-recovery-services/meet-clara>

9. <https://crisisresponse.google>

zations are increasingly utilizing open-access data to enhance emergency planning, as demonstrated by NASA's Disasters Data Hub¹⁰.

Crowdsourcing and Community-Based Disaster Resilience

Citizen science initiatives by crowdsourced and social media-based platforms have become integral to modern disaster response strategies by enabling rapid, localized, and real-time information sharing from affected populations. Platforms like OpenStreetMap and the Humanitarian OpenStreetMap Team (HOT)¹¹ engage volunteers in mapping disaster-affected areas, improving emergency response and recovery efforts through detailed and up-to-date geographic data (Soden & Palen, 2014). Ushahidi, a platform originating in Kenya, collects and visualizes emergency reports through SMS and online submissions, allowing local communities to contribute directly to crisis mapping efforts (Meier, 2015). Similarly, Facebook Crisis Response¹² and Google SOS Alerts¹³ provide social media users with tools to mark themselves safe, receive real-time disaster updates, and access local emergency services during a crisis (Palen & Hughes, 2018). Another example is LastQuake¹⁴, which gathers eyewitness reports of earthquakes globally by analyzing online search behavior within seconds of seismic events. It uses visual communication, such as cartoons, to crowdsource personal experiences, map earthquake impacts, and deliver safety tips related to both earthquakes and tsunamis (Bossu *et al.*, 2018). These community-driven approaches underscore the importance of integrating local knowledge and participation in disaster preparedness and response strategies.

10. <https://www.earthdata.nasa.gov/data/projects/lance/hazards-and-disasters>

11. <https://www.hotosm.org>

12. <https://www.facebook.com/about/crisisresponse>

13. <https://support.google.com/sosalerts>

14. <https://m.emsc.eu>

Challenges in Risk Communication

Informing tourists about risks, whether natural (earthquakes, tsunamis, hurricanes) or security-related (theft, disease, conflict), is a challenge for several reasons. Depending on their region of origin, they may be completely unaware of certain risks

and may not understand their seriousness, while local tourism stakeholders may be tempted to minimize risks. Finally, language barriers and even a lack of trust in local authorities can exacerbate these difficulties.

A risk communication strategy that relies on tourists spontaneously seeking information is doomed to failure. The first element of the solution is to make the developed tools available in physical and digital places of obligatory passage, such as train stations, airports or visa application sites, travel agency sites, or transport ticket purchase sites. The second element is to provide interactive, engaging, and easy-to-understand information (e.g., using visual communication) for people who are unfamiliar with the local geography and culture. The number of tools should be kept to a minimum. No tourist will install an app for earthquakes, another for weather, and a third for tsunamis. The information provided should not be limited to prevention. In the event of a risk or perceived risk, the tool must cover all the information needs of tourists: safety instructions, behavior to avoid, and even psychological support to help them through the ordeal. Ideally, this tool should not be limited to risks, in order to avoid a possible (conscious or unconscious) rejection reaction, but should be integrated into a one-stop shop for tourists, a “travel companion” where they can find all the information they need for a smooth trip. Although these principles are relatively simple, their application is complex and requires excellent knowledge of local actors and contexts, as well as considerable integration work.

Vision for the Next Five Years in Indonesia

Indonesia is actively advancing its disaster preparedness strategies by integrating digital tools and technologies. The nation’s vision for the next five years emphasizes the development and implementation of innovative solutions to enhance resilience and response capabilities. A key component of this vision is the “ICT Roadmap on Disaster Management for 2025 and Beyond”, developed by the ASEAN Coordinating Centre for Humanitarian Assistance on Disaster Management (AHA Centre). This roadmap serves as a guideline to align ICT initiatives with organizational plans and strategic directions, aiming to ensure that

ICT infrastructure and solutions effectively support disaster management efforts. It emphasizes the importance of data sharing, partner engagement, and the development of integrated information systems among ASEAN Member States (AHA Centre, 2023). In line with this roadmap, Indonesia’s National Disaster Management Authority (BNPB) has been focusing on enhancing early warning systems and disaster risk assessments. Partnerships with institutions such as the Pacific Disaster Center (PDC) have resulted in thorough assessments, including the National Disaster Preparedness Baseline Assessment (NDPBA), which takes into account Indonesia’s 2025–2029 National Disaster Management Plan (RENAS-PB) as well as Regional Disaster Management Plans (RPB) at the local level (Pacific Disaster Center, 2020).

Vision for the Next Five Years in Vietnam

In the coming five years, Vietnam aims to significantly enhance its disaster preparedness and resilience in ecotourism and vulnerable coastal areas by developing integrated IT-based tools tailored to both local communities and international tourists. The vision includes the deployment of user-friendly, multilingual platforms that consolidate early warning systems, real-time hazard updates, and emergency guidance into a single, intuitive interface – acting as a “digital travel companion.” These tools will be strategically integrated into physical and digital touchpoints such as airports, travel websites, and transport hubs to ensure proactive engagement. A focus on visual communication, AI-driven personalization, and psychological support features will help overcome language, cultural, and informational barriers. To realize this, Vietnam must foster collaboration among local authorities, tourism stakeholders, and technology developers, creating a scalable, context-aware IT ecosystem that ensures no one – resident or tourist – is left unprepared in the face of natural hazards.

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Ability of situational awareness AIs to adapt to changing situations and information needs¹⁵

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Introduction

The acceleration and diversification of contemporary crises – including natural disasters, global pandemics, cyber-attacks and geopolitical conflicts – necessitate a re-evaluation of crisis management methodologies, with an emphasis on the capacity to comprehend and predict intricate, volatile scenarios in real-time. Effective decision-making in crisis situations necessitates the capacity to analyze voluminous data streams in real time, while addressing the distinct and evolving requirements of a diverse range of decision-makers (operational, tactical, strategic). Situational awareness (SA), as defined by (Endsley, 1995), is the three-stage process of perceiving, understanding and projecting events into the future. It has become the foundation of effective, coordinated decision-making. For over a decade, the crisis management community has been interested in using artificial intelligence (AI) to support decision-makers and their information needs during the SA process (Palen *et al.*, 2020). With massive data processing capabilities, AI, especially recent deep and machine learning approaches, sound indeed ideal allies for situation awareness, enabling data streams to be interpreted on the fly to produce situational models, and leaving the focus on the decision-making process itself (Benaben *et al.*, 2020). However, existing AI systems, which are often specialized for a given type of crisis or user, encounter difficulties in maintaining rele-

vant SA in the face of unpredictable dynamics, such as those generated by climate change. The development of an AI for each type of crisis or for each type of decision-making user is not only costly, but also inflexible, unable to absorb the growing unpredictability of crisis contexts (Montarnal *et al.*, 2024). In response to this need for flexibility, there has been a strategic focus on the development of adaptive AIs, which are capable of adjusting their decision-making behaviour in real-time just as the metacognitive abilities of a human being. In response to the fragmentation of AI, recent research has proposed the integration of adaptive and bio-inspired multi-agent AIs, incorporating perceptual learning, symbolic reasoning, and cognitive interaction mechanisms to feed a multidimensional AS, adjusted to the strategic, tactical, or operational roles of potential users (Montarnal *et al.*, 2024).

This Topic “Ability of situational awareness AIs to adapt to changing situations and information needs” aims at investigating two main challenges: Defining the informational needs of decision-makers in Vietnam and Indonesia when facing a crisis situation ; Consolidating the works initiated by (Montarnal *et al.*, 2024) in designing a new multi AI agents framework able to adapt to new contexts and decision levels.

Context

Two of Southeast Asia’s most climate-vulnerable nations are Vietnam and Indonesia, which are dealing with more complicated environmental issues like wildfires, regular flooding, rising sea levels, and tropical storms. Rapid urbanization, ecological deterioration, and sociopolitical diversity all contribute to these disasters, creating extremely dynamic and unpredictable crisis situations. Traditional static crisis management technologies find it difficult to adapt to these situations and the ever-changing information needs. Decision-makers generally ope-

rate in fragmented ecosystems where data flows are varied, and operational responses must be agile and scalable across strategic, tactical, and field levels. Because of this unpredictability, technology systems must be able to continuously sense and analyze their surroundings, updating their priorities and models in real time. The dynamic risk environment in both nations emphasizes how urgently adaptive AI systems that can work well in quickly changing, data-intensive environments are needed, particularly for crisis response, mitigation, and resilience building.

State of the Art

Real-time situational awareness systems that not only analyze data at scale but also change with the crisis setting are necessary in Indonesia and Vietnam due to the rapidly shifting environmental and social conditions, such as flash floods in Jakarta or the salinization of the Mekong Delta. The meta-cognitive flexibility necessary to adjust to the changing nature of such events is lacking in traditional crisis-response AI systems, which are usually rule-based or limited in their training. Promising remedies for this gap are provided by newly developed adaptive AI systems.

Artificial intelligence (AI) is built to continuously incorporate new environmental data, such as social media alerts, disaster bulletins, or rainfall patterns, and modify its behavior through feedback loops. Specifically, bio-inspired and neuro-symbolic architectures are being investigated to facilitate this dynamic adaptation. These methods allow AI to simultaneously support operational, tactical, and strategic decision-making levels, adapt internal

models depending on new field realities, and learn from incomplete and unclear data.

This is especially true in places where the crises are complex and change in unanticipated ways, like Vietnam and Indonesia. Bio-inspired multi-agent frameworks, for instance, provide decentralized yet coherent interpretations of complicated environments by imitating human cognitive flexibility. By combining several incomplete models into a cohesive and useful situational awareness, these AIs employ techniques similar to cortical column voting, which enables more contextually aware and informed decision-making.

By converting AI from passive data processors into situationally aware agents that can adapt to the setting in which they are used, the implementation of such systems in Southeast Asian contexts has the potential to completely change the way local governments and foreign assistance organizations handle crises.

On neuro-symbolic AI approaches

Although not new, neuro-symbolic AI approaches are currently undergoing a revival in tandem with advances in connectionist AI. The temptation is great to hybridize these two approaches in order to benefit from the advantages of each paradigm. (Hitzler *et al.*, 2022) notes a second reason for this flourishing, coming directly from the cognitive sciences: “we can understand artificial neural networks as an abstraction of the physical workings of the brain, while we can understand formal logic as an abstraction of what we perceive, through introspection”. (Wang *et al.*, 2023) exposes the ability of human metacognition to juggle 4 dimensions of symbolism and connectionism: Symbols vs Neurons, Deduction vs Induction, System 1 vs System 2 and Compositionality vs Continuity. The first two dimensions are fairly common, and the third one was already introduced in the neuroscience problem statement of this proposal and is further documented in the next paragraph. Continuity refers to the sequential activation of neurons in a continuous but variable signal (nota-

bly in the “weight” of information circulating) transmitted from neuron to neuron. Compositionality refers to the encoding of information in more or less large structures, enabling the generation of composite knowledge representations at variable levels of abstraction. In light of this, the literature shows that neuro-symbolic systems are particularly promising for implementing a form of artificial metacognition, as argued in (Montarnal *et al.*, 2024).

Recent articles such as (Booch *et al.*, 2021; Dong *et al.*, 2019) show efforts have been made in this direction. That said, (Wang *et al.*, 2023) notes that no hybridization paradigm currently allows us to effectively address the 4 dimensions between symbolism and connectionism sought in the human metacognition process. Based on neuroscientific observations and physiological evidence, Hawkins *et al.* (Hawkins *et al.*, 2017) defends bio-inspired cognitive AIs built on a three-layered framework found in the human neocortex. *Neurons* transmit information in a distributed

and loose way. *Cortical columns* are “functional units of information processing” that perceive data from the environment and process it through a back-and-forth circulation in its neural networks and provide specific atomic models of sub-systems of the environment (i.e. one partial point of view model). Cortical columns would thus produce a partial symbolic representation. Hawkins’ theory is based on Mountcastle’s observation of short and long-range connections between cortical columns and suggests the existence of a *voting process* by which the thousands of models produced by cortical columns offering different points of view of the same environment can be reconciled into a single, also stable, perception of the environment (Hawkins *et al.*, 2017; Mountcastle,

1997). This theory can be directly related to the inhibition theory of System 3, proposed in By Houde & Borst (Houdé & Borst, 2015). (Hole & Ahmad, 2021) proposes a bio-inspired AI architecture based on Hawkins’ theory, with promising properties such as continuous learning, integration of contextual data, multiple predictions, and support for a new paradigm resistant to neural loss, i.e. an ability to rely on compound units rather than a single network. While not achieving yet the metacognition levels aimed by this proposal, this enthusiasm for neuro-inspired AIs definitely shows promising possibilities and the need for an executive system to pilot the current AI units is extremely topical, as stressed by (LeCun, 2022).

Transdisciplinary vision at stakes for the five forthcoming years

Two main challenges were raised in introduction and will lead to complementary activities.

Defining the dynamics of crises in Vietnam and Indonesia and investigating the informational needs

This survey concerns the conceptualization of the end-users needs, in particular in terms of situational awareness i.e., in our case, the ability of the AI system to automatically extract actionable information from heterogeneous data flows.

It implies two main actions: field observation and interviews and Metamodeling of the information

needs of Vietnamese and Indonesian crisis management stakeholders

Proposing a new multi-agent framework embedding a bio-inspired executive system to adapt data processing to the specific needs of users and crisis contexts

This second set of activities relies aims at proposing a new framework, implementing a framework on a specific case as a POC, and testing this framework during an exercise.

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Optimizing Tsunami Evacuation Plans through Geospatial Analysis and Local Knowledge in Lampung, Indonesia

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Introduction

Indonesia is one of the countries most exposed to tsunami risk in the world, due to its location on the Pacific Ring of Fire. Faced with this recurring threat, the ability to effectively organize mass evacuation is a vital issue for coastal populations. However, standard evacuation systems show their limits in contexts with high territorial, social, and cultural complexity (Wisner, 2009). It is now widely acknowledged that crisis management strategies must be

rooted in local realities, incorporate community knowledge, and be co-developed with field actors to be effective (Gaillard J.C. et Mercer J., 2012; Dé, L. L., Defosse, S., & Leone, F., 2020). This roadmap aims to outline the major directions of a five-year action-research program in Indonesia, focusing on the province of Lampung, to optimize tsunami evacuation plans using geospatial data, traditional practices, and innovative modeling techniques.

The Lampung Province context

The province of Lampung, located at the southern tip of Sumatra, is directly exposed to potential tsunamis resulting from the subduction of the Indo-Australian Plate beneath the Eurasian Plate (Hartoko *et al.*, 2016; Supendi *et al.*, 2023). It is experiencing rapid population growth and increasing coastal density, heightening both physical and human vulnerabilities (Freire & Aubrecht, 2012; Mayaguezz *et al.*, 2023). Its population is charac-

terized by significant ethnic and linguistic diversity, along with strong community structures-factors that must be incorporated into emergency planning (Bird, Gisladdottir & Dominey-Howes, 2011). The project, led by the University of Lampung (UNILA) and Paul-Valéry Montpellier 3 University (UPVM3), builds on this reality to develop tsunami risk management tools that combine advanced mapping and local knowledge.

State of the art

Tsunami risk - Lampung Province

The megathrust subduction zone along the west coast of Lampung Province to the southern part of Banten Province is a seismic gap area, storing tectonic energy without release, which could trigger tsunamis up to 34 meters high (Hartoko *et al.*, 2016; Supendi *et al.*, 2023).

The high population density in the coastal areas of Lampung increases the tsunami risk (Freire & Aubrecht, 2012; Mayaguezz *et al.*, 2023). The latest tsunami occurred in late 2018, caused by the natural flank failure by the eruption of Mount Anak Krakatau (Ye *et al.*, 2020; Luthfi *et al.*, 2020). This event stands out as an anomalous and alarming event in Indonesia's disaster history. Unlike the more frequent tsunamis caused by tectonic earthquakes, this event highlighted the limitations of conventional early

warning systems, which are often not calibrated to detect volcanic-induced tsunamis in real time. As a result, it has prompted a rethinking among scientists, local authorities, and national stakeholders about the scope and design of tsunami early warning strategies in volcanic regions. In this context, the development and integration of detailed vulnerability and hazard maps have become crucial tools – not only to anticipate future risks, but also to guide land use planning, evacuation protocols, and community preparedness in high-risk coastal zones.

For Disaster Risk Reduction (DRR), preventive, mitigation, and preparedness measures are needed, involving all stakeholders (Putera *et al.*, 2016). Mapping plays a crucial role in tsunami evacuation planning (Papathoma-Köhle *et al.*, 2016; Cienfuegos *et al.*, 2024). The success of these tools depends on taking account of local knowledge and co-construct-

tion processes involving the groups of stakeholders involved in risk management.

This approach is all the more important given that a large part of the country's economy is based on tourism, the number of which has declined in the region following the 2018 event. The main reason for this is the lack of security guarantees. Community preparedness, early warning systems, evacuation routes and shelters on small islands where tourist destinations are very important (Persada & Rusmiati 2021).

Integrating local knowledge into tsunami evacuation planning

The evacuation process is a complex one, with the aim of integrating all its operational, cultural and social facets. Over and above the forecasts on which the plan is based, it is important to anticipate deviations from the evacuation model that has been constructed, and unexpected behaviour on the part of the population (Roudier, 2023). For example, spontaneous evacuations or refusals to evacuate are two well-known scenarios that affect the effectiveness of plans. This was the case in Japan in 2011 (Murakami *et al.*, 2012; Yun and Hamada, 2012), but also in Indonesia in December 2018. Of course, these refusal factors are not exclusive to the tsunami risk. The men of Pulau Pasaran, after helping women and children to evacuate, returned to protect the island from potential thieves (Roudier, 2023). Similar behaviour occurred in La Palma during the Tajogaite eruption in 2021 (Rey *et al.*, 2023). Domestic or livestock animals are also a factor in the reluctance to evacuate. Geographical location is also a factor. Some sites are particularly sensitive and offer few possibilities in terms of horizontal evacuation. As a result, it is sometimes difficult to act/react in the time available (Roudier, 2023; Péroche, 2016).

Formalising these evacuation processes involves building dedicated maps. However, creating these maps can be complex, and involves both technical and social challenges. Their design, integration and application depend on a number of criteria. The researcher therefore needs to consider the veracity of the data as well as the design and cartographic semiology employed (Bertin, 1967). The result is the ability to read and interpret/appropriate the data, which is essential for good coordination between stakeholders and communities. This capacity is influenced by a cognitive schema that enables users to perceive, interpret and memorise visual data,

thus facilitating pattern recognition and efficient navigation through maps. Cultural aspects are important because they determine how people perceive and interpret symbols, colours and shapes on a map. Cartographic conventions can vary from one country to another, influencing how information is understood. User experience is also essential, as it influences their ability to understand and use maps effectively (Candela, 2021).

Maps must be understandable and properly implemented during a disaster, considering the ethnic and linguistic differences of the population (Li *et al.*, 2024). Collaboration between local stakeholders, local governments, NGOs, and international institutions is essential to strengthen the information network and disaster response (Oktari *et al.*, 2018).

Numerous studies (scientific and institutional) have focused on the knowledge and practices of traditional communities, also known as indigenous or folk, in disaster risk reduction (Mercer *et al.*, 2010). And their knowledge contributes to their capacities to effectively cope with natural hazards (Gaillard 2007; Le Masson et Kelman 2010; McNamara and Prasad 2014). Their ability to cope with and recover from hazards also depends on several characteristics such as land use, customs, social practices, and preservation of their traditional knowledge. For example, indigenous fisherfolk survived a magnitude 8.1 earthquake and subsequent tsunami that hit the western Solomon Island in 2007 (Lauer, 2012). So, traditional societies have demonstrated their ability to develop adapted responses to natural disasters, for example by spontaneously evacuating to a safe place (Arnold, 2017).

Traditional knowledge integrated, through a participatory approach, into the design of evacuation plans would improve the appropriation and acceptability of these tools by local populations. In fact, if traditional knowledge, is the preferred prism for accounting for the cultural dimension of risk (Roudier, 2023). For evacuations, their usefulness is recognized (Gaillard *et al.*, 2011; Mayaguezz, 2016, 2017; Péroche, 2016; UNESCO/IOC, 2022), but prospects for integration remain limited. Territories such as Lampung province aim to increase their tourism potential. As a result, these temporary populations will be exposed to risks. And with no experience of natural phenomena, and little knowledge of the territory, they are considered vulnerable (Burby & Wagner, 1996). Yet it has been shown that, when a disaster occurs, tourists rely on the local population to take care of them.

Figure 6
Participatory mapping exercise in Kunjir (Roudier V., 2023)



Figure 7
Results of a participatory mapping exercise in Kunjir (Roudier V., 2023)



Perspective of a local method for a global coastal community issue

A central focus will be optimizing evacuation routes using realistic spatio-temporal models that incorporate topographic features, actual movement speeds, and available infrastructure (Wood & Schmidtlein, 2012; Bonilauri *et al.*, 2021; Tsai & Chang, 2023). The EXPLOIT method, developed by Leone and Péroche (2014, 2013), will be at the heart of this modeling, identifying the most effective paths according to different classes of roads (streets, trails, paths accessible to two-wheelers).

Integrating sociocultural specificities into the construction of plans is a second key challenge. Ethnographic studies, conducted using qualitative and “thick description” methods (Geertz, 1973), aim to

understand risk perceptions, relationships to authority, and community dynamics in all their complexity. The goal is to produce evacuation maps and materials adapted to different social groups, including culturally appropriate symbols (Candela, 2021, Li *et al.*, 2024; Gilles *et al.*, 2017; Jaenichen & Schandler, 2017; Bertin, 1967).

The third challenge is community-based: training and empowering resilience groups capable of ensuring continuity in risk management (Bird *et al.*, 2011). The inclusion of women, the elderly, and people with disabilities must be ensured (UNDRR, 2022), along with targeted awareness efforts in multiple languages (Li *et al.*, 2024).

Figure 6 Example of a tsunami evacuation plan produced in Kunjir using a participatory approach, then represented using a standardized graphic chart (Roudier V., 2023)



The fourth challenge concerns digital tools: interactive, offline-accessible applications based on ArcGIS Online will allow users to calculate their optimal evacuation routes in real-world situations (Chen *et al.*, 2022; Commission, 2020).

By encouraging this collaborative approach between local communities, governments and state institutions, this project hopes to improve the sustainability of the system, in particular by promoting the UNESCO/IOC 'Tsunami Ready' recognition through the economic aspects linked to tourism and the need to guarantee the safety of this non-permanent population. It may also be possible to adapt certain indicators from the international Tsunami Ready recognition to create an internal recognition system for hotel establishments, thereby encouraging a more serious consideration of this hazard. As they are in direct contact with the tourist population, hotel establishments and their staff form an essential link in the chain of ensuring the safety of visitors in the event of a tsunami. Such an initiative had already been implemented in Thailand in hotel establishments following the 2004 tsunami, and more recently, a similar approach has been successfully applied in the city of Cannes, where the tourism sector was engaged in tsunami preparedness through the signing of a specific charter by the main seafront establishments.

The integration of accurate, integrated mapping with socio-cultural ownership is essential for effective tsunami evacuation planning in Lampung province. By involving all stakeholders, sustainable strategies can be established to significantly improve the capacity of communities to respond to

tsunami threats, thereby contributing to the overall resilience and safety of the coastal population.

This participatory approach tested in Sumatra, in the Lampung region, has shown promising results in enhancing the relevance and effectiveness of tsunami response plans. Given the significant tsunami exposure of East Nusa Tenggara – particularly to events originating in the Flores Sea, such as the devastating tsunamis of 1977 and 1992 – this region represents a strategic area for scaling up this method. The rapidly developing tourist city of Labuan Bajo, in particular, would greatly benefit from such an initiative, as it combines high exposure to tsunami risk with the urgent need to align tourism growth with robust community-based disaster preparedness.

Partnership

This project is based on an interdisciplinary collaboration between the University of Lampung (UNILA), Paul-Valéry Montpellier 3 University (UMPV), and the National Research and Innovation Agency (BRIN). The teams bring together complementary expertise in geography, digital modeling, coastal management, and social sciences. UNILA and UPM3 have been actively collaborating for several years, with co-supervised PhDs, joint research projects, and publications on tsunami risks in Lampung, Mayotte, and other exposed regions. The LAGAM (UMPV) specializes in risk mapping, using tools such as EXPLOIT, which have been deployed in Mayotte, the Mediterranean, the Caribbean, and Indonesia. BRIN brings expertise in geomatics and spatial data management.

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Resilience of coastline to flooding and subsidence

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Introduction

The coastline is a natural area that is both rich and fragile. It is defined as the fluctuating interface between three interacting environments: land, sea and air. It is influenced in particular by geology, geomorphology, hydrology, hydrogeology, ecosystems and climatology. Climate change causes or amplifies the physical phenomena that affect each of the environments that make up our coastlines. As a result, it is a powerful vector for coastal transformation.

At the same time, these same areas are ideal for human activities. The sea is a source of economic wealth for coastal populations. Low-lying coasts are ideal for building dwellings and have been used as such for thousands of years. Economic exchange-

es are boosted by the possibilities offered by sea and river routes over ever greater distances. These coastal areas are very attractive for tourism, thanks to their natural landscapes and varied activities. What's more, these regions are often rich in cultural and historical heritage, adding an extra dimension to the tourist experience.

The challenge of ensuring the long-term occupation of coastal areas in the context of climate change now requires a systemic vision of these areas, acting on different spatial scales and at different timescales, getting different fields to work together, and dealing with the issues in their complexity and comprehensiveness. This is the purpose of a territorial resilience approach.

Context

Indonesia is heavily exposed to climate change and natural hazards. Among the natural hazards, flooding is the one that affects the greatest number of people. What's more, this risk is greatly affected and exacerbated by global warming, in terms of rising sea levels and marine submersion, as well as by the increase in heavy rainfall, which can cause river flooding or run-off in urban areas.

Semarang is the capital city of Central Java Province, with an urban population of approximately 1.7 million residents. It serves as a key administrative and economic center on the island of Java, playing a vital role in supporting national development, particularly in terms of industrialization. The Semarang agglomeration is situated along an urbanized coastal strip that is especially vulnerable to natural hazards, including flooding from continental overflows, runoff from urban areas, and rising sea levels (Villar *et al.*, 2016).

A significant issue facing the Semarang coastline is active soil subsidence (Yossie, 2023). This subsidence interacts with other natural hazards, such as submersion and erosion, exacerbated by the dynamics of urbanization and human activity. The consequences of subsidence and its associated processes are detrimental to both economic activities and the living conditions of local communities (Miladan, 2016). Furthermore, the pronounced subsidence of the coastal region heightens the risk of flooding.

These interconnected processes generate harmful effects on the quality of life and economic viability for residents. Enhancing resilience is essential to ensuring sustainable development in the area while adequately addressing the challenges posed by climate change.

State of the art

In its work on resilience, Cerema defines it as the ability to design a disaster prevention solution that is accepted by the majority of stakeholders and actively involves them in its implementation, while recognising that it cannot completely eliminate damage. In this sense, resilience differs from the concept of the sustainable city (Toubin, 2012) in that it takes into account the existence of processes that disorganise urban functioning; it acknowledges the inevitability of these disruptions, which must be anticipated in order to cope with and adapt to them.

A number of levers will help to make the region more resilient (Cerema, 2020):

- Think of the territory as a whole, crossing themes, time scales and territories;
- Encourage diversity and cooperation between local actors, so that they can learn from each other, build trust and develop appropriate collective responses;
- Encourage learning and innovation, to learn from the past and move forward collectively, by highlighting innovative solutions that break with conventional responses;
- Reduce vulnerabilities, bearing in mind that the challenges we face will continue to be damaging;
- Affirming specific regional characteristics, because building on a region's identity and strengths is essential to fostering its resilience;
- Promote monitoring and anticipation, by imagining the disruptions that could affect the region and the measures to be taken to prevent them; this will enable us to organise ourselves better so that we can get through future periods of turbulence.

Because of the challenges it faces, the city of Semarang is the subject of a great deal of scientific work defining action plans to increase its resilience. Hamdani *et al.*, (2020) stated that no specific zoning plans or development programs have been implemented. The preparedness in Semarang is a multifaceted and ongoing effort, currently at a moderate level (Findyani *et al.*, 2024). However, adaptations have only been temporary, and there is a lack of effective mitigation programs, monitoring, or even adequate measures related to the subsidence issue in Semarang (Andreas *et al.*, 2017). Instead of recognizing tidal flooding as a risk, the community

in the research area tends to overlook this hazard, believing that tidal flooding is no longer a threat to their well-being (Marfai & Hizbaron, 2011). Strong cooperation and commitment among stakeholders, along with an increased adaptive capacity of local communities, are essential (Wijaya, 2015).

From 2008 to 2010, the city of Semarang took part in an initiative as part of the Asian Climate Change Resilience Network (ACCCRN, 2010), which led to the proposal of a strategy and actions, broken down by key sector, namely: drinking water, infrastructure, the sea and fisheries, the environment, human resources and institutional development.

The approach adopted gave pride of place to group work, with local community actors, government agencies and specific organisations, to encourage strong ownership and integration of resilience planning processes into long-term urban planning.

The forward-looking vision has been based on climate and development scenarios, but lacks reliable knowledge of future phenomena linked to climate change.

Of the main actions proposed, 4 are considered to be priorities:

- Managing water resources in dry and vulnerable areas through rainwater harvesting,
- Disaster risk reduction by building shelters in flood-prone areas,
- The creation of the Centre for Cities and Climate Change, as an information and capacity-building centre,
- Managing domestic liquid waste to protect water resources.

In 2016, as part of the 100 Resilient Cities Programme (2016), which aims to help cities deal with three major challenges and threats - growing urbanisation, globalisation and climate change - the city of Semarang carried out new work to formulate a resilience strategy aimed at identifying the main risks and the best ways of dealing with them within its territory.

The work was carried out from late 2013 to mid-2016, involving a wide range of stakeholders, civil servants, academics, the business sector, young people and community representatives. It was supported by the establishment of a dedicated resil-

ience team within the council, and in particular a Head of Resilience.

53 initiatives have been identified to strengthen the city's resilience. They are structured around 6 pillars: sustainable water and energy, new economic opportunities, disaster and disease preparedness, integrated mobility, transparent public information and governance, and competitive human resources.

While some of the levers promoted by Cerema in its research work and in its operational applications in France can be found in the above-mentioned stud-

ies, some are largely under-dimensioned or even completely absent. This is the case in particular for the cooperative approach adopted by all the actors in the region in the development and implementation of actions, for the innovation that has not been emphasised enough above, and above all for the fact that the region is rich in history and identity, and that this is an essential lever for promoting its resilience.

Based on these findings, Cerema, Diponegoro University and AFD launched a project to increase Semarang's resilience to coastal subsidence and flooding risks.

Local coastal risk management strategy: development and implementation of a methodology adapted to the local context

Given the systemic nature of the phenomena that are having a lasting impact on the Semarang region, an approach that would unify all the initiatives, make the most of them, combine them and complete them with the missing links, that would mobilise all the actors to take up the current challenge together, and that would draw on the region's human and cultural resources, is needed to achieve significant results.

It consists of setting up actions with a view to :

- Acting for and with all stakeholders, by adapting strategies and local governance, and supporting cohesion and solidarity
- Preparing upstream to be able to react during, through knowledge, monitoring, preparation and innovation
- Agreeing on what is essential to protect it, sharing a common vision of the future, and agreeing to transform ourselves

To date, Cerema and Diponegoro University, with the financial support of the AFD, have embarked on this process via a project whose results will be (end 2025):

- A preliminary study of the feasibility of setting up a coastal risk observatory

An observatory can have several objectives, providing physical support (via a website, for example)

to the territorial resilience approach. In this way, an observatory can develop and disseminate knowledge, provide a link for exchange and consultation between stakeholders, and help to implement and monitor policies by providing specific expertise.

- An assessment of the resilience of the region to date in relation to these risks, based on a tool developed by Cerema called the Resilience Compass.
- A proposed strategy and action plan to manage these risks for and by all actors of the territory.

Unfortunately, as part of this project, this strategy and action plan cannot be co-constructed with local stakeholders, or even shared with them. The actions to follow would therefore be to ensure that all the stakeholders (local government, public institutions, population, associations, businesses, etc.) take ownership of these proposals, implement them, monitor and then assess these actions and, depending on the results, co-construct a new version of the strategy to move towards sustainable resilience in the area.

This work proposes an approach that can bring together all the actors, at the different territorial levels, through collective action.

In the longer term, the methods developed in the context of Semarang should be able to be used and implemented in other areas, in Indonesia on the one

hand, but also in other coastal areas subject to river and coastal flooding phenomena, which are exacerbated by climate change. The first step will be to capitalise on this experience, and then to study the possibility of reproducing, improving or even adapting it. Other experimental sites will be welcome for this phase.

At five years, the following actions could be carried out:

- The methods developed in the context of Semarang should be able to be used and implemented in other areas, in Indonesia on the one hand, but also in other coastal areas subject to river and coastal flooding phenomena, which are exacerbated by climate change. The first step will be to capitalise on this experience, and then to study the possibility of reproducing, improving or even adapting it ;
- This methodology will then need to be tested at a second site in Indonesia to consolidate the tools and methods in contact with other stakeholders, and to generalise the methodology to the Indonesian administrative and cultural context ;
- Finally, the methodology will be tested at one or more sites in Vietnam and adapted to the local and national context.

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Caroline Rizza (*Ed.*)

Part 2

Crisis Management and resilience of population in South-East Asia

Context & Risks

- + 11,5 Mio Tourists, + 54 Different Nationalities [3, 4]
- Highly exposed to Hazards such as Volcanic Eruption, Earthquakes, Tsunami [17]
- Excellent Mobile Network Coverage in Touristic Areas [8]
- Need of a **rapid alert delivery overcoming language barriers**

Proposed Approach : the United Nations EW4All Framework [15]




[19]

✓ Pillar 1: Disaster Risk Assessment
Strong disaster risk framework with multi-hazard assessments supported by solid legal and institutional foundations [11, 12, 14].

✓ Pillar 2: Detection, Monitoring & Forecasting
Existing Early Warning Systems (EWS) for Tsunami and Earthquake, Climate, and Meteorological hazards, (InaTEWS [9, 11, 12, 14], InaCEWS, and InaMEWS [11]).

✓ Pillar 3: Warning Dissemination
Governance : Local governments are responsible for starting evacuation, activating the sirens and ensuring that alerts reach the community at risk [14].
Existing Channels: SMS, fax, email, websites, warning receiver systems, social media, five smartphone applications [12], SMS blast and digital TV broadcast [13].

✓ Pillar 4: Preparedness to Respond
Hotels certified in disaster preparedness, and tourism-related businesses that provide evacuation-route facilities, as well as training for employees [10].
Establishment of the standards ISO 22327 (landslides) and ISO 22328-3 (tsunami) [2].



Tsunami Alerts Dissemination in Costal Touristic Areas

1. Tsunami alert infrastructures faced equipment failure, theft, damage, and poor maintenance [11].
2. Tsunami sirens and SMS alert system experienced failure during the 2018 earthquake and tsunami events in Palu, preventing the issue of evacuation warnings [14]
3. Multilingual & Multinational inclusive communication should be better addressed
4. “[...] **delays in information dissemination via SMS can have deadly consequences**” [14, p.14]



Proposition

Integrate the Multilanguage Cell-Broadcast (CB) Technology within the InaTEWS
CB is recognized as an effective channel for warning tourists in disaster-affected areas [16]:

- **Near Real-Time geolocalized alerts compatible with the roaming devices** of the tourists. Unlike traditional SMS, CB is not subjected to network congestion, critical during crisis time [1].
- **CB can deliver simultaneous multilingual alerts** [7] based on SIM nationality, as multilingual communication is essential for reaching foreign tourists and speeds up their arrival to shelters [5]. With AI-powered translation, alerts can reach tourists from all 54 nationalities in their own languages, ensuring clear and timely understanding of evacuation instructions [5].
- CB is **independent of new local infrastructures**, reducing the risk of poor maintenance and theft in the field [7].

First Analyze on the CB Integration : Policy & Funding

- **Regulation:** Indonesian regulations permit the direct dissemination of alerts to the public [6], though a specific review of CB regulations is required for further improvements.
- **Procedures:** Local government procedures for issuing evacuation warnings via CB need to be reviewed to enhance the speed and multilingual translation of alerts, facilitated through an alert origination interface [14].
- **Funding & Implementation** : The Multilanguage CB Technology implies initial investments. By **joining the EW4All Initiative**, Indonesia would gain access to funding opportunities and become part of a globally coordinated effort, aligning with its existing international partnerships on early warning systems [2, 12, 13, 17].

Conclusion

1. By joining the EW4All Initiative, Indonesia could access funding opportunities to strengthen its disaster management capabilities.
2. Integrating the CB technology within existing Indonesia EWS will enable timely, multilingual alerts, enhancing tourist safety in Indonesia.

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Sources



Toward Near Real-Time Multilingual Early Warnings to Protect Tourists in Indonesia

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Disaster-prone areas like Indonesia (World Bank, n.d.) face challenges in timely emergency communication, as traditional systems like SMS and sirens often experience delays or failures (Rahayu *et al.*, 2018; UN Office for Disaster Risk Reduction [UNDRR], 2019). The 2018 earthquake and tsunami in Palu, which resulted in more than 3,800 deaths, highlighted both the strengths and critical weaknesses of the existing Indonesian Early Warning System (EWS), as underlined by the UNDRR study case of Palu-Donggala (UNDRR, 2019). In 2023, more than 11.5 million foreign tourists from more than 54 different nationalities visited Indonesia (BPS-Statistics Indonesia, n.d.-a, n.d.-b), making the stakes even higher for an effective EWS, as language barriers and unfamiliarity with local hazards can put lives at greater risk during emergencies.

By applying the four pillars framework outlined by the Early Warning for All (EW4All) Initiative (UNDRR, n.d.) to the actual EWS of Indonesia, we concluded that Pillars 1 (Disaster Risk Assessment), 2 (Detection, Monitoring & Forecasting), and 4 (Preparedness to Respond) are relatively well-developed (Batam News Asia, 2024; Karnawati, 2022; Pacific Disaster Center, 2020; Rahayu *et al.*, 2018; Sadly, 2021; Tempo, 2024; UNDRR, 2019), though they still present areas for improvement. The poster addresses three

identified gaps of Pillar 3 (Warning Dissemination) concerning tourist's safety regarding high kinetic disasters: 1. Deterioration of local alert infrastructures (Rahayu *et al.*, 2018); 2. Delays in current warning channels (UNDRR, 2019); 3. Multilanguage stakes linked to foreign tourists (Choi *et al.*, 2024).

The multilanguage Cell Broadcast (CB) technology seems to address the three above-mentioned gaps (Williams *et al.*, 2014): it is not dependent on new local infrastructures (Grangeat *et al.*, 2023), it is near real-time (Asian and Pacific Training Centre for Information and Communication Technology for Development, 2010; Grangeat *et al.*, 2023), and it can send simultaneous multilingual alerts (Grangeat *et al.*, 2023) based on the SIM card nationality detection. With AI-powered translation, alerts can reach tourists from all 54 nationalities in their own languages, ensuring clear and timely understanding of evacuation instructions (Choi *et al.*, 2024). Moreover, tourist areas in Indonesia already benefit from strong mobile network coverage (GSM Association, n.d.). By joining the EW4All Initiative, Indonesia would benefit from an international framework to review its regulation (Deutsche Gesellschaft für Technische Zusammenarbeit, 2006) and procedures linked to the CB usage, as well as accessing funding opportunities, ensuring ultimately tourists' safety.

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Harnessing Online News through Spatiotemporal Mapping for Localized Disaster Awareness in Labuan Bajo

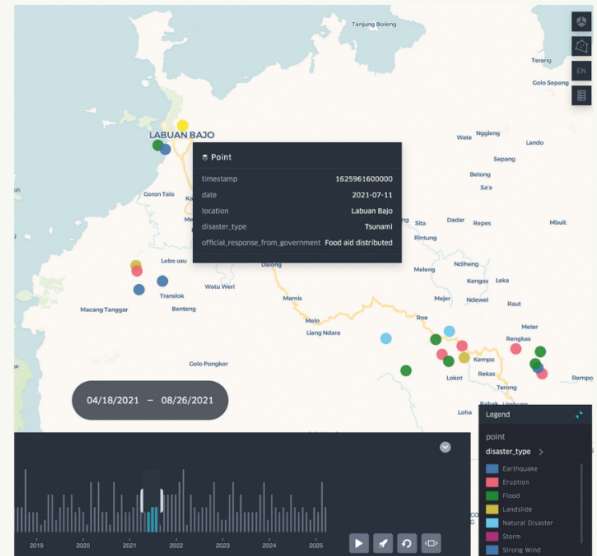
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INTRODUCTION

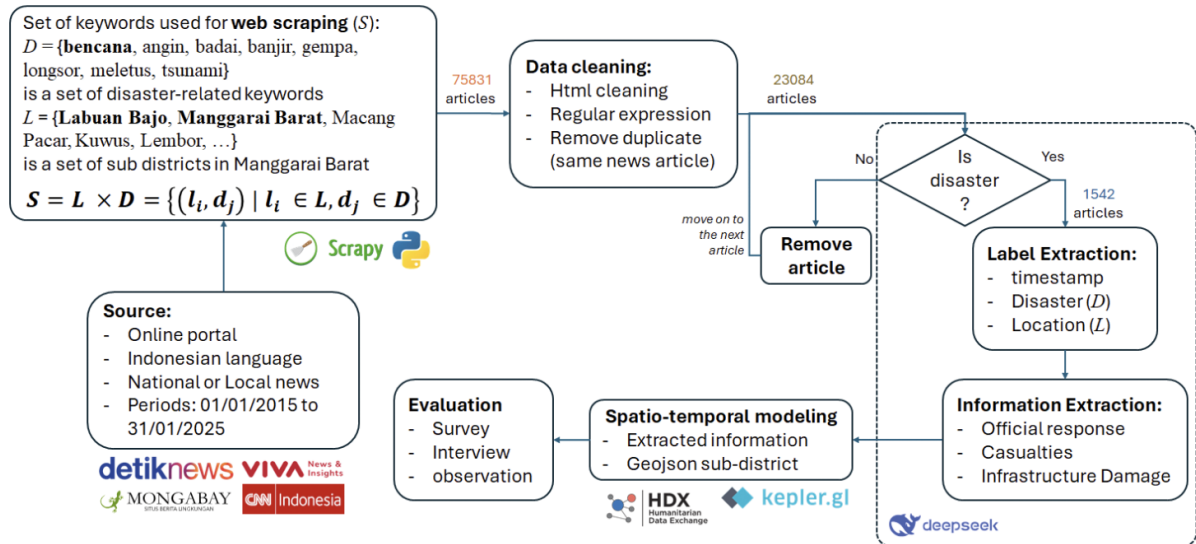
In disaster-prone regions like Labuan Bajo, Indonesia, understanding historical disaster events is crucial for formulating effective mitigation and preparedness strategies. Electronic news archives serve as valuable repositories of information, capturing detailed accounts of past disasters, including their types, impacts, and the responses they elicited (Taylor et al., 2015). By extracting and analyzing this information, patterns and trends that inform future disaster risk reduction efforts can be identified. Advancements in natural language processing, particularly the use of large language models (LLMs), have enhanced the ability to process unstructured textual data from news sources, facilitating the extraction of relevant disaster-related information (Maibaum et al., 2024). Combining the extracted information with spatiotemporal mapping techniques enables the depiction of disaster events across both time and geographic dimensions, offering deeper insight into areas of vulnerability and supporting the development of focused mitigation efforts (Duan et al., 2022). This approach not only aids in learning from past events but also enhances community resilience by informing proactive disaster preparedness planning.



QUESTION

1. What methods can be used to gather data on past disaster mitigation and response efforts?
2. What types of natural hazards have occurred in Labuan Bajo over the past decade, and what impacts have they caused?
3. How can disaster information be modeled using spatial and temporal techniques?

PROPOSED METHOD



CONCLUSION

1. Data on past disaster response can be collected from online news through keyword-based scraping, cleaning, filtering, and spatiotemporal extraction.
2. Labuan Bajo has faced various hazards over the last decade; LLMs helped identify 1,542 relevant reports from 75,831 articles, capturing key impacts and responses.
3. Spatiotemporal modeling can be done using low-code tools, which enable the interactive visualization of large-scale geo-tagged datasets over time.

RELATED LITERATURE

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Harnessing Online News through Spatiotemporal Mapping for Localized Disaster Awareness in Labuan Bajo

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In disaster-prone regions such as Labuan Bajo, Indonesia, enhancing community awareness and preparedness requires a clear understanding of past disaster events and their impacts. While formal disaster records may be limited or fragmented, electronic news archives offer a rich and largely untapped source of historical disaster information. This study proposes a framework for harnessing online news content to improve localized disaster awareness through the integration of natural language processing (NLP) and spatiotemporal mapping.

The objective of this research is to extract, classify, and visualize disaster-related information from online news articles published over the past decade in the Labuan Bajo region. By focusing on disaster types, official responses, mitigation efforts, casualties, and infrastructure damage, the approach aims to uncover patterns that inform future disaster risk reduction strategies. The study begins by defining a set of disaster-related and location-based keywords, such as names of subdistricts and known hazard terms, which are then used to collect data through web scraping. A total of 75,831 articles were initially collected. To automate the analysis of this large corpus, Deepseek v3, one of Large Language Models (LLMs) API, was employed to filter out irrelevant content and extract essential disaster information. The LLM were capable of identifying nuanced contexts such as government responses, severity levels, and affected infrastructure; significantly reducing the need for manual intervention. From the scraped corpus, 1,542 articles were classified as disaster-rel-

evant. This subset forms the basis for further spatial and temporal analysis.

The extracted data was then geotagged and structured for spatial visualization. To enrich the spatial context, GeoJSON boundary data for the Labuan Bajo region was obtained from The Humanitarian Data Exchange (HDX), resulting in a comprehensive spatiotemporal dataset. This dataset was visualized using Kepler.gl, an open-source, low-code platform for geospatial analytics. The interactive maps display disaster occurrences over time and space, highlight vulnerability hotspots, and allow users to filter events by type, severity, and administrative region. These visual tools offer actionable insights for local governments, NGOs, and emergency planners seeking to improve disaster mitigation strategies and enhance preparedness.

Our findings demonstrate that combining LLM-based text extraction with spatiotemporal visualization is a feasible approach for enhancing disaster situational awareness at the local level. The interactive maps generated can support stakeholders in identifying high-risk zones, assessing past responses, and planning targeted mitigation strategies. Furthermore, this framework is scalable and adaptable, making it applicable to other regions with similar needs and data availability. In conclusion, this study shows that leveraging online news archives through NLP and mapping tools can transform unstructured historical data into actionable insights, contributing to more informed and resilient disaster preparedness planning in Labuan Bajo.

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ENHANCING COMMUNITY AND TOURIST PREPAREDNESS: DISASTER RISK COMMUNICATION STRATEGIES AND EDUCATIONAL VISUAL MEDIA IN LABUAN BAJO



Authors :

Benedicta Ayu Indiwara Wuryantari, Irena Rahmawati

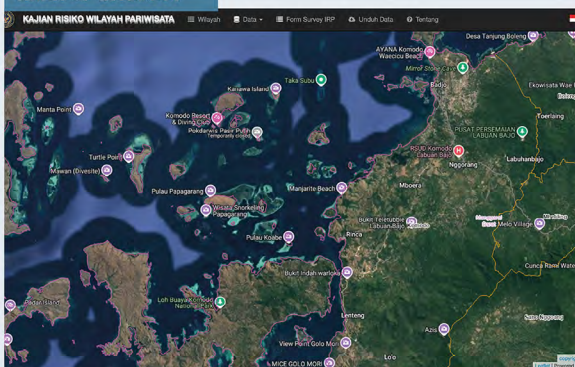
INTRODUCTION

Labuan Bajo, a top Indonesian tourist destination near Komodo National Park, faces high disaster risks due to its location in the Pacific Ring of Fire. These hazards threaten critical transportation infrastructure essential for tourism and local communities. However, disaster risk communication remains inadequate, hindered by language barriers and inconsistent preparedness. This study proposes an integrated visual communication strategy to enhance disaster awareness and preparedness among tourists, operators, and locals—supporting resilient and sustainable tourism development in Labuan Bajo.

RESEARCH QUESTIONS

- What risk communication strategies are effective for local communities and tourists?
- How can educational visual media be used to improve preparedness?
- What is the role of technology (social media and visualization) in supporting disaster communication?

AREA OF INTEREST



- Location: Labuan Bajo, West Manggarai, NTT, Indonesia.
- Context: Major tourist destination vulnerable to disasters (floods, earthquakes, landslides, forest fires, and extreme weather).
- Challenges: Need to strengthen risk communication and improve community and tourist preparedness.

OVERVIEW

- As a top-priority tourist destination, Labuan Bajo attracts thousands of visitors annually.
- Despite its economic potential, the region faces natural hazards such as earthquakes, tsunamis, and droughts.
- Both locals and tourists remain highly vulnerable, especially with low levels of disaster awareness and knowledge.

STATE OF ART

- Risk Communication: An important strategy in disseminating disaster risk information quickly, accurately, and effectively.
- The Role of Social Media & Educational Visuals: Platforms such as Twitter, Instagram, and educational visual videos can increase public awareness of disaster threats.
- Local Disaster Literacy: Local community understanding of potential risks is still limited and requires education-based interventions.

METHODS

- Qualitative: In-depth interviews with stakeholders (BPBD, port authorities, local residents, tourism actors).
- Analysis: Media content analysis and interview coding with Nvivo Software
- Visual Media Creation: Infographics, animations, and videos based on research results. Trials on local community groups.

EXPECTED OUTPUTS

- Local-based risk communication strategy guide.
- Educational visual media package (infographics, animations) for use by BPBD, Tourism Board of Authority Labuan Bajo-Flores and communities.
- Policy recommendations to improve disaster literacy in tourism communities.

TEMPORARY CONCLUSION

- Visual education and technology-based risk communication can improve preparedness in disaster-prone tourism areas.
- Multi-stakeholder collaboration is essential for strategy effectiveness.

RELATED LITERATURE

- Agyepong, L. A., & Liang, X. (2022). Mapping the knowledge frontiers of public risk communication in disaster risk management. *Journal of Risk Research*, 26(3), 302–323. <https://doi.org/10.1080/13669877.2022.2127851>
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Enhancing Community and Tourist Preparedness: Disaster Risk Communication Strategies and Educational Visual Media in Labuan Bajo

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Labuan Bajo, situated on the western tip of Flores Island in East Nusa Tenggara, has rapidly transformed into one of Indonesia's leading tourist destinations. Its natural beauty, strategic access to Komodo National Park, and vibrant marine biodiversity attract thousands of international and domestic visitors annually. However, this tourism boom has occurred alongside significant disaster vulnerability. Located within the Pacific Ring of Fire, Labuan Bajo is highly prone to natural hazards such as earthquakes, tsunamis, landslides, and extreme weather events, which directly threaten its critical aviation and maritime infrastructure that supports both tourism and local livelihoods.

Despite increasing awareness of these risks, disaster preparedness in Labuan Bajo remains uneven across stakeholders. International tourists, transportation operators, hospitality businesses, and local communities all face complex emergency situations with differing levels of disaster knowledge and readiness. Current disaster risk communication mechanisms are not yet fully tailored to the region's multilingual and multicultural context, leading to critical gaps in understanding and response during emergencies.

This research aims to address these gaps by developing an integrated disaster risk communication strategy that incorporates educational visual media

to enhance preparedness. The study focuses on overcoming barriers such as language differences, fragmented information dissemination, and inconsistent preparedness protocols across the tourism sector. Through the use of visual tools such as infographics, icons, maps, and multilingual materials, the strategy seeks to improve accessibility and clarity of disaster information for a wide range of stakeholders. The methodology includes qualitative data collection and analysis using NVivo, with sources drawn from key institutions such as BNPB, the Regional House of Representatives, the Labuan Bajo-Flores Tourism Authority, Komodo National Park, BMKG (Komodo Manggarai Barat), the Marine Police, ASKAWI (Tour Boat Association), the Port Authority, as well as interviews with residents, tourists, educational institutions, and the head of the airport authority. This diverse data set allows for a holistic understanding of disaster communication challenges and stakeholder needs in Labuan Bajo.

A central concept in this research is tourism resilience, defined as the ability of tourism systems, destinations, and communities to adapt, recover, and rebuild more effectively after disruptions such as natural disasters. Building such resilience in Labuan Bajo is essential, not only to protect the tourism sector but also to support the broader socioeconomic stability of the region, which relies heavily on tourism-based liveli-

hoods. Furthermore, community resilience plays a key role in ensuring long-term sustainability. It refers to the capacity of local communities to maintain and restore their social, economic, and cultural structures in the face of disaster-related disruptions and tour-

ism pressures. By enhancing both tourism and community resilience through improved disaster communication and educational visual media, this study contributes to developing safer, more prepared, and more sustainable tourism practices in Labuan Bajo.

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The resilience of local population in the tourist area of Le Thuy, Quang Binh, Vietnam: Insights from the 2024 Trami Tropical storm

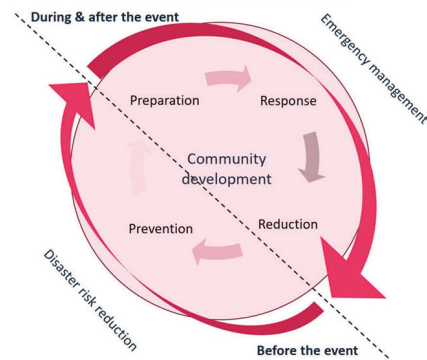
Authors: Luong Thi Duyen, Dinh Nhat Quang, Caroline Rizza

Transdisciplinary Research Strategy On Crisis Management And Population Resilience (STRAP) Project

1. Structuring a roadmap for BNPB and Vietnamese stakeholders
2. Conducting a transdisciplinary approach to natural hazards in Vietnam & Indonesia



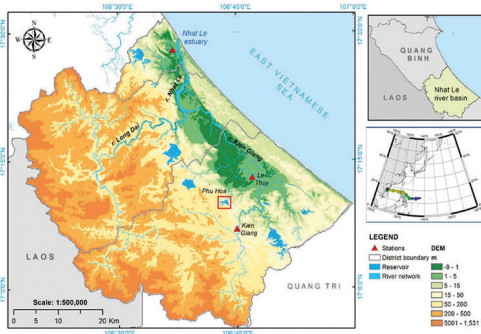
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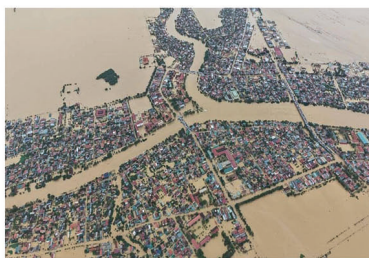
- Moatty&Reghezza-Zitt (2018) present two conceptions of resilience, depending on whether it is the antonym of vulnerability, or whether it is more encompassing by focusing on both the territorial system and its (infrastructure) network.
- Rizza (2025) combines the 4 phases of crisis management cycle with the 3 dimensions of community resilience (Dufty, 2012) to position the community development at the center of process.
- Risk culture and social media support community development in terms of information, communication and organisation.
- The increasing use of smartphones highlights the potential of mobile applications in term of risk and crisis management.

Introduction

Le Thuy, Quang Binh area



Topographic map of Nhat Le River Basin and Track of Severe Tropical Storm Trami 2024



Kien Giang River, Le Thuy District on October 2024



FloodGuard Quang Binh mobile application

Research questions

1. What are the dimensions of community resilience in this area?
2. How ICT, and specifically mobile app., may support community resilience in this area?

Methodology

- 12 exploratory interviews with four types of actors: local authorities, crisis managers, tourist guide and local people
- An online ethnography of news media, official websites, and social media.



Results and discussion

- **Combining traditional and social media to face the typhoon**
Each actor uses digital devices (e.g. smartphones & social media) to spread information and preparation. Traditional devices (i.e. news media & loudspeakers) remain the main channels to alert local population.
- **A resilient community built to cope with the risk of flooding**
People have developed their own "risk culture" mainly based on the 2020 flooding. They are able to organize by themselves. They mobilize digital technology to communicate with each other.
- **The potential of the "FloodGuard Quang Binh" mobile application to foster community resilience is at stake**
The mobile application can enhance community resilience, but its appropriation is challenged by concrete barriers among which existing local coping capacities and specialized apps.

Conclusion

- The population of Quang Binh showed strong resilience, having adapt to typhoon and flood risks based on their own experience.
- They effectively used both traditional and digital tools for preparedness and local coordination during and after the event.
- The FloodGuards app shows potential for crisis communication but still faces usability challenges to be addressed.

The resilience of local population in the tourist area of Le Thuy, Quang Binh, Vietnam: Insights from the 2024 Trami tropical storm

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The project “Transdisciplinary research strategy on crisis management and resilience of population” (STRAP) has been the opportunity to conduct a pilot survey in Le Thuy district, Quang Binh province (Vietnam). Le Thuy district is a low-lying area prone to frequent and severe flooding. Specifically, a historical flood occurred in October 2020. More recently, at the occasion of the Trami tropical Storm, the peak of the flooding lasted from October 27th to 29th 2024. This poster, based on the results of the first part of this pilot survey, summarises the outcomes of a paper to be presented at the forthcoming IS-CRAM 2025 conference (Luong *et al.*, 2025). The paper aims to get a picture or understanding of the resilience community of the Province of Quang Binh based on their experience of the 2024 Trami tropical storm.

Moatty & Reghezza-Zitt (2018) define resilience as the antonym of vulnerability and resilience as a systemic and network-based capacity. Based on their definition, we differentiate infrastructures and community and focus mainly, in this paper, on community resilience. Dufty (2012) identifies three dimensions of community resilience: risk reduction, emergency management and community development. (Rizza, 2025) merges these three dimensions with the crisis management cycle in order to situate community development at the center of the process. Moreover, risk culture (Courant *et al.*, 2021)

and social media (Jurgens & Helsloot, 2018) are both components and supports to community development. Lastly, the increasing use of smartphones highlights the potential of mobile applications as devices for effective risk and crisis communications (Ahmed Al-Sadi *et al.*, 2023).

The research is based on two 5-day-field studies conducted in the Province of Quang Binh in July and December 2024 the data collected on the field has been completed by an online ethnography aiming at understanding which types of information have been published at the time of the Trami typhoon. The first field study consisted of a visit to the three main flooded areas of the province along the river (KienGiang River) to its mouth and their monitoring, warning and safety infrastructures, accompanied by the director of the meteorological center. The second field trip consisted of conducting exploratory interviews with four types of actors: local authorities, crisis managers, tourist guide and local people.

Three main results have been highlighted:

- 1) While digital channels (e.g. smartphones and social media) seem relevant to spread information and preparation among each category of actors, traditional channels (e.g. news media and loudspeakers) remain the main means to alert the local population.
- 2) Local citizens have developed their own “risk culture” (Courant *et al.*, 2021) mainly based on the 2020

flooding and they are able to organize themselves and mobilize digital technology to communicate with each other as well as with institutions despite some issues.

3) Usability of the mobile app. “FloodGuard Quang Binh” is at stake when it comes to fostering community resilience in the Province of Quang Binh.

Indeed, despite the beliefs and projections of each category of actors interviewed, concrete barriers challenge its appropriation among which: the strong community resilience itself and the existence of specific apps. developed by national authorities and already used by local crises managers and authorities.

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**ISCRAM****SILDARO**

Resilience of local community in the tourist area of Labuan Bajo, Indonesia: A perspective from risk and crisis communication

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Transdisciplinary Research Strategy On Crisis Management And Population Resilience (STRAP) Project



1. Structuring a roadmap for BNPB and Vietnamese stakeholders
2. Conducting a transdisciplinary approach to natural hazards in Vietnam & Indonesia



1. Introduction

Labuan Bajo

- Labuan Bajo is one of Indonesia's top tourist destinations, renowned for its marine tourism.
- Potential hazards: tsunamis, earthquakes, floods, volcanic eruptions, landslides, extreme weathers, strong currents.

Research questions

- What are the main dimensions of the community resilience in Labuan bajo in order to define and foster resilience tourism in this area?
- How ICT may support both community and tourism resiliencies

Main research objectives

- Proposing a communicational perspective of resilience in the tourist area of Labuan Bajo
- Testing a transdisciplinary approach to support both community and tourism resiliencies

2. State of the art

- **Territorial resilience** is the combination of both the territorial system (infrastructure networks) and its network of actors (Moatty & Reghezza-Zitt, 2018). The development of a resilient (because competent) community becomes a central element.
- **Tourism resilience** refers to the ability of tourism management, destinations, and communities to adapt, recover, and rebuild better, ensuring that tourist destinations remain sustainable and resilient in the face of potential hazards in the future.
- **Risk communication process** is crucial for warning and preparing people before a disaster occurs and for guiding their recovery afterwards (Fokaefs & Sapountzaki, 2021).
- **Crisis communication** plays a key role in providing updated and accurate information to the public, helping them understand the situation and act quickly during a crisis or emergency period (Heinkel et al., 2025).
- **Information & Communication Technologies (ICT)**, including social media platforms and mobile applications, support risk and crisis communications. They allow to disseminate alerts and critical information quickly and effectively to a large audience in real time (Kar & Cochran, 2019; Rizza, 2023)

4. Preliminary results

- **Dissemination of information appears centralized and led by BMKG**, the Meteorology, Climatology, and Geophysics Agency.
- **Population warning relies on both traditional channels** (e.g. sirens or press releases) and **digital channels** (e.g. official websites, social media, and mobile app).
- Risk and crisis communication analysis sheds light on a **close network of actors** combining both regional and local authorities as well as official institutions and civil society.
- **Digital channels** (e.g. WhatsApp) appear to facilitate alerts and coordination among these categories of actors.
- **Tourism actors and institutions also appear relevant and competent to reach and keep safe tourists**
- Despite these assets, **the community resilience, and consequently tourism resilience, is comparatively weak and limited.**

3. Methodology



Data collection

- 22 exploratory interviews with 4 categories of actors: local authorities, crisis managers, tourist institutions & local people
- A practitioners workshop gathering 12 participants (local authorities, crisis managers and tourist institution)

Analysis

- All collected data from the interviews was coded and analyzed using Atlas.ti software
- Work still in progress for the practitioners workshop

5. Conclusion

- Robust infrastructure is vital for developing resilient communities. The integration of ICTs (including smartphones and social media) alongside conventional media (including sirens), significantly mitigates the risk and exposure of communities.
- Despite frequent exposure to catastrophes, communities generally possess a limited capacity to respond, marked by insufficient evacuation planning and readiness for such catastrophes.
- Reliance on governmental or local authority is significantly elevated to enhance community resilience

Next steps

- Integrating the data collected during the practitioners' workshop (Jakarta, April 2025) in order to deepen these preliminary results
- Testing the replicability of the transdisciplinary approach in other Indonesian tourist regions

Towards Tourism resilience in Labuan Bajo Field trips restitution

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The project “Transdisciplinary research strategy on crisis management and resilience of population” (STRAP) has been the opportunity to conduct a pilot survey in Labuan Bajo, one of Indonesia’s ten priority tourism destinations, known for its marine tourism and natural landscapes. Labuan Bajo comprises numerous small islands, each with unique cultural and ecological features – most notably, the Komodo dragon. However, Labuan Bajo also faces multiple natural hazards, including earthquakes, floods, volcanic eruptions, landslides, and extreme weather. In a communication perspective, this pilot survey aims to explore the community resilience of this area, to examine the potential role of Information and Communication Technology (ICT) in strengthening both community and tourism resiliencies. From a methodological point of view, it aims to test the replicability of the transdisciplinary approach as implemented in the project.

Resilient tourism refers to the ability of tourism management, destinations, and communities to adapt, recover, and rebuild better, ensuring that tourist destinations remain sustainable and resilient in the face of potential hazards in the future. One of the ways to achieve resilient tourism is through strong and effective risk and crisis communication. The risk communication process is crucial for warning and preparing people before a disaster occurs and for guiding their recovery afterwards (Fokaefs & Sapountzaki, 2021). Meanwhile, crisis communication plays a key role in providing updated and accurate information to the public, helping them understand the situation and act quickly during

a crisis or emergency period (Heinkel *et al.*, 2025). Both risk and crisis communication are supported by the role of information and communication technologies (ICT), including social media platforms and mobile applications, which help disseminate alerts and critical information quickly and effectively to a large audience in real time (Kar & Cochran, 2019; Rizza & Pereira, 2014). Efficient management of these aspects is crucial to maximizing the benefits of ICT in crisis scenarios (Rizza, 2023).

This research has been conducted in three steps: a first exploratory five-day-field trip in July 2024, followed by a five-day-fieldwork involving interviews with 22 participants (three local authorities, five crisis managers, seven representatives from tourist institutions, and seven citizens including local and international tourists) in March 2025, as well as a practitioners’ workshop gathering 12 participants (crisis managers, local authorities and tourism actors) in April 2025. While the first field trip allowed to discover the Labuan Bajo area, to meet with relevant supportive actors and launch the bases of the next steps of the survey, the interviews aimed to explore the concept of tourism resilience in Labuan Bajo, drawing on participants’ experiences in facing multiple hazards, their level of preparedness, and the role of ICTs in enhancing both community resilience and risk perception. The interview data were analyzed using Atlas.ti software and coded under eight categories: tourism resilience, community development, infrastructure networks, risk communication, information, organization, crisis communication, and ICT. Lastly, the practitioners workshop allowed its atten-

dants to share their experiences, discuss their views and issues and propose concrete processes of communication and collaboration. The analysis of the data collected during the practitioners' workshop is still in progress.

The preliminary results of the survey highlight the assets and weaknesses of community and tourism resilience in Labuan Bajo, from a communication perspective, with a specific attention on ICTs according to three main axes to be deepened in the next steps of the research. First of all, dissemination of information appears centralized and led by BMKG, the Meteorology, Climatology, and Geophysics Agency. Warning the population relies on both traditional channels, such as sirens (tsunami alert) or press releases when

there is time to get prepared, and digital channels, such as official websites, social media platforms, and mobile applications. Second, risk and crisis communication analysis sheds light on a close network of actors combining both regional and local authorities as well as official institutions and civil society. Digital channels, such as WhatsApp, appear to facilitate alerts and coordination among these categories of actors. While the tourism actors and institutions also appear relevant and competent to reach and keep safe tourists. Nevertheless, despite these assets, important weaknesses and challenges remain in terms of means, coordination, and effectiveness during the risk reduction and response phases. These aspects will be deepened based on the analysis of the data collected during the practitioners' workshop.

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