

Inclusive WhatsApp-based early warning system for visually impaired micro-entrepreneurs in Kupang, Indonesia

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Abstract. *Ndaparoka SL, Hadiyati E, Sjion EW, Dhana IMA. 2026. Inclusive WhatsApp-based early warning system for visually impaired micro-entrepreneurs in Kupang, Indonesia. Intl J Trop Drylands 10 (1): t100104. <https://doi.org/10.13057/tropdrylands/t100104>.* In tropical dryland urban centres, extreme weather events increasingly threaten informal livelihoods, yet standard early warning mechanisms often fail to accommodate marginalized populations. This accessibility gap creates profound socioeconomic vulnerabilities for micro-entrepreneurs with visual impairments who rely heavily on outdoor trading activities. This study examines the implementation of an inclusive WhatsApp-based Early Warning System (EWS) designed to support visually impaired micro entrepreneurs in Kupang City, East Nusa Tenggara, during extreme weather events. Utilizing an exploratory qualitative design, in-depth interviews were conducted to eight purposefully selected informants, comprising six visually impaired vendors and two institutional stakeholders. Data collected during the extreme weather cycle (December 2024-April 2025) were analysed and methodologically triangulated with the Standard Operating Procedure (SOP) documents of the system and digital message archives. The findings demonstrate the practical use of the system in converting visual meteorological alerts into accessible audio formats within a rapid 3-to-5-minute dissemination window. Qualitative evidence from user experiences suggests that these audio alerts appear to strengthen immediate economic decision making, such as enabling vendors to secure their kiosks or suspend outdoor trading activities before a storm onset. The novelty of this study lies in its documentation of a community driven, inclusive governance model within a vulnerable tropical dryland urban setting. While persistent challenges include mobile data affordability and a critical reliance on a single human resource for content production, the system offers a potentially adaptable model for strengthening inclusive disaster risk reduction and livelihood in other urban centres.

Keywords: Disaster risk reduction, dryland, extreme weather, inclusive early warning, microenterprises

INTRODUCTION

Kupang City, a prominent urban centre in a tropical dryland region in Indonesia, is facing increasingly severe extreme weather events in recent years. These hydrometeorological phenomena, characterized by erratic rainfalls and high-speed winds, pose significant risks to both public safety and urban infrastructure. According to the Indonesian Meteorology, Climatology, and Geophysics Agency (Badan Meteorologi Klimatologi dan Geofisika (BMKG)), such events necessitate continuous vigilance and highly responsive information dissemination (BMKG 2022). This is particularly important in the context of East Nusa Tenggara Province, where the geoclimatic condition creates vulnerabilities, including sudden storm surges following prolonged dry periods. The devastating tropical cyclone Seroja in 2021 is an example of extreme weather event in the region that requires disaster risk reduction strategies that align with the Sendai Framework 2015-2030. The Sendai Framework for Disaster Risk Reduction 2015-2030 is a global blueprint endorsed by the UN General Assembly following the 2015 Third UN World Conference on Disaster Risk Reduction (WCDRR) to advocate

substantial reduction of disaster risks and losses in lives, health, livelihoods, and socioeconomic or environmental assets across communities and countries. Crucially, while it recognizes that national governments hold the primary role in minimizing disaster risk, it emphasizes that this responsibility must be shared collectively with local authorities, the private sector, and civil society stakeholders.

Beyond physical damage, extreme weather disproportionately impacts marginalized people, including micro entrepreneurs with visual impairments whose climate vulnerability is deeply compounded by intersectional socioeconomic barriers (Glowka et al. 2024; Nastasia and Rives 2025; Nwokocha and Gift 2025). In Kupang City, many individuals rely on informal, outdoor livelihoods, such as feather duster vendors, snacks sellers, and traditional massage services. These activities are highly sensitive to weather events, yet their vulnerability is compounded by a profound lack of accessible early warning dissemination (Abikoye and Abikoye 2025; Becker et al. 2025; Myeni and Roffe 2025). For micro entrepreneurs lacking the sensory capacity to observe visual atmospheric changes, the absence of inclusive

warnings often results in direct asset loss or physical injury. This accessibility gap is not specific to Kupang context, but a global challenge. Chisty et al. (2021) noted that visually impaired people in Bangladesh have challenge on inclusive warning mechanisms that prevent timely protective action. Similarly, the ASEAN Secretariat (2024) identified a persistent failure to accommodate the diverse communication needs, leading to significant gaps in warning effectiveness (Hajad and Ikhsan 2024).

A primary barrier remains in the visually oriented nature of meteorological alerts, for example BMKG warnings are predominantly issued in textual, graphical, and map-based formats that are fundamentally inaccessible to those relying on auditory information as articulated by one informant. Maps and text-based alerts from official sources fail to provide direct, auditory information required for rapid decision making. These visually oriented formats are fundamentally inaccessible to individuals who rely on auditory information. To address these systemic barriers, the Regional Disaster Management Agency (BPBD) of Kupang City in collaboration with the Disaster Risk Reduction Forum (FPRB) and the Indonesian Blind Union (PERTUNI), established an inclusive early warning mechanism. Fully implemented in December 2024, this system systematically converts BMKG's visual weather warnings into accessible audio messages disseminated via WhatsApp. This initiative represents a significant step toward inclusive disaster governance. Despite the recognized importance of inclusive disaster risk reduction, a critical research gap remains regarding practical operationalization of inclusive Early Warning System (EWS), especially in the context of tropical dryland region. While previous studies have documented sensory barriers, few have empirically evaluated a functional, community driven system that provides measurable time to dissemination benchmarks and governance roles.

Therefore, this study aimed to assess WhatsApp-based EWS implementation of visually impaired micro

entrepreneurs in Kupang City, East Nusa Tenggara, during extreme weather events. To investigate this phenomenon, the study addresses three primary research questions: (i) How is the inclusive WhatsApp-based EWS system operationalized for visually impaired micro-entrepreneurs in Kupang City? (ii) To what extent do rapid audio warnings influence their immediate economic decision-making during extreme weather events? (iii) What are the persistent operational challenges, and what strategic recommendations can ensure the system's long-term sustainability? The novelty of this study lies in its empirical documentation of a transferable system that bridges the gap between official meteorological data and inclusive audio dissemination, specifically focusing on its perceived value for the livelihood protection of micro entrepreneurs.

MATERIALS AND METHODS

Study area

The research was conducted in Kupang City, East Nusa Tenggara Province, Indonesia (Figure 1). The primary target population was the visually impaired communities residing across various sub-districts in Kupang City, specifically focusing on micro-entrepreneurs engaged in outdoor and direct service activities. Within the context of a tropical dryland region, Kupang City is highly exposed to severe hydrometeorological hazards during the wet season. This study specifically focuses on extreme weather events such as heavy rainstorms, tropical cyclones, and strong winds that typically occur between December and April, as verified by the official Kupang City Disaster Risk Assessment document and stipulated in the academic draft of the Kupang City Regional Medium-Term Development Plan (RPJMD) 2025-2029 (Pemerintah Kota Kupang 2024).

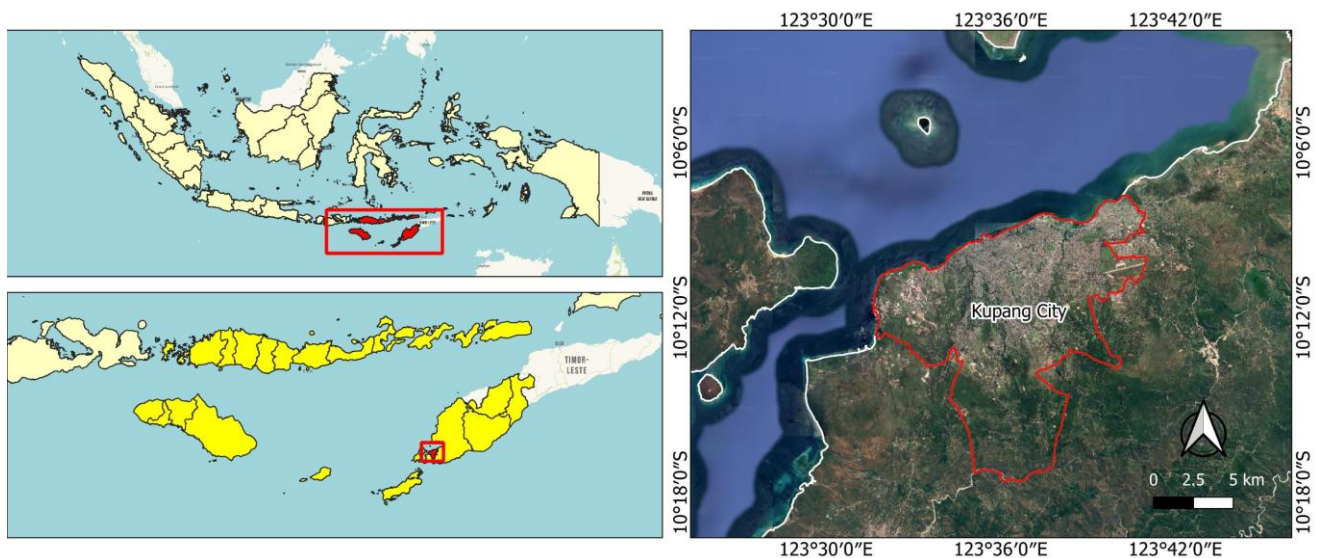


Figure 1. Map of study area of Kupang City, East Nusa Tenggara Province, Indonesia

The dry season is explicitly excluded from this study's scope. Kupang City was purposively selected as the study site for three primary reasons. First, the city hosts the only social rehabilitation centre for the visually impaired people in East Nusa Tenggara Province, drawing individuals from various districts. This facility provides specific vocational training, resulting in a high concentration of visually impaired micro-entrepreneurs specializing in feather duster production and traditional massage whereas those engaged in snack vending selling typically resell products manufactured by sighted individuals. Second, it is currently the only city in the province possessing a comprehensive, "by name and by address" database of visually impaired individuals and their specific micro-enterprise activities, facilitated by the highly proactive local branch of PERTUNI. Third, Kupang is the only municipality in the region where an inclusive EWS with Standard Operating Procedure (SOP) specifically tailored for the visually impaired people. The formal implementation of this SOP commenced in December 2024, strategically coincide with the onset of the extreme weather season, immediately following its final design and field simulation with the local Regional Disaster Management Agency (BPBD) in November 2024.

Research procedures

This study utilized a qualitative research design, employing in-depth interview method with a snowball sampling approach. A total of eight informants were purposefully selected and categorized into two groups. The primary group consisted of six visually impaired micro-entrepreneurs. To ensure sample relevance, the inclusion criteria required participants to be visually impaired, actively running a micro-enterprise in Kupang City, and targeted by the inclusive early warning SOP. The snowball recruitment process initiated with a key informant engaged in traditional massage and feather duster vending, who subsequently referred other vendors operating within similar commercial corridors. The referral chain continued through various informal networks of visually impaired micro-entrepreneurs. The recruitment process was intentionally concluded at the sixth micro-entrepreneur when data saturation was reached. At this point, no new substantive themes regarding extreme weather vulnerabilities and early warning responses were emerging from the interviews, thereby justifying the adequacy of the sample size for this qualitative inquiry.

The second group comprised two key institutional stakeholders responsible for the SOP implementation: one representative from the Kupang City BPBD and one from the Kupang City DRR Forum (FPRB). These institutions were selected as key stakeholders because BPBD holds the formal governmental mandate for urban disaster management, while FPRB is the primary civil society coordinator facilitating the inclusive SOP on the ground. Data collection was conducted over a rigorous timeframe from December 10 to 15, 2024. This specific period was purposefully selected to capture the informants' immediate, real-time experiences right at the onset of the extreme

weather season and concurrently with the SOP's initial rollout.

To ensure the depth and quality of information, the researcher allocated one full day data collection per informant. Consequently, each in-depth interview session lasted extensively between 3 to 4 hours. To uphold strict research ethics and prevent any exploitative impact on this low-income community, all visually impaired micro-entrepreneurs were provided with monetary compensation of IDR 100,000 to fairly replace their lost daily income and refreshments (bottled water). This ensured that their extensive participation did not impose a financial burden on their household livelihoods. All interviews were conducted in Bahasa Indonesia to build rapport, audio-recorded with the participants' consent, and transcribed verbatim for thematic analysis. These three institutions play a central role in converting BMKG early warning information from text into audio formats and disseminating it to visually impaired communities and broader multi-stakeholder networks (Jamroni 2024)

Data analysis

The study employed a rigorous thematic analysis approach to process the qualitative data. Following the in-depth interviews, all audio recordings were transcribed verbatim into text. The researcher initiated the analysis with a familiarization phase, reading the transcripts multiple times deeply to gain a comprehensive understanding of the participants' narratives. Subsequently, a manual coding process was conducted, wherein similar responses and recurring patterns were systematically marked and categorized to generate the main analytical themes regarding the inclusive early warning system and micro-enterprise resilience. To ensure data validity and trustworthiness, methodological triangulation was applied by cross-checking the qualitative claims from the interviews against the documented EWS SOP and the digital archives of the WhatsApp EWS messages. Finally, to establish absolute credibility, a member-checking process was conducted. The identified themes and preliminary conclusions were communicated back to all six visually impaired informants to verify that the researcher's interpretations accurately and authentically represented their intended meanings and experiences.

Ethical considerations

This research prioritizes strict ethical standards, particularly concerning the involvement of vulnerable populations (persons with visual impairments). Institutional approval and formal written permission to conduct and publish this study were officially granted by the Head of the PERTUNI Kupang City. To ensure participatory research governance and community representation, the Head of PERTUNI was also actively involved as a co-author. Recognizing the participants' visual impairments, the informed consent process was adapted appropriately. Explicit verbal consent was obtained and recorded via WhatsApp voice messages prior to all interview sessions. Participants were thoroughly informed about the study's objectives and voluntarily agreed to the publication of the

research findings. Regarding anonymity, to protect participant privacy and strictly comply with standard academic publishing ethics, the identities of all visually impaired informants were completely anonymized. Pseudonyms (e.g., Informant 1, Informant 2) are used consistently throughout this manuscript to represent their invaluable experiences while safeguarding their personal information.

RESULTS AND DISCUSSION

Demographic profile of the visually impaired people in Kupang City

According to the most recent database (July 2025) maintained by the PERTUNI Kupang City, there are 118 people with visual impairments residing in Kupang City, consisting of 75 males and 43 females. The database also indicates that the age range of persons with visual impairments in Kupang City spans from 25 to 70 years. In terms of residential distribution, persons with visual impairments are located across various sub-districts, with the highest concentration in Maulafa (57 people), followed by Oepura (24 people). Other sub districts have smaller populations, such as Sikumana (5 people), Oebufu (4 people), and South Oesapa (3 people). Several additional sub-districts including Tuak Daun Merah, Manutapen, and Fatululi each record between one and two individuals with visual impairments. These data demonstrate considerable spatial variation in the distribution of visually disabled populations across Kupang City. Most individuals reside in social care facilities or rented accommodation, while 29 households have independent home ownership.

The distribution of education level among persons with visual impairments is presented in Figure 2. It presents the distribution of educational level among people with visual impairments in Kupang City, grouped into five categories: tertiary education, senior secondary education, junior secondary education, primary education, and no formal education. The data show that the largest proportion (72 people) has not completed formal education. Meanwhile, 22 people attained senior secondary education, 7 completed

primary education, 6 completed junior secondary education, and 6 achieved a tertiary degree. These findings reveal a substantial disparity in educational level within this group, especially at the secondary and tertiary levels. The majority of adults with visual impairments rely on Android-based smartphones as their primary communication device, whereas children exhibit lower levels of adoption, indicating differentiated levels of technology enabled early warning accessibility.

Micro enterprise activities of persons with visual impairments in Kupang City

To sustain their livelihoods, many people with visual impairments engage in informal micro-enterprise activities. The predominant types of micro-enterprises include feather duster street-vendor, food street-vendor (such as fried corn snacks), and traditional massage service. The distribution of these livelihood activities is presented in Figure 3.

The livelihood activities of people with visual impairments in Kupang City reflect adaptive strategies to physical limitations while enabling economic participation and household support. A total of 71 individuals engage in feather duster vending, illustrating the viability of micro enterprise activities that rely on direct selling practices despite visual impairments. These products are typically sold through moveable street vending tools or direct marketing approaches, enabling engagement with consumers without the need for complex technology. Vendors commonly operate in commercial corridors such as shop fronts, small retail outlets, and convenience stores across the city. Feather dusters are generally sold at a unit price of IDR 25,000.

Additionally, 26 people work as traditional massage service providers, a livelihood dependent on fine motoric skills and an understanding of physical wellness needs. This occupation offers flexibility in both workspace and scheduling, enabling service provision to the broader community. The standard rate for traditional massage services is approximately IDR 100,000 per hour. There are currently three fixed massage service locations operating in Oepura, Bakunase, and Manutapen.

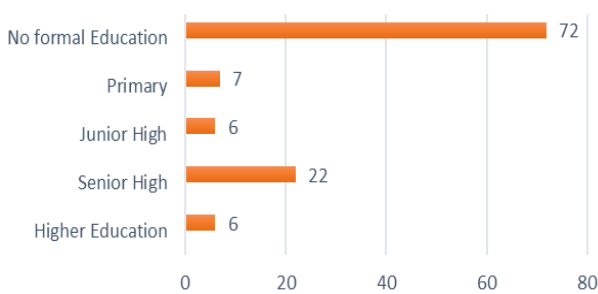


Figure 2. Distribution of educational level among people with visual impairments in Kupang City, Indonesia

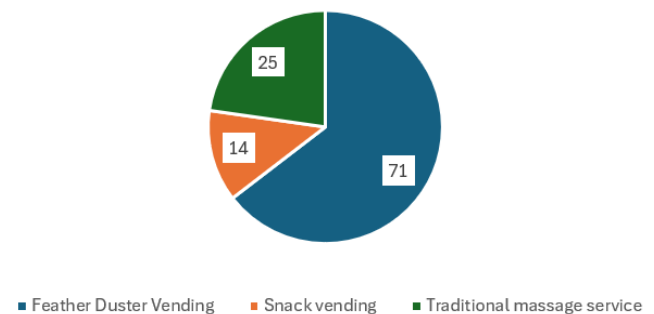


Figure 3. Distribution of micro-entrepreneur activities among people with visual impairments in Kupang City, Indonesia. Note: Value is in absolute numbers

Meanwhile, 15 people engage in small-scale food vending, particularly fried corn snacks, demonstrating utilisation of opportunities within the informal economy supported by low-capital business models. This livelihood not only generates income but also facilitates direct community interaction. Snack products are generally priced between IDR 5,000 and IDR 10,000 per packet. Engaging in outdoor activities exposes visually impaired people to significant physical and economic risks during the rainy season. This issue was profoundly articulated by one of the informants:

“We often heard on the TV or from neighbours that there was an extreme weather warning, but they always said ‘look at the map’. Maps, graphics, and text messages from the government don’t help us at all. We need something we can hear directly.” (Informant 2, female, traditional massage therapist).

The severe impact of extreme weather on their livelihood, prior to the implementation of the inclusive EWS, was highlighted by an informant:

“Before this warning system, I would go out to sell feather dusters and suddenly get caught in a severe storm. I couldn’t see the dark clouds coming, and my goods would get completely ruined by the heavy rain. It meant I had no income for days and struggled to go back home safely.” (Informant 1, male, feather duster vendor).

Good practice of the inclusive Early Warning System for people with visual impairments

The use of the inclusive Early Warning SOP for people with visual impairments aims to ensure that visually disabled communities receive BMKG’s early warning information rapidly and on time, which is reproduced by the early warning team into an audio format. Implementation of the SOP began following field testing in November 2024 and has continued through mid-2025, particularly during the extreme weather season from December to April.

This SOP was developed from the Version 1 Guidelines for Producing Extreme Weather and Disaster Early Warning Information for Vulnerable Groups issued by Yayasan Pikul. Early warning must prompt individuals and communities at risk to take appropriate actions within sufficient lead time to reduce the likelihood of injury, threats to life, and damage to assets and the environment when a hazard occurs. Communities, particularly those most vulnerable, represent the most essential element in an inclusive EWS (Attoh et al. 2025; Teku et al. 2026)

The workflow for reproducing and disseminating extreme weather early warning information for people with visual impairments in Kupang City is presented in Figure 4. The process begins with the monitoring of early warning information issued by BMKG through a WhatsApp group to obtain the most recent data on extreme weather conditions that may pose threats. Each piece of information obtained from BMKG is further reviewed, including graphical, map-based, tabular, and textual components. Early warning information from BMKG is received through the “Info BMKG” WhatsApp group, in which BPBD Kupang City and the Disaster Risk Reduction Forum (FPRB-API) of Kupang City are registered members. This information serves as the official notification of potentially hazardous extreme weather conditions affecting Kupang City and the broader East Nusa Tenggara region.

Once the information is received, BPBD and FPRB-API are responsible for forwarding it to the Person in Charge (PIC) representing the visually impaired community. This step must be executed as efficiently as possible, within three minutes after receiving the WhatsApp message. To ensure accessibility, the early warning content is then reproduced in an audio format by a member of the visually impaired community. This reproduction process utilises AI-based tools, with a maximum duration of three minutes.

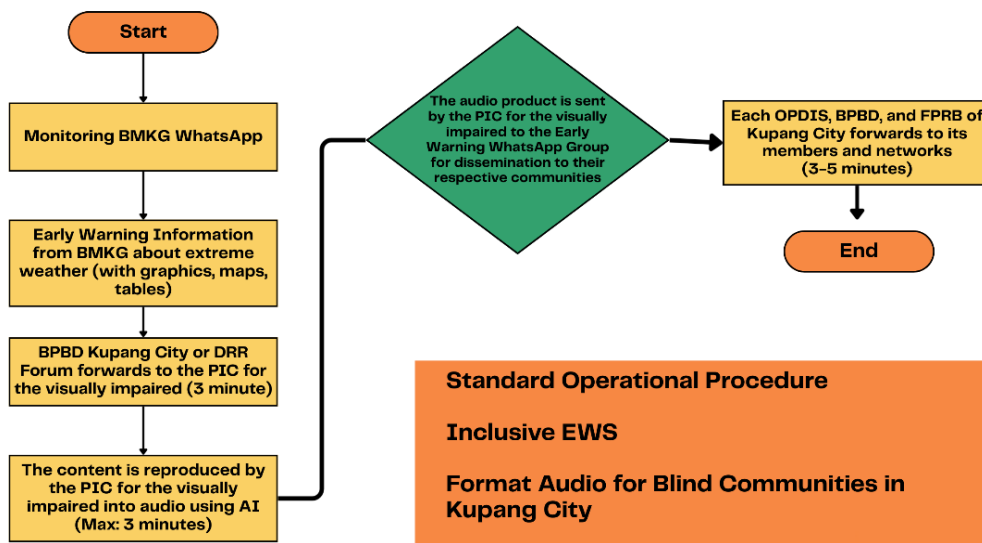


Figure 4. Flowchart of the Standard Operating Procedure for inclusive early warning information for the visually impaired people in Kupang City, Indonesia

The generated audio is subsequently disseminated back into the Early Warning WhatsApp Group to ensure that all community members can quickly and accurately access the information. Within three minutes of distribution, Organizations of Persons with Disabilities (OPDIS), especially those representing persons with visual impairments, along with BPBD and FPRB, forward the audio message to their respective members. Per information from the PERTUNI Kupang City, 76 visually impaired persons are currently included in this WhatsApp group.

Through this well-coordinated sequence of actions and highly time-efficient process flow, the system ensures the rapid and timely delivery of extreme weather early warnings to people with visual impairments in accordance with established procedures. The process concludes (End) once the early warning information has been disseminated and received by people with visual impairments in accordance with the established procedures. The monitoring and evaluation of the SOP are conducted through two primary mechanisms within the WhatsApp platform. First, the EWS dissemination team utilizes WhatsApp's native message info features (such as read receipts and the 'played' status for audio files) to estimate the immediate reach of the warnings. While exact quantitative tracking of open rates falls outside the scope of this qualitative study, observations during the extreme weather cycle indicated a high usability rate, with the majority of the 76 group members actively playing the audio messages within the crucial time window. Second, operational success is continuously evaluated through qualitative feedback loops; group members frequently reply to the warnings with voice notes to confirm receipt or report their real-time safety status, allowing BPBD and PERTUNI to monitor the system's practical effectiveness on the ground. The implementation of the system has demonstrated positive outcomes for the visually impaired community. They can receive extreme weather early warning information quickly and in an accessible audio format, enabling them to make decisions to anticipate weather-related risks. In practice, individuals have been able to temporarily suspend outdoor economic activity while continuing to monitor subsequent extreme weather updates disseminated through the WhatsApp group. The operational effectiveness and the direct livelihood protection provided by the micro-entrepreneurs:

“Now, as soon as the weather turns bad, I get a voice in our WhatsApp group. It is very fast. If the audio says strong winds are coming to my area in Maulafa Sub-district, I immediately pause my vending activities and secure my kiosk. It saves my life and protects my business.” (Informant 3, male, snack and feather duster vendor).

Challenges on the application of Early Warning System for people with visual impairments

Interviews conducted with representatives of PERTUNI, Kupang City Branch, identified two primary challenges in implementing the inclusive early warning SOP. The first challenge concerns insufficient mobile data credit for activating WhatsApp. This issue is significant, as

persons with visual impairments rely heavily on digital messaging platforms such as WhatsApp to receive early warning information. Many individuals have limited access to adequate data packages to support real-time information delivery, particularly when the warning content is disseminated as audio files that require higher bandwidth. As expressed by one of the vendors:

“The audio warnings from the group are incredibly helpful, but downloading them takes data credit. Sometimes at the end of the month, I run out of internet quota. I have to ask my neighbour or a nearby shop owner to connect to their Wi-Fi just so I can hear the extreme weather alert for PERTUNI.” (Informant 4, female, feather duster vendor).

The second challenge relates to dependence on human resources for audio content reproduction. At present, this task can only be performed by a single individual with strong IT and AI-related skills. While the reproduction process is generally executed effectively, occasional delays still occur. Producing audio-format warning information relies on multiple factors, including voice quality, accuracy of data processing, and the availability of personnel who are willing and able to work rapidly under time constraints. These conditions may create operational challenges when there are insufficient trained personnel or volunteers to support the task effectively. The community recognizes this vulnerability within the current system:

“We are very thankful for the PIC who always translates the BMKG text into voice notes for us so quickly. But what if he is sick, or his phone is broken, or the power goes out? We worry that the warnings will stop.” (Informant 5, male, PERTUNI Member).

The findings of this study strongly resonate with the broader literature concerning the intersection of sensory impairments and the "digital divide" in disaster communication. While the WhatsApp platform provides an instantaneous and familiar medium for audio dissemination in Kupang City, the financial burden of mobile data highlights a systemic inequality. This aligns with observations by Chisty et al. (2021) in Bangladesh, where visually impaired populations frequently lack accessible warning mechanisms due to compounded socioeconomic barriers. In the Kupang context, the transition from visual BMKG maps to localized audio warnings successfully resolves the sensory barrier; however, it inadvertently introduces an economic issue. This phenomenon supports the argument by de Perez et al. (2022) that early warnings must not only be comprehensible but also economically accessible, preventing undue financial strain on the most vulnerable end-users.

Furthermore, the intersection of visual impairment and informal micro-enterprise activities creates unique exposure profiles during extreme weather. As demonstrated in the results, feather duster vendors and traditional massage therapists rely heavily on mobility and outdoor public interaction. The immediate ability to pause economic activities, as expressed by the informants, demonstrates the high actionability of the inclusive SOP. Actionable warnings are a critical component of effective disaster risk reduction. Similarly, Sherman-Morris et al. (2020) noted that visually impaired individuals face

significant barriers to taking protective action during rapid-onset hazards. In Kupang, the stringent 3-to-5-minute audio dissemination benchmark effectively bridges this gap, granting vendors the crucial lead time required to secure their physical assets and seek safe shelter. Nevertheless, for daily wage earners, pausing economic activity inherently equates to a direct loss of income, underscoring the necessity for broader social protection mechanisms to complement the EWS.

From a risk governance perspective, the operationalization of this SOP underscores the profound efficacy of Community-Based Disaster Risk Management (CBDRM). The strategic collaboration between local government (i.e. BPBD), civil society (i.e. FPRB), and visually-impaired advocacy institution (i.e. PERTUNI) represents a vital paradigm shift from traditional, top-down warning dissemination to a participatory, decentralized model. The active involvement of PERTUNI ensures that the warnings are not merely translated but are culturally and contextually tailored to the specific technological realities of their members. Moving forward, as suggested by recent explorations into automated community flood responses (Kalogiannidis et al. 2025; Ou et al. 2025), integrating emerging AI technologies for automated text-to-audio conversion could further strengthen this community-led initiative by reducing human fatigue, provided these technological tools are designed inclusively and do not exacerbate existing digital divides.

Proposed solutions include encouraging solidarity from owners of shops, kiosks, and minimarkets in Kupang City to provide free Wi-Fi access for visually disabled vendors operating around their premises. Mutual checking through phone calls among group members may also help ensure safety monitoring, especially for those conducting economic activities outside their homes. SMS text transmission serves as an alternative method for information delivery (BMKG 2010). Similar barriers have been reported in the United States, where Sherman-Morris et al. (2020) found that individuals with visual impairments are disproportionately vulnerable to severe weather hazards such as tornadoes, particularly in the southeastern region, where exposure is compounded by physical and socioeconomic factors. Their interviews with 25 persons with visual impairments in Alabama, Louisiana, and Mississippi examined how they receive and respond to tornado warnings. Evidence from several other global studies further reinforces these findings (Brooks 2006; de Perez et al. 2022; Lusambili et al. 2024; Ou et al. 2025)

To mitigate challenges related to content production and dissemination, a proposed solution involves team capacity strengthening. As suggested by the participant themselves:

“We cannot rely on just one person forever. We need more visually impaired friends in Kupang City to be trained to use the AI voices tools. If three of four of us know how to make the audio, we can take turns and make sure the warning are never delayed.” (Informant 6, female, massage service provider).

Therefore, two to three volunteers among persons with visual impairments should be trained to provide mutual

support in content reproduction. More intensive mentoring from previously trained volunteers would further accelerate the dissemination workflow of early warning information. An alternative solution is the adoption of a multi-channel dissemination approach.

This includes broadening communication platforms beyond radio by utilising internet-based media, social media, direct messaging from trusted sources, and establishing partnerships with telecommunications service providers to improve reach to remote areas, as demonstrated in Tuvalu in the Pacific region (Red Cross Red Crescent Climate Centre (RCCC 2022)). In this regard, PERTUNI could collaborate with local radio broadcasters in Kupang City to expedite the delivery of early warning information, while individual members could utilise portable radios or mobile phones equipped with radio functionality.

The observed disparities in educational attainment among the visually impaired community in Kupang further complicate the landscape of disaster communication. With a significant portion of the population having limited formal education, the reliance on audio-based WhatsApp alerts is not merely a preference but a functional necessity. This educational profile suggests that any inclusive EWS must prioritize intuitive, non-textual interfaces to ensure that warnings are comprehended by all users, regardless of their literacy levels.

To ensure the long-term sustainability of this system, local disaster governance should transition from a volunteer dependent model to a more institutionalized framework. Strategic capacity building is required to expand the pool of trained volunteers within PERTUNI, thereby mitigating the risk of relying on a single individual for content production. Moreover, addressing the ‘digital divide’ will necessitate cross-sectoral partnerships, such as collaborating with telecommunications providers to subsidize data access or utilizing low-bandwidth communication channels. By integrating AI-supported text to audio tools and strengthening community led technical competencies, this inclusive model appears to offer a viable pathway for enhancing urban resilience in tropical dryland settings without imposing additional financial burdens on marginalized households.

Furthermore, the heavy reliance on a single technical volunteer highlights the vulnerability of Community-Based Disaster Risk Management (CBDRM) frameworks when institutional mapping and external budgeting are absent. To mitigate these constraints, integrating emerging AI tools like *InstaReader* and *Be My Eyes* must be balanced with multi-channel approaches such as local radio broadcasting partnerships and telecom-subsidized data access-to ensure long-term system sustainability without imposing additional financial strains on daily wage earners.

In conclusion, this study indicates that the inclusive WhatsApp-based EWS appears to strengthen disaster resilience of visually impaired micro-entrepreneurs in Kupang City by providing an accessible and rapid information channel. The transition from visual meteorological alerts to audio formats facilitates more informed livelihood decisions, such as securing

commercial assets before extreme weather onset. However, the system's perceived effectiveness is currently constrained by mobile data costs and a high dependency on limited human resources for audio conversion. While these findings are context specific and limited by the small purposive sample size, they offer a potentially adaptable model for other urban centres. Future research should evaluate the scalability of this inclusive governance approach in more resource constrained regional context to further validate its impact on inclusive disaster risk reduction.

REFERENCES

- Abikoye O, Abikoye A. 2025. Marine policy and community engagement: Rethinking the role of vulnerable groups in climate and ocean action on Lagos' Atlantic coast, Nigeria. *Mar Pol* 182: 106850. <https://doi.org/10.1016/j.marpol.2025.106850>.
- ASEAN Secretariat. 2024. Strengthening ASEAN Multi-Hazard End To End Early Warning System For Natural disasters: An Assessment of Current Capacity. ASEAN Secretariat, Bangkok. <https://asean.org/book/strengthening-asean-multi-hazard-end-to-end-early-warning-system-for-natural-disasters/>.
- Attoh, Emmanuel MNAN, Giriraj A. 2025. Climate risk management a framework for addressing the interconnectedness of early warning to action and finance to strengthen multiscale institutional responses to climate shocks and disasters. *Climate Risk Manag* 47 (December 2024): 100689. <https://doi.org/10.1016/j.crm.2025.100689>.
- Badan Meteorologi Klimatologi dan Geofisika (BMKG). 2010. Prosedur Standar Operasional Pelaksanaan Peringatan Dini, Pelaporan, dan Diseminasi Informasi Cuaca Ekstrem. BMKG, Jakarta. [Indonesian]
- Badan Meteorologi Klimatologi dan Geofisika (BMKG). 2022. Penyediaan dan Penyebarluasan Peringatan Dini Cuaca Ekstrem. BMKG, Jakarta. [Indonesian]
- Becker AK, Leppert G, Köngeter A. 2025. Vulnerable entrepreneurs' preferences for climate risk management: A discrete choice experiment with micro-enterprises in the Philippines. *J Environ Manag* 392: 126485. <https://doi.org/10.1016/j.jenvman.2025.126485>.
- Brooks M. 2006. Challenges for Warning Populations with Sensory Disabilities. In: Van de Walle MTB (eds.). *Proceed ISCRAM 2006 - 3rd Intl Conf Info Syst Cris Respon Manag* (pp. 137-140). Royal Flemish Academy of Belgium, Newark, Brussels.
- Chisty MA, Nazim A, Rahman MM, Dola SEA, Khan NA. 2021. Disability inclusiveness of early warning system: A study on flood-prone areas of Bangladesh. *Dis Prev Manag* 30 (4-5): 494-509. <https://doi.org/10.1108/DPM-05-2021-0177>.
- de Perez EC, Berse KB, Depante LAC, Easton-Calabria E, Evidente EPR, Ezike T, Heinrich D, Jack C, Lagmay AMFA, Lendelvo S, Marunye J, Maxwell DG, Murshed SB, Orach CG, Pinto M, Poole LB, Rathod K, Shampa, Sant CV. 2022. Learning from the past in moving to the future: Invest in communication and response to weather early warnings to reduce death and damage. *Clim Risk Manag* 38: 100461. <https://doi.org/10.1016/j.crm.2022.100461>.
- Glowka G, Eller R, Peters M, Zehrer A. 2024. Risk perception in small- and medium-sized hospitality family enterprises. *Tour Rev* 80 (7): 1335-1351. <https://doi.org/10.1108/TR-06-2023-0421>.
- Hajad V, Ikhsan I. 2024. Ecofeminism as a movement: Choosing between economics and nature protection. *Theor Pract Res Econ Field* 15 (29): 91-100. [https://doi.org/10.14505/tpref.v15.1\(29\).09](https://doi.org/10.14505/tpref.v15.1(29).09).
- Jamroni R. 2024. Sistem Peringatan Dini (Early Warning System) dalam Mengurangi Risiko Bencana: Tinjauan Konsep, Implementasi, dan Contoh Kasus di Berbagai Negara. BMKG, Jakarta. <https://www.bmkg.go.id/artikel/sistem-peringatan-dini-early-warning-system-dalam-mengurangi-risiko-bencana-tinjauan-konsep-implementasi-dan-contoh-kasus-di-berbagai-negara>. [Indonesian]
- Kalogiannidis S, Spinthiropoulos K, Chatzitheodoridis F, Kalfas D, Kantzios N. 2025. Communication ethics in business: Examining the role of ethical communication in building trust and sustainability. *Intl J Innov Res Sci Stud* 8 (3): 1770-1783. <https://doi.org/10.53894/ijriss.v8i3.688>.
- Lusambili A, Filippi V, Nakstad B, Natukunda J, Birch CE, Marsham JH, Roos N, Khaemba P, Kovats S. 2024. Community perspectives of heat and weather warnings for pregnant and postpartum women in Kilifi, Kenya. *PLoS One* 19 (11): e0313781. <https://doi.org/10.1371/journal.pone.0313781>.
- Myeni L, Roffe S. 2025. Towards effective weather and/or climate services in South Africa: Profiling sectoral needs and constraints. *Environ Dev* 55: 101240. <https://doi.org/10.1016/j.envdev.2025.101240>.
- Nastasia I, Rives R. 2025. Successful strategies for occupational health and safety in small and medium enterprises: Insights for a sustainable return to work. *J Occup Rehabil* 35 (4): 767-782. <https://doi.org/10.1007/s10926-024-10255-2>.
- Nwokocha NV, Gift OO. 2025. The role of strategic alliance as a coping strategy for climate change by SMEs in Nigeria. *GeoScape* 19 (1): 12-24. <https://doi.org/10.2478/geosc-2025-0002>.
- Ou TH, Yang TH, Chang PZ. 2025. Combination of large language models and portable flood sensors for community flood response: A preliminary study. *Water* 17 (7): 1055. <https://doi.org/10.3390/w17071055>.
- Pemerintah Kota Kupang. 2024. Naskah Akademik Rancangan PERDA Tentang RPJMD Tahun 2025-2029. Pemerintah Kota Kupang, Kupang. [Indonesian]
- Red Cross Red Crescent Climate Centre (RCCC). 2022. Community-Based Early Warning Early Action (EWEA) in the Pacific: Findings from Tuvalu. Red Cross Red Crescent Climate Centre, The Hague, Netherlands.
- Sherman-Morris K, Pechacek T, Griffin DJ, Senkbeil J. 2020. Tornado warning awareness, information needs and the barriers to protective action of individuals who are blind. *Intl J Disast Risk Reduct* 50: 101709. <https://doi.org/10.1016/j.ijdr.2020.101709>.
- Teku, Degfie, Getasew DT. 2026. Effectiveness of early-warning systems and disaster risk reduction for rural food security under hydro-meteorological hazards in Sub-saharan Africa: Systematic review. *Intl J Sustain Dev World Ecol* 33 (1): 101-22. <https://doi.org/10.1080/13504509.2025.2595056>.