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Understanding Flood Risk Perceptions and Preparedness Gaps among Migrant and Mobile Populations in Chiang Mai, Thailand: Implications for Inclusive Flood Risk Management

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Abstract: Urban flood risk is increasingly shaped by population mobility, yet disaster preparedness research continues to often assume stable residence, secure housing, and equal access to official warning systems. This study examines flood risk perception and preparedness among migrant and mobile populations in Chiang Mai, Thailand. Using a mixed-methods design combining a multilingual survey (206 responses; 201 with valid mobility-status data), expert interviews (n = 16), and mapping of participant-reported flood locations, it compares hidden populations (undocumented and other precarious residents), international migrants, digital nomads, and tourists/short-term visitors. Findings show that flood risk is widely recognised but preparedness action remains limited. Prior flood experience is highest among hidden populations (76.5%) and international migrants (63.8%), yet only 6.3% of respondents report being very prepared, and 32.5% have taken no preparedness measures. Preparedness is concentrated in low-cost actions, such as saving emergency contacts, while measures requiring financial resources, stable housing, or longer-term planning are far less common. Logistic regression indicates that perceived flood likelihood and institutional trust are positively associated with undertaking at least one preparedness action. However, preparedness still centres on relatively low-cost behaviours, suggesting that while awareness and trust may facilitate initial action, they do not overcome the legal, financial, housing, and informational constraints that limit more substantial forms of preparedness. The paper conceptualises this disconnect as a "feasible preparedness gap"; the distance between recognising risk and possessing the legal, financial, spatial, and informational capacity to act. It advances a Mobility-Aware Protective Action Decision Model that extends existing frameworks by incorporating legal status, housing security, information access, and social networks as key determinants of protective action. The study offers a contextually grounded yet transferable framework for analysing disaster vulnerability in mobility-intensive urban environments and provides practical insights for more inclusive flood risk governance in Southeast Asia and comparable settings.

Keywords: flood risk perception; flood preparedness; migrant and mobile populations; urban resilience; legal precarity; protective action decision model; inclusive disaster risk reduction

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1. Introduction

Floods remain one of the most frequent and destructive hazards worldwide, accounting for nearly half of all recorded disasters since 2000 [1]. Their impacts are particularly severe in urban areas, where exposure interacts with inequality, governance complexity, and rapid socio-spatial transformation, resulting in disproportionate mortality, morbidity, displacement, and economic loss [2,3]. In rapidly urbanising cities such as Chiang Mai, flood risk is further exacerbated by land-use change, limited drainage capacity, and the expansion of settlements into low-lying and hazard-prone areas [4,5]. Climate change compounds these challenges by increasing the frequency and intensity of heavy rainfall and extreme flood events across many regions [6–9]. However, flood risk is not determined by physical exposure alone. Those most at risk are often the least visible to, or least protected by, formal disaster governance systems [10]. Migrants, undocumented residents, digital nomads, and tourists/short-term visitors may live, work, or move through flood-prone urban environments without reliable access to official early warning systems, preparedness information, or post-disaster assistance [11–13].

In response, the international community has advocated for more inclusive approaches to resilience [14]. The Sendai Framework for Disaster Risk Reduction, the global blueprint for managing hazards, promotes an "all-of-society" approach and emphasises that no one should be left behind [15], explicitly recognising migrants as a group whose specific needs must be addressed in disaster planning [16]. However, these principles have yet to be fully translated into practice. Asylum seekers, migrants, undocumented residents, and other mobile populations remain frequently excluded from disaster preparedness and response systems, even as flood governance becomes increasingly reliant on formal registration, platform-mediated communication, and state-linked service delivery [13,17]. More broadly, flood risk is shaped not only by where people live, but also by how they are recognised, connected, and protected within urban governance systems.

This exclusion matters because flood preparedness continues to exhibit a persistent awareness–action gap, whereby individuals and communities recognise flood risks yet fail to take protective measures [18,19]. Behavioural disaster research has traditionally explained this gap through cognitive and motivational factors, including perceived risk severity, response efficacy, prior experience, trust in authorities, and the effectiveness of risk communication [20–23]. However, these explanations implicitly assume relatively stable residence patterns, baseline institutional trust, and consistent access to official warning systems. Such assumptions increasingly fail to reflect contemporary urban realities shaped by intensified mobility, legal precarity, and digitally mediated governance infrastructures [24–26].

For migrant and mobile populations, preparedness is not simply a function of individual motivation or risk appraisal. It is also constrained by legal invisibility, linguistic exclusion, housing insecurity, and fragmented access to trusted information systems [27,28]. As a result, high perceived flood risk does not always translate into protective action, not because awareness is absent, but because preparedness is shaped by governance arrangements, mobility status, and unequal access to resources that determine whether action is feasible in the first place [24,29,30]. In this context, preparedness among migrant and mobile groups is better understood as an outcome conditioned by mobility status and governance design, rather than as a simple behavioural choice.

1.1. Flood Preparedness and Protective Action

Flood preparedness is widely framed in disaster risk reduction research as a key mechanism for reducing losses from recurrent hazards, particularly where households and communities can take anticipatory measures before an event [1,15,23,31]. Empirical studies show that household-level precautionary measures, including flood-adapted interior fittings and other building- or content-related actions, can substantially reduce flood losses [31–34]. However, uptake remains uneven, even among households exposed to comparable hazards.

This pattern is well established in the literature: despite often high levels of flood risk awareness and direct experience, the adoption of precautionary measures remains limited and may decline over time following an event [18,19,34–36]. Recent studies in disaster-prone settings in South Asia similarly show that protective action is constrained by socioeconomic conditions, insecure tenure, livelihood pressures, weak institutional support, and uneven governance, even where hazard awareness is high [37–40]. This reinforces the view that preparedness outcomes are shaped by structural conditions rather than awareness alone.

Behavioural and decision-oriented approaches explain the awareness–action gap by examining how individuals interpret hazard cues, evaluate severity and likelihood, assess protective options, and judge whether action is feasible and worthwhile [18,21]. Within this tradition, the Protective Action Decision Model (PADM) outlines a staged process in which warning exposure and social cues shape threat appraisal, protective action appraisal, and action selection, with information seeking and institutional credibility influencing each stage [21]. Complementary evidence from protection motivation theory shows that both threat appraisal and coping appraisal are significant predictors of

flood preparedness intentions and behaviour across contexts [41]. Reviews of flood risk perception further highlight the roles of experience, affective responses (such as worry and fear), trust in authorities, and perceived controllability, although their effects vary across contexts and population groups [19,20,42,43].

At the same time, this body of work has been criticised for implicitly framing preparedness as primarily a matter of individual motivation and choice, even where households face unequal capacities, resources, and structural constraints [44,45]. The "risk perception paradox" literature shows that high perceived risk does not consistently translate into preparedness, as action is mediated by trust, efficacy beliefs, competing priorities, and barriers that are often social, economic, or institutional rather than purely psychological [18,19]. Insights from risk-as-feelings theory further suggest that emotionally salient hazards can lead to either action or inaction, depending on whether individuals perceive feasible pathways for response [46]. More recent syntheses describe a broader "behavioural turn" in flood risk management that promotes private precautionary action, while cautioning that such approaches may reproduce inequalities when they assume stable residence, secure tenure, and reliable access to warnings and support [45].

Taken together, literature indicates that preparedness is shaped by more than knowledge or awareness alone. The explanatory power of behavioural models further depends on specifying how unequal capacity, trust, information access, and opportunity structures condition whether protective action is realistically attainable. Building on these insights, this study treats preparedness as the primary outcome and examines how mobility-related constraints shape the feasibility of protective action, positioning mobility and governance conditions as core elements of the decision environment rather than background context.

1.2. Mobility, Migration and Differentiated Preparedness in Urban Flood Contexts

The uneven uptake of flood preparedness identified in the wider literature becomes more pronounced where exposed populations are not socially or institutionally uniform. In many Southeast Asian cities, a substantial share of residents live and work under conditions of mobility, partial documentation, or transient residence, reshaping not only vulnerability but also the everyday feasibility of protective action [25,47]. In this paper, migrant and mobile populations are conceptualised as a set of heterogeneous mobility positions rather than a single "vulnerable group". These include international migrants, hidden populations, digital nomads, and tourists/short-term visitors. International migrants may include labour migrants and asylum seekers, while hidden populations refer to undocumented migrants and other precarious residents who may have limited visibility within formal governance systems. These groups are often characterised by varying degrees of administrative integration, local embeddedness, and reliance on digital platforms and informal networks. These distinctions matter because they shape the resources and permissions underpinning preparedness, including housing choice, tenancy security, local knowledge, and the ability to engage with official systems without fear or friction [28,48].

Legal status is particularly consequential, as it influences access to formal employment, welfare and health protections, and willingness to engage with authorities during warnings, evacuations, or relief distribution [28,49]. Evidence from Thailand shows that undocumented migrants and asylum seekers, particularly from Myanmar, face compounded risks linked to legal precarity, fear of enforcement, and exclusion from formal support mechanisms [27]. At the same time, newer forms of mobility such as digital nomadism highlight that even relatively privileged groups may remain detached from local disaster governance and official risk communication channels [50–54]. These differences suggest that preparedness is shaped by more than perceived risk alone. Legal status, language access, housing security, institutional trust, and digital connectivity influence who receives warnings, who trusts them, and who can act on them [11,12,55].

1.3. Limits of Behavioural and Governance Accounts of Preparedness in Mobility-Conditioned Settings

Persistent shortfalls in flood preparedness among migrant and mobile populations expose a conceptual gap between how preparedness is typically theorised and how it is enabled or constrained in practice. Behavioural models such as the Protective Action Decision Model (PADM) acknowledge contextual influences, yet empirical applications rarely treat legal status, administrative exclusion, digital gatekeeping, language barriers, insecure tenure, and eligibility for formal support as core determinants of action feasibility [21,45]. As a result, low preparedness is often interpreted as a deficit in motivation, risk understanding, or trust, even where constraints are material, institutional, and unevenly distributed across populations [44].

This limitation is particularly important as preparedness is increasingly shaped by governance arrangements that route warnings, guidance, and emergency support through digitally mediated infrastructures. Digital disaster systems can expand the reach of risk communication, but they can also create uneven access where warnings depend on platform use, digital literacy, language, documentation, and network position [56–58]. For migrants,

these dynamics intersect with legal precarity and institutional mistrust, compounding barriers to official information and assistance [11,28,55,59].

These dynamics reveal a misalignment between prevailing models of protective action and the conditions under which preparedness is enacted. A more adequate approach must connect decision-making processes to the institutional filters that regulate warning access, credibility, and the practical feasibility of action, particularly in mobile and legally stratified urban settings [24,29,60].

1.4. Mobility-Conditioned Protective Action: A Conceptual Framework for Inclusive Flood Preparedness

Existing behavioural models have significantly advanced understanding of how individuals perceive hazards and decide whether to undertake protective actions. However, many applications implicitly assume stable residence, secure housing, and straightforward access to official warning systems. In mobility-intensive urban settings, preparedness is shaped not only by risk appraisal but also by the conditions that enable individuals to receive, interpret, and act upon risk information. To address these limitations, this study advances the concept of mobility capital, defined as the combination of legal status, digital connectivity, housing autonomy, and social embeddedness that shapes an individual's capacity to receive, interpret, and act upon hazard information [26,61–63]. This framing aligns with mobility justice scholarship and vulnerability theory, which locate disaster risk in unequal access to rights, infrastructures, and institutional protection rather than in hazard exposure alone [62–65].

Building on this, the study conceptualises mobility-conditioned risk environments as urban contexts in which hazard exposure, warning access, and preparedness opportunities are systematically shaped by mobility status and governance design, rather than by hazard characteristics alone [24,26]. Within such environments, legal precarity, linguistic exclusion, and digital gatekeeping act as structural filters that can block, delay, or distort the perception–action sequence central to behavioural preparedness models. Chiang Mai, as discussed in Section 1.6, exemplifies such an environment, where flood risk is co-produced by hydrological exposure and ID-dependent governance systems.

These concepts underpin the development of a Mobility-Aware Protective Action Decision Model (PADM). Rather than extending PADM through the addition of individual-level variables, this framework reconceptualises protective action as a process mediated by mobility-conditioned governance filters, thereby bridging behavioural decision-making with political-ecological perspectives on disaster risk and vulnerability, and foregrounding the governance conditions that shape whether protective action is feasible.

1.5. Aim and Contributions of the Study

This study investigates how mobility shapes flood risk perception, access to warnings, and the feasibility of household preparedness among migrant and mobile populations in Chiang Mai, Thailand. It focuses on populations present in the city but unevenly recognised by governance systems, including international migrants, hidden populations, digital nomads, and tourists/short-term visitors. By examining exposure, housing autonomy, language, institutional trust, and digitally mediated access to warnings, the paper demonstrates how mobility produces distinct preparedness pathways that are not adequately captured by household-centred flood preparedness research. Preparedness is thus analysed as a key outcome through which mobility-conditioned vulnerability becomes visible.

The paper makes three contributions. First, it advances preparedness theory by extending the Protective Action Decision Model (PADM) into a mobility-aware framework that treats protective action as conditional on governance filters rather than cognitive appraisal alone. In doing so, it reframes the classic awareness–action gap as a feasibility problem, showing how legal status, administrative recognition, housing conditions, and platform-mediated communication shape what individuals can realistically do as risk escalates. While PADM remains valuable for tracing how cues, appraisals, and decisions unfold, this study explains why these stages diverge across mobile groups when access to hazard information, institutional trust, and capacity for action are unequally distributed. Second, the study contributes empirically by providing multilingual evidence on populations that are typically missing from flood preparedness datasets, particularly hidden and precarious residents who may avoid official channels. By comparing mobility subgroups within the same urban flood setting, the analysis demonstrates how preparedness differences persist even under shared hydrometeorological conditions, as vulnerability is co-produced by housing markets, information environments, and the terms of inclusion within local risk governance systems. Third, the study contributes to practice by translating these mechanisms into design implications for more inclusive flood risk management in mobility-driven cities. These include warning systems that do not require national ID registration, multilingual risk communication delivered through trusted intermediaries alongside official channels, and preparedness options that account for rental constraints and short-term residence strategies.

These contributions position Chiang Mai as a critical case for understanding how contemporary urban mobility and digitised governance reshape the conditions under which protective action becomes possible.

1.6. Study Area: Chiang Mai As a Mobility-Conditioned Flood Risk Environment

Chiang Mai city and its surrounding metropolitan districts host an estimated urban population of over one million residents, alongside substantial unregistered and transient populations linked to labour migration, tourism, education, and short-term residence [47]. Within the city, migrants from Myanmar constitute one of the largest mobile groups, with recent assessments indicating that a significant share remains in irregular situations and is therefore absent from official urban population registers [47]. Prior studies show that rental and informal housing are often concentrated in flood-exposed neighbourhoods along the Ping River and in low-lying urban corridors, increasing susceptibility to displacement during recurrent flood events [28,66].

Major flooding in 2011 and repeated seasonal inundation in 2022, 2024, and 2025 have caused displacement, housing damage, and livelihood disruption across Chiang Mai city, with cumulative impacts affecting thousands of residents [67,68]. Disaster risk management operates under Thailand's centralised system led by the Department of Disaster Prevention and Mitigation, where access to early warnings and post-disaster assistance is closely tied to household registration and legal identification. This may contribute to the systematic exclusion of mobile and undocumented urban residents [59,69].

In this context, Chiang Mai represents a critical analytical site where high physical exposure to flooding intersects with diverse and often institutionally invisible mobility flows. This combination makes it well suited for examining how disaster vulnerability is produced not only by hazards but also through the interaction of mobility, legal precarity, and the design of risk governance systems [10,26,29]. The city therefore exemplifies the mobility-conditioned risk environments that underpin this study's theoretical framework (Figure 1).

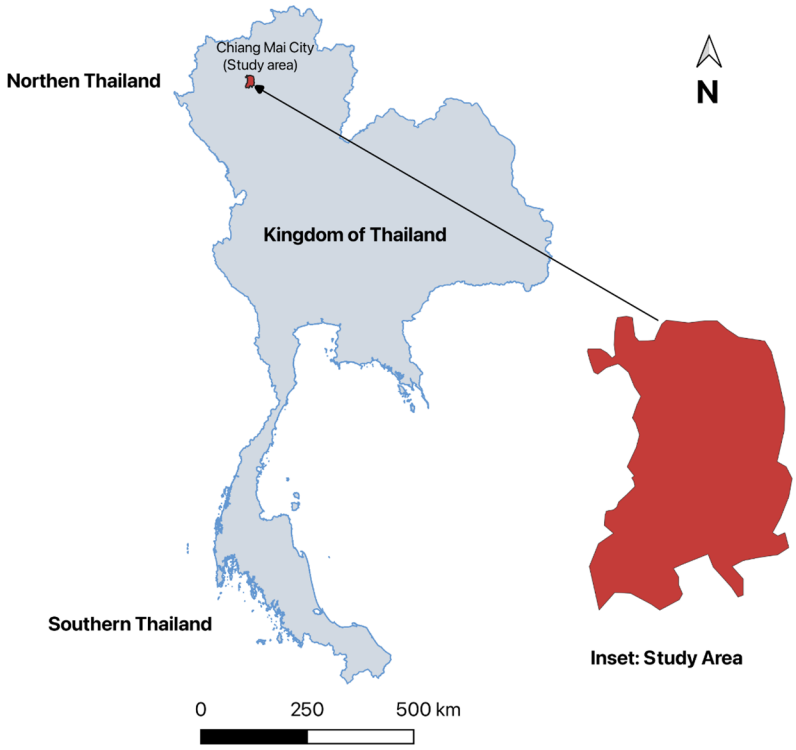


Figure 1. Location of the study area, Chiang Mai City, in northern Thailand. Created by the first author (OpenStreetMap [70]).

2. Methodology

2.1. Research Design

This study employed a convergent mixed-methods design combining multilingual surveys, expert interviews, and spatial analysis to examine flood risk perception and preparedness among migrant and mobile populations in Chiang Mai, Thailand. Data were collected between 1 and 31 July 2025. The follow-up interviews added an explanatory sequential element [71], in which quantitative findings informed subsequent qualitative interpretation. This approach enabled both broad pattern identification and in-depth explanation of how mobility shapes flood preparedness.

2.2. Sampling Procedure and Recruitment

Migrant and mobile populations are frequently absent from national registries; therefore, a purposive and chain-referral recruitment strategy, informed by respondent-driven sampling principles, was employed [72]. Digital recruitment relied on QR-coded multilingual flyers distributed through WhatsApp, Telegram, and Facebook groups used by migrants, digital nomads, tourists and expatriates. Field-based recruitment targeted Burmese-majority neighbourhoods in San Sai and Hang Dong districts and food and vegetable markets, capturing groups less active online or wary of institutional contact. The sampling strategy prioritised diversity across mobility positions and aimed to reach groups typically excluded from official datasets. Eligibility criteria required participants to be aged 18 years or older, to have resided in Chiang Mai for at least one month, and to self-identify as migrant, mobile, or transient. Surveys were administered in English, Thai, Burmese, French, and Russian to ensure linguistic inclusivity.

The survey generated 206 responses. Mobility status information was available for 201 respondents, which forms the basis of the subgroup analyses presented in Table 1. While the sample is not statistically representative of all migrant and mobile residents in Chiang Mai, it is analytically robust for comparing preparedness patterns across major mobility subgroups. Recruitment was monitored throughout the data collection period to ensure participation across the four analytical mobility subgroups used in the study: international migrants, digital nomads, hidden populations and tourists or short-term visitors. This reduced over-reliance on easily accessible groups and ensured sufficient representation for comparative analysis of flood risk perception and preparedness.

To complement the survey data, 16 expert interviews were conducted to capture institutional perspectives on migrant inclusion, governance constraints, and communication practices shaping preparedness beyond individual decision-making. Participants were purposely selected to include officials from the Department of Disaster Prevention and Mitigation (DDPM), representatives of local and international NGOs, and leaders of community-based organisations working with migrant populations in Chiang Mai. Experts were identified through organisational directories and professional networks, invited via direct email, and all those who agreed during the data collection period were included.

Table 1. Distribution of survey respondents by mobility subgroup.

Mobility Subgroup	n	% of Sample
International Migrants	70	34.8%
Digital Nomads	61	30.3%
Hidden Populations	51	25.4%
Tourist/Short-term Visitor	19	9.5%
Total	201	100%

Note: Mobility status information was available for 201 respondents; percentages are based on valid responses.

2.3. Quantitative Data

The quantitative component used a structured, multilingual online survey hosted on KoBoToolbox, a platform that enables secure and mobile-accessible data collection in low-connectivity contexts. The survey instrument was developed drawing on the Protective Action Decision Model [21] and Protection Motivation Theory [73] and captured five core domains. These included: (1) demographic and mobility characteristics (age, gender, nationality, visa type, duration of residence, housing type); (2) flood risk perception (perceived likelihood, severity, and controllability); (3) preparedness behaviour at individual and household levels (protective actions, emergency planning, and access to resources); (4) information access and institutional trust (primary information channels, language of communication, and perceived reliability of authorities); and (5) awareness of multiple hazards, including floods, air pollution, heatwaves, and earthquakes.

The concept of mobility capital was operationalised using three proxy indicators. Legal status was measured through visa type as an indicator of institutional access; digital and information access were assessed through language of information consumption and primary communication channels; and social embeddedness was captured through reported participation in migrant networks or online community groups. Survey items were measured using five-point Likert scales, and internal consistency for relevant multi-item constructs met the threshold of Cronbach's $\alpha \geq 0.70$.

Descriptive statistics, chi-square tests, and logistic regression analyses were conducted using SPSS (v.29) to examine relationships between flood risk perception, preparedness behaviours, and mobility capital indicators.

2.4. Qualitative Data

The qualitative phase contextualised the quantitative findings. Sixteen semi-structured expert interviews were conducted with officials from the Department of Disaster Prevention and Mitigation (DDPM) (n = 2), NGO representatives (n = 8), and academics or community leaders (n = 6). These interviews explored institutional perspectives on migrant vulnerability, inclusivity in disaster risk reduction (DRR) systems, and communication barriers affecting preparedness. Interviews lasted up to 45 min and were conducted in English and Thai, with interpreters used where necessary. All interviews were audio-recorded, transcribed verbatim, and translated into English. Analysis followed a hybrid deductive–inductive coding approach using NVivo 14. Deductive codes were derived from PADM constructs, including threat appraisal, coping appraisal, barriers, and cues, while inductive coding captured emergent themes such as digital gatekeeping, legal precarity, and informal trust networks. To enhance validity, follow-up interviews were conducted with a purposively selected subset of 12 survey participants. These participants were selected to reflect variation across mobility subgroups and preparedness levels.

2.5. Spatial Analysis

Spatial analysis was used to link reported preparedness patterns with the physical geography of flood exposure. Using OpenStreetMap [70] and DDPM shapefiles, survey-reported residential locations were mapped in ArcGIS Pro 3.2 against flood risk zones. This enabled the identification of spatial clustering between participant residence areas and flood-prone locations. The analysis further examined how flood exposure intersected with mobility status, housing conditions, and preparedness outcomes across the study population. Residential proximity, self-reported flood experience, specified flood locations, and official flood-risk classifications were triangulated to assess whether participants were drawn from flood-exposed settings.

2.6. Data Analysis

Findings were synthesised using a convergent triangulation framework [74,75], enabling reciprocal validation across quantitative, qualitative, and spatial data sources. Quantitative, qualitative, and spatial analyses were initially conducted separately and then integrated through joint analytic tables organised around core PADM elements: exposure and experience, threat appraisal, protective action appraisal, barriers, and cues. Areas of convergence, complementarity, and divergence across data sources were identified and used to refine the Mobility-Aware PADM, ensuring that it captured not only cognitive processes but also the governance and mobility-related constraints identified across the dataset.

Policy and practice recommendations were derived directly from this integrated analysis rather than added post hoc. For each preparedness gap, the analysis examined how combinations of mobility capital (including legal status, housing conditions, and digital access), governance arrangements, and information pathways shaped opportunities for protective action. Recommendations were then developed by identifying targeted adjustments to early warning design, communication channels, eligibility criteria, and local support mechanisms that could reduce these constraints. The resulting recommendations were cross-checked against expert interview data and relevant Thai disaster risk reduction policies to ensure institutional realism and alignment with the priorities of the Sendai Framework for Disaster Risk Reduction.

2.7. Ethical Considerations

Ethical approval was obtained from the University of Leicester Research Ethics Committee (Ref: ENV-2024-021). Participation was voluntary, informed consent was obtained in participants' preferred language, and all responses were fully anonymised. No personally identifying information or identifying immigration records were collected; visa type was recorded only as a broad, self-reported category. Mobility subgroups were based on participants' self-reported status; no identity documents, visa numbers or verification of legal status were requested. All data were encrypted and stored on secure servers. Special care was taken when working with hidden and legally precarious populations. Survey and interview instruments avoided questions that could increase legal or personal risk, and interviews were conducted in neutral, participant-selected locations. Translators and field assistants received training in confidentiality and trauma-sensitive communication. Reflexivity was maintained through field journaling and peer debriefing to monitor positionality and potential sources of bias, particularly given the researcher's role as a non-Thai researcher working through local mobility networks. Ethical practice was consistent with established guidance on ethical research with migrant and refugee populations [76], with particular attention to the principles of non-harm, informed consent, and cultural sensitivity.

3. Results

This section presents empirical findings from a multilingual survey (n = 201), open-ended survey responses (n = 147), 16 expert interviews, and mapping of participant-reported flood locations. The analysis is organised around four mobility-defined groups: hidden populations, international migrants, digital nomads, and tourists or short-term visitors. These categories are used as heuristic lenses to capture patterned differences in legal status, housing access, linguistic integration, and mobility capital. They are not treated as internally homogeneous groups but as analytical constructs through which structurally differentiated disaster vulnerability can be examined. The findings show that disaster vulnerability in Chiang Mai is shaped not only by flood exposure but also by the interaction of mobility status, housing conditions, governance arrangements, and access to information. These factors influence exposure, flood experience, risk appraisal, warning access, and the feasibility of preparedness.

3.1. Spatial Exposure and Housing-Based Vulnerability

Flood exposure was not evenly distributed across mobility groups; rather, it was closely tied to housing position, tenure security, and access to safer segments of the local rental market. Mapping of participant-reported flood locations identified concentrations of reported flooding in Hang Dong, Chang Khlan, Wat Ket, Nong Hoi, Nong Pa Khrang, and along the Ping River corridor. These clusters closely correspond with officially designated municipal flood-risk zones, suggesting that participants' lived experiences of flooding were strongly aligned with formal hazard classifications (Figure 2).

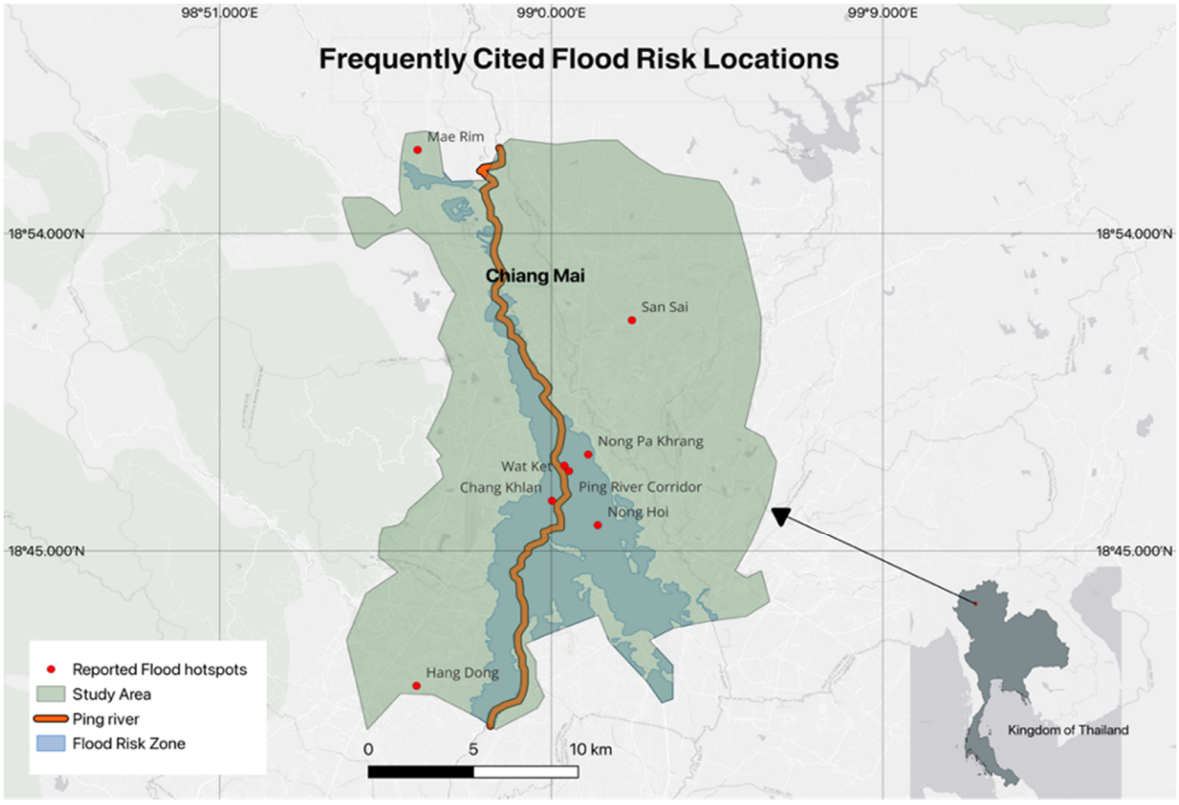


Figure 2. Spatial distribution of participant-reported flood exposure across Chiang Mai.

Figure 2 maps participant-reported flood exposure overlaid with municipal flood-risk zones and the Ping River corridor. Hotspots reflect self-reported flooding experiences from survey data and participant-reported flood locations, showing spatial clustering in low-lying districts such as Hang Dong, Chang Khlan, Wat Ket, Nong Hoi, and Nong Pa Khrang. Source: Authors' analysis based on participant survey data and GIS shapefiles (OpenStreetMap [70]).

Of the 145 respondents who estimated the distance between their residence and the nearest river, canal, or other water source, 116 (80.0%) lived within 1 km. Among the 115 respondents within this distance who also answered the flood-experience question, 69 (60.0%) reported having experienced flooding in Chiang Mai. This included 26 of 40 respondents (65.0%) living within 100 m, 28 of 46 respondents (60.9%) living between 100 and 500 m, and 15 of 29 respondents (51.7%) living between 500 m and 1 km. Across the full sample, 111 of the 200 respondents who answered the flood-experience question (55.5%) reported previous flood experience. Together

with the spatial patterns presented in Figure 2, these findings indicate that a substantial proportion of respondents lived in potentially flood-exposed settings and had prior experience of flooding. Residential proximity to a water source was treated as an indicator of potential exposure rather than proof of direct impact.

Hidden populations and lower-income international migrants were disproportionately represented in these high-exposure districts. Survey and qualitative data indicate that respondents in these groups most commonly resided in subdivided rental rooms, shared accommodation, or employer-assigned housing, typically located at ground level and characterised by limited elevation and inadequate drainage. Recurrent water intrusion during the rainy season was frequently reported, turning flooding from an occasional hazard into a repeated feature of everyday residential insecurity.

By contrast, digital nomads and tourists were largely insulated from direct flood impacts, most commonly residing in elevated condominiums or hotels with formal safety protocols. Exposure gradients therefore reflected unequal access to protective housing, rather than a uniform urban flood risk shared equally across the city. Housing conditions, tenure arrangements, documentation status, and economic constraints combined to shape where different mobility groups could live and, consequently, how exposed they were to recurrent flooding.

3.2. Flood Experience, Hazard Triage, and Multi-Hazard Contexts

In total, 55.5% of respondents reported having experienced flooding in Chiang Mai, although exposure varied substantially across mobility groups (Table 2). Hidden populations reported the highest levels of prior flood exposure (76.5%), followed by international migrants (63.8%), while fewer than half of digital nomads (44.3%) and very few tourists (5.3%) reported direct experience.

Table 2. Self-reported prior flood experience by mobility group (n = 200).

Mobility Group	% with Prior Flood Experience	Count (Yes/Total)
Hidden Populations	76.5%	39/51
International Migrants	63.8%	44/69
Digital Nomads	44.3%	27/61
Tourists/Short-term	5.3%	1/19

The distribution of flood experience closely mirrored the spatial exposure patterns identified in Section 3.1, with hidden populations and international migrants reporting substantially greater direct experience of flooding than more transient or spatially insulated groups. Reported experiences were frequently linked to recurrent seasonal flooding affecting residential areas, transport routes, and access to livelihoods. When respondents assessed hazard severity, floods and air pollution dominated everyday risk perceptions, while earthquakes were less prominent in routine appraisal but became more salient when respondents considered potential lethality (Figure 3).

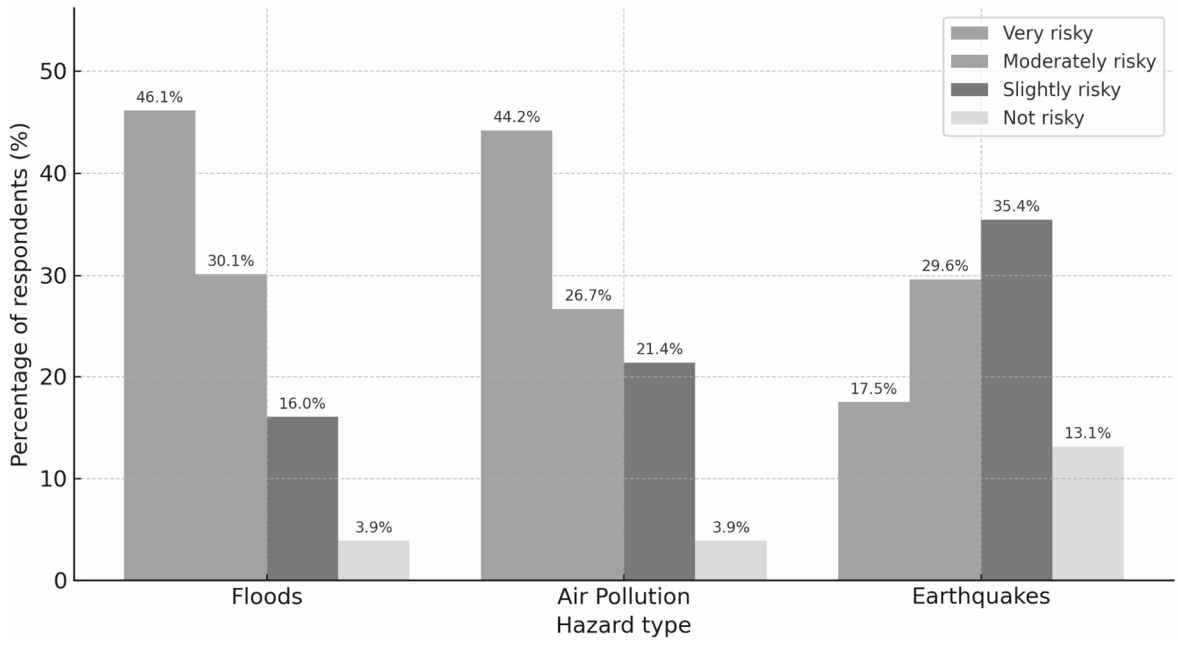


Figure 3. Perceived severity of floods, air pollution, and earthquakes.

Figure 3 presents perceived hazard severity using a five-point Likert scale. Floods and air pollution were most frequently rated as "very risky", reflecting their chronic presence in daily life, whereas earthquakes were less salient in routine appraisal despite being recognised as potentially catastrophic. Open-ended responses indicate that air pollution was perceived as chronic, unavoidable, and harmful to health, while earthquakes were described as sudden and unpredictable. Approximately one quarter of earthquake-related responses referenced the March 2025 Myanmar earthquake [77], highlighting the influence of recent regional disaster events on hazard appraisal.

These findings suggest that flood risk perceptions were formed within a broader multi-hazard environment rather than in isolation. Respondents simultaneously navigated recurring concerns related to flooding, seasonal air pollution, and less frequent but potentially high-impact seismic events. The salience of different hazards varied according to lived experience, residential circumstances, and recent exposure to disaster-related information, illustrating the complex risk environment within which preparedness decisions were made.

3.3. Risk Perception and Mobility-Conditioned Appraisal

Perceived flood risk differed significantly across mobility groups ($H(3) = 10.57$, $p = 0.014$), with the highest perceived risk among hidden populations and international migrants, the lowest among tourists and short-term visitors, and digital nomads occupying an intermediate position (Figure 4). Although the effect size was small ($\varepsilon^2 = 0.04$), the results indicate that mobility status was associated with meaningful differences in how flood risk was perceived and experienced.

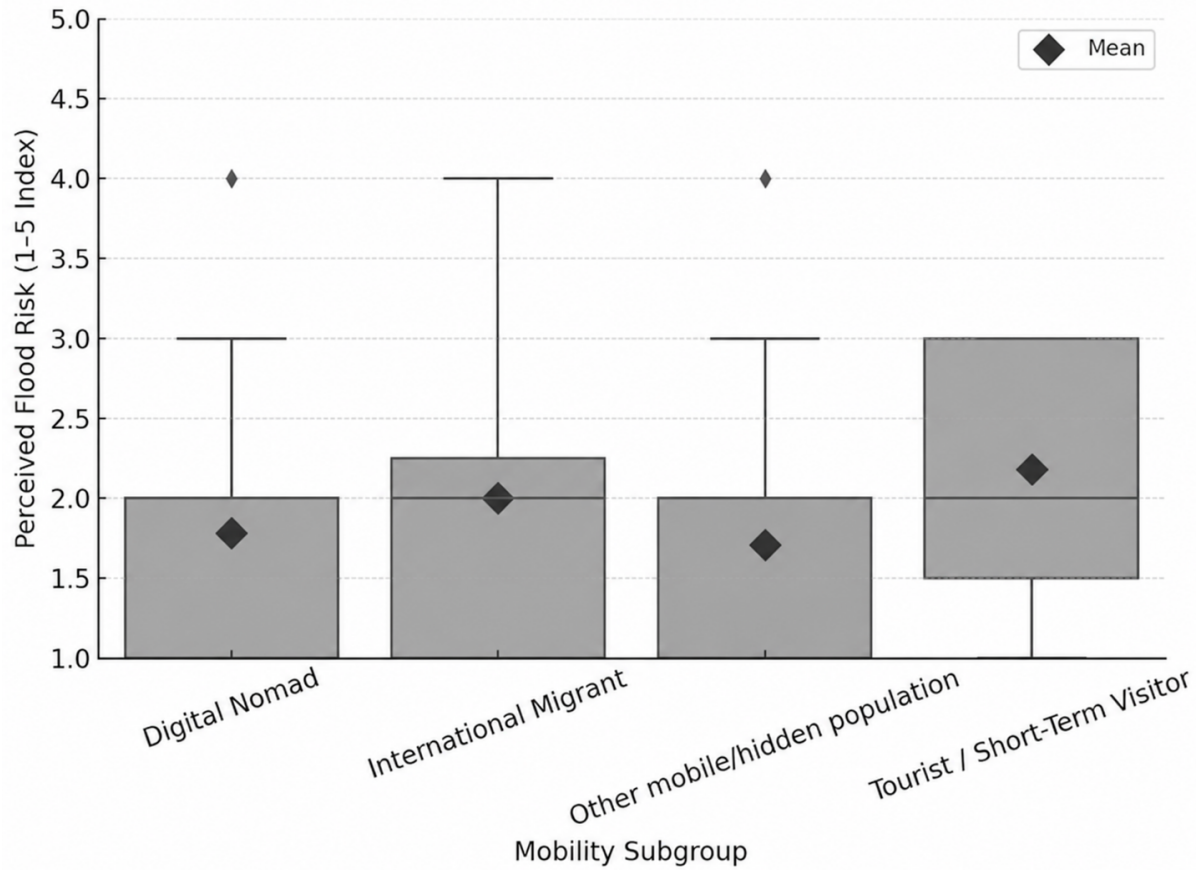


Figure 4. Variation in perceived flood risk by mobility status.

Figure 4 presents variation in perceived flood risk across mobility-defined groups on a five-point scale. Higher perceived risk was concentrated among respondents with greater exposure to flood-prone environments, while lower perceived risk was more common among groups with greater residential flexibility and access to protective housing.

The differences observed were closely linked to residential and livelihood conditions. Higher perceived flood risk was associated with longer residence in Chiang Mai, ground-floor occupancy, and informal or shared housing arrangements, suggesting that risk appraisal develops through cumulative exposure to flood-related disruption and accumulated local experience rather than awareness alone. Open-ended responses provide further insight into how respondents interpret flood risk every day. Respondents in precarious housing and livelihood contexts frequently

linked flood risk to disrupted mobility and income loss. As one participant explained, "*When it's raining or flooding, I cannot work in the field*", while another explained, "*If the roads flood, I can't get to work, and I lose a day's pay*". For these respondents, flood risk was experienced not only as a physical hazard but also as a recurring threat to economic stability and daily routines. By contrast, respondents with greater mobility capital frequently described flooding as a manageable inconvenience. Access to elevated housing, building management systems, private transport, and the option of short-notice relocation reduced the perceived consequences of flood events. As a result, similar flood hazards were interpreted differently depending on respondents' housing conditions, livelihood dependencies, and capacity to adapt or relocate.

3.4. Preparedness and the Feasible Preparedness Gap

Results show that preparedness levels were generally low across the sample. When asked to rate their overall preparedness for flooding, only 6.3% of respondents reported being "very prepared", while over half reported being "not very" or "not at all" prepared (Figure 5). This indicates that flood awareness and prior exposure did not translate into high levels of self-reported preparedness.

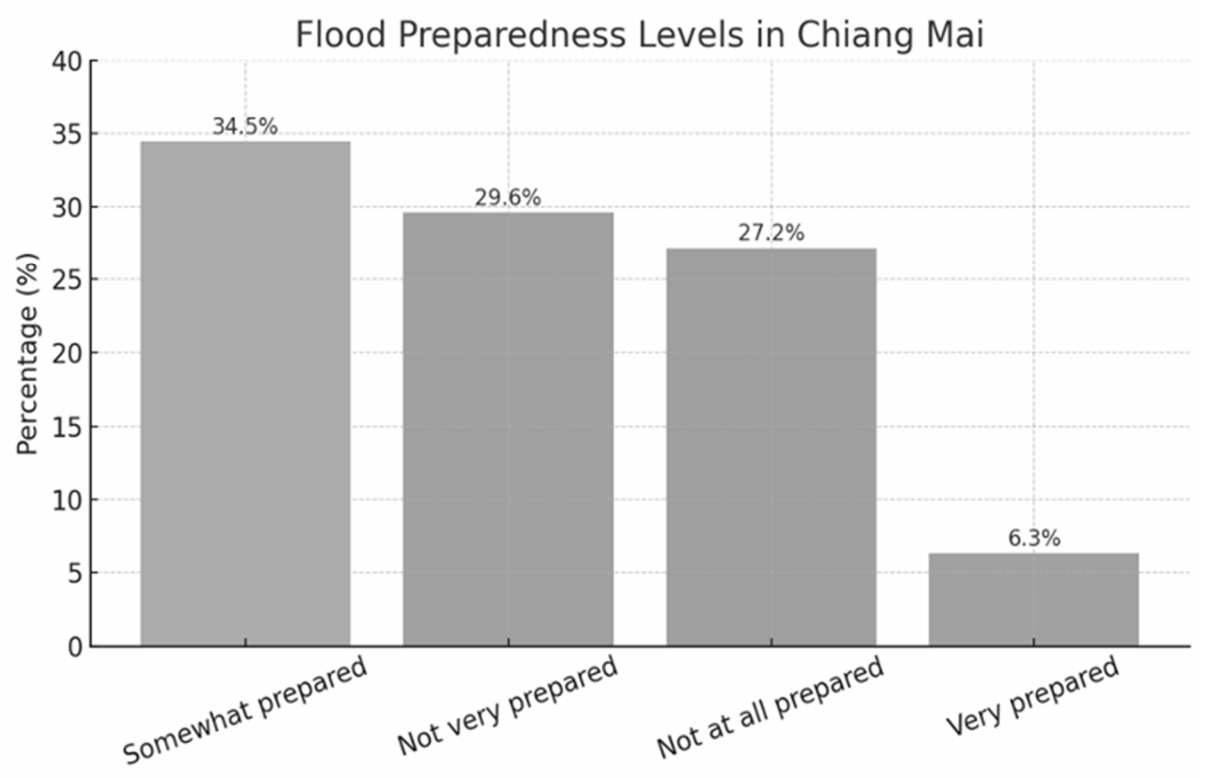


Figure 5. Self-reported preparedness for flooding.

Figure 5 displays respondents' self-reported preparedness levels. Overall preparedness was low, with only 6.3% reporting that they were "very prepared".

Preparedness actions were limited in scope and concentrated in low-cost activities. The most commonly reported measure was saving emergency contacts (48.1%), followed by searching for information about flood risk (20.9%). More resource-intensive actions were less common: 19.4% of respondents reported assembling emergency supplies, 18.0% identified evacuation routes, and 11.2% had installed sandbags or other protective barriers. Notably, nearly one-third of respondents (32.5%) reported taking none of the listed measures. The distribution of preparedness actions reveals a clear distinction between minimal and more resource-dependent forms of preparedness. Actions requiring limited financial cost, physical space, or housing control were more common, whereas measures requiring equipment, dwelling modification, storage capacity, or longer-term planning were considerably less frequent. This pattern suggests that preparedness was shaped not only by awareness of flood risk but also by the practical conditions under which respondents could act.

Preparedness patterns also varied across mobility groups. For digital nomads and tourists, low levels of material preparedness were often accompanied by references to temporary relocation or other mobility-based coping strategies. Among hidden populations and lower-income migrants, however, high perceived risk frequently coexisted with limited action, alongside reported concerns relating to legal insecurity, financial constraints,

insecure tenancy, and limited capacity to modify dwellings. The findings point to a feasible preparedness gap: the distance between recognising flood risk and having the legal, financial, spatial, and informational capacity to act on that risk. Respondents facing greater legal, financial, or housing constraints frequently reported fewer preparedness measures despite expressing elevated concern about flooding, suggesting that preparedness was shaped by the feasibility of action rather than awareness alone. Preparedness therefore emerged as an uneven capacity, shaped by mobility status, housing autonomy, and access to resources, rather than as a simple behavioural outcome of risk awareness.

Predictors of Preparedness

To examine factors associated with preparedness, a binary logistic regression model was estimated using perceived flood likelihood, risk severity, institutional trust, housing security, and mobility status as predictors. Preparedness was operationalised as a binary outcome indicating whether respondents had undertaken at least one flood preparedness action (1 = at least one action, 0 = none). Mobility status was entered as a binary indicator contrasting hidden populations (undocumented and other precarious residents) with all other mobility groups.

As shown in Table 3, perceived flood likelihood and institutional trust were positively associated with preparedness. Respondents who perceived flooding as more likely had higher odds of undertaking at least one preparedness action (odds ratio [OR] = 1.78, 95% confidence interval [CI] [1.20, 2.63], $p = 0.004$). Similarly, higher levels of institutional trust were associated with greater odds of preparedness (OR = 1.94, 95% CI [1.30, 2.89], $p = 0.001$). By contrast, risk severity, housing security, and mobility status were not statistically significant predictors of preparedness in the pooled model. These results suggest that perceived flood likelihood and institutional trust were associated with undertaking at least one preparedness action. However, the descriptive and qualitative findings indicate that housing insecurity, legal precarity, and mobility-related constraints continue to shape the scope and feasibility of preparedness, particularly for more resource-intensive measures.

Table 3. Logistic Regression Predicting Any Flood Preparedness Action. Outcome: 1 = at least one preparedness action; 0 = no listed action.

Predictor	Odds Ratio (OR)	95% Confidence Interval	*p*-Value
Perceived flood likelihood	1.78	1.20–2.63	0.004 **
Risk severity index	1.16	0.86–1.57	0.316
Institutional trust	1.94	1.30–2.89	0.001 **
Housing security	0.77	0.34–1.76	0.543
Mobility status (Hidden populations = 1, Others = 0)	1.08	0.54–2.18	0.827

Model fit: N = 192; Cox & Snell $R^2 = 0.113$; Nagelkerke $R^2 = 0.156$; Classification accuracy = 72.4%. Note. OR = odds ratio. Outcome coded as 1 = at least one preparedness action and 0 = no preparedness action. ** $p < 0.01$.

At the same time, descriptive and subgroup analyses revealed substantial variation across mobility groups and socioeconomic circumstances that was not fully captured by the pooled regression model. Hidden populations (undocumented and other precarious residents) reported the highest levels of unpreparedness, with 74.5% indicating that they were either "not at all prepared" or "not very prepared" for flooding. Tourists and other short-term residents also reported low preparedness levels, while unemployed and part-time workers were consistently less prepared than respondents in full-time employment. Additional subgroup analysis highlighted the importance of housing conditions among structurally vulnerable groups. Among hidden-population respondents experiencing higher levels of housing insecurity, 66.7% reported being "not at all prepared" for flooding, compared with 21.2% among those experiencing lower levels of housing insecurity.

Conversely, 78.8% of respondents with lower housing insecurity reported at least some level of preparedness, compared with only 33.3% of those experiencing higher housing insecurity. Although these subgroup differences were not formally tested in a separate regression model, the magnitude of the observed contrasts suggests that housing conditions may influence preparedness capacity in ways that are not fully reflected in the aggregate model. The findings therefore point to an important distinction between factors associated with undertaking any preparedness action and those shaping the capacity to adopt more resource-intensive or substantial preparedness measures.

3.5. Warning Access, Institutional Trust, and Fragmented Risk Publics

Warning access in Chiang Mai was strongly mediated by digital infrastructures and varied across mobility groups. These differences were associated not only with levels of digital access, but also with institutional trust,

legal positioning, and perceptions of official information systems. Hidden populations and some lower-income migrants reported limited use of Thai-language government platforms, including official disaster warning applications and municipal social media channels. Respondents attributed this pattern to a combination of language barriers, low institutional trust, and concerns about personal information. As one respondent explained, "*Official apps ask for ID—I don't use them*".

Survey and interview data further indicated that concerns relating to surveillance, data sharing, and potential immigration consequences influenced engagement with official information sources among undocumented and precariously documented residents. For these respondents, access to warnings was not simply a question of information availability but also of perceived safety and trustworthiness. In place of official platforms, respondents frequently relied on informal and networked information pathways, including migrant-run Facebook pages, WhatsApp groups, employers, friends, and community leaders. These channels were often described as more accessible, linguistically appropriate, and responsive to the realities of migrant and mobile populations than official communication systems.

The findings suggest the existence of fragmented risk publics, whereby different groups accessed, interpreted, and acted upon hazard information through distinct communication networks. While some respondents were embedded within formal warning infrastructures, others relied primarily on community-based or transnational information systems that operated largely outside official disaster governance arrangements. Respondents also reported differences in the perceived timeliness, detail, and reliability of warning information. Digital nomads and international migrants generally described receiving flood-related information through multiple channels, including social media, accommodation providers, weather applications, and international news sources. By contrast, hidden populations often reported greater uncertainty regarding where to obtain reliable information during flood events and were more likely to depend on interpersonal communication and informal networks.

These differences indicate that warning access was unevenly distributed across mobility groups and shaped by broader processes of inclusion and exclusion within local governance systems. Access to risk information depended not only on technological connectivity but also on language accessibility, institutional trust, legal positioning, and social embeddedness. As a result, the effectiveness of warning systems varied considerably across the study population, even within the same urban hazard environment.

4. Discussion

4.1. Understanding the Feasible Preparedness Gap

The findings suggest that flood preparedness in Chiang Mai is shaped not only by awareness of risk but also by the practical capacity to act under conditions of legal precarity, insecure housing, unequal mobility capital, and fragmented access to trusted warning systems. In this study, the awareness–action disconnect is therefore interpreted not as a behavioural deficit, but as a feasible preparedness gap produced through the interaction of mobility status and governance arrangements.

This pattern aligns with evidence from disaster-prone settings where communities recognise environmental hazards but struggle to implement protective measures when livelihoods are insecure, institutional support is weak, or resources are limited [37–40,78,79]. This study extends this literature by showing how mobility status, legal precarity, and ID-linked digital infrastructures further condition preparedness feasibility in an urban flood context, particularly for undocumented and lower-income migrants who must manage livelihood insecurity while weighing the risks of engaging official systems.

Taken together, the results indicate that disaster vulnerability in Chiang Mai is produced through the interaction of legal status, housing access, digital inclusion, and mobility capital. While the empirical patterns are context-specific, the analytical framework is transferable to secondary cities characterised by migrant diversity and platform-mediated governance, where warning systems and risk communication are increasingly mediated through digital infrastructures and remain unevenly accessible. These findings show why protective action should be understood as conditional on mobility-related constraints, rather than as a straightforward outcome of risk perception or warning exposure.

4.2. Mobility-Aware PADM

The Mobility-Aware PADM developed in this study identifies three mechanisms through which mobility shapes preparedness: the Legal Precarity Filter, Networked Trust, and Adaptive Coping Pathways. These mechanisms show how warning access, institutional trust, housing conditions, and social networks shape whether protective action is possible in practice.

4.2.1. The Legal Precarity Filter

Findings from this study demonstrate that legal and economic precarity systematically condition exposure to flood risk through restricted access to safe housing, elevated dwellings, and formal rental markets. Undocumented migrants and lower-income international migrants were disproportionately concentrated in low-lying districts and ground-floor accommodation, where recurrent flooding was experienced as a chronic disruption rather than an episodic event.

These dynamics are conceptualised as a Legal Precarity Filter, defined as a structural mechanism through which documentation status, tenancy insecurity, and income constraints limit access to protective infrastructure, early warnings, shelters, and preparedness resources. The legal precarity filter shows how documentation status and fear of institutional exposure can limit access to official warnings, reduce trust in authorities, and constrain preparedness even where flood risk is recognised.

Similar relationships between social vulnerability, informal housing, and concentrated hazard exposure have been documented in landslide-prone settlements in Southeast Bangladesh, where informal tenure, regulatory gaps, and low-income constraints increase residents' exposure despite widespread awareness of risk [38]. The findings from Chiang Mai extend these observations by demonstrating that legal status and migration governance operate alongside income and regulatory factors to shape access to safer housing in urban flood environments. In doing so, the Legal Precarity Filter addresses a key limitation of behavioural risk models when applied to heterogeneous urban populations. It shows that protective action cannot be fully explained by perception or motivation when the basic conditions for safety, recognition, and institutional access are unequally distributed.

4.2.2. Networked Trust and Digitally Mediated Cue Reception

Findings reveal that access to hazard warnings in Chiang Mai is sharply conditioned by mobility status and institutional trust. Official Thai-language warning systems were frequently avoided by undocumented or precariously documented residents, not solely because of language barriers but also because of concerns related to surveillance, data misuse, or unintended exposure to immigration enforcement. In response, respondents relied on migrant-run social media groups, workplace communication, religious leaders, employers, and peer networks as primary information channels. These practices are conceptualised as Networked Trust, an adaptive mechanism through which hazard information is filtered through socially trusted networks when official platforms are perceived as inaccessible or unsafe. Networked Trust shows that warning effectiveness depends not only on message content, but also on whether information systems are perceived as accessible, safe, and trustworthy. While these networks can enhance situational awareness, they rarely provide the resources necessary for evacuation, shelter access, or material preparedness. Cue effectiveness is therefore contingent not only on message content and format but also on institutional trust and the governance arrangements that shape who feels able to engage with official information systems.

4.2.3. Adaptive Coping Pathways and Feasible Action

Responses to flood risk diverged sharply across mobility groups, even when awareness was high. Digital nomads and tourists frequently adopted mobility-enabled coping strategies such as temporary relocation, short-term travel, or reliance on serviced accommodation. These approaches effectively externalised flood risk rather than encouraging household-level preparedness. By contrast, hidden populations and lower-income migrants adopted necessity-driven adaptive strategies, including reactive movement of belongings, reliance on social networks, and acceptance of recurring loss. This divergence is conceptualised as Adaptive Coping Pathways, which extend PADM's action stage by recognising that protective responses are stratified by mobility capital. For some groups, preparedness is materially infeasible regardless of risk perception, producing the feasible preparedness gap, defined as the structural distance between recognising a hazard and possessing the capacity to act upon that recognition. This finding resonates with studies of climate adaptation among Bangladeshi coastal fishers and smallholder farmers, who frequently acknowledge increasing climate risks but adopt coping strategies shaped by constrained livelihood options, limited credit access, and inadequate institutional support [39,40]. However, whereas those studies primarily emphasise rural livelihood constraints, the present analysis highlights how mobility capital, legal visibility, and rental insecurity create additional restrictions on preparedness in urban environments.

4.2.4. Integrated Reframing of PADM

Figure 6 presents the Mobility-Aware PADM, showing how the Legal Precarity Filter, Networked Trust, and Adaptive Coping Pathways intervene across the protective action process. The framework illustrates that

preparedness is shaped not only by hazard appraisal, but also by the legal, social, housing, and information conditions that determine whether action is feasible.

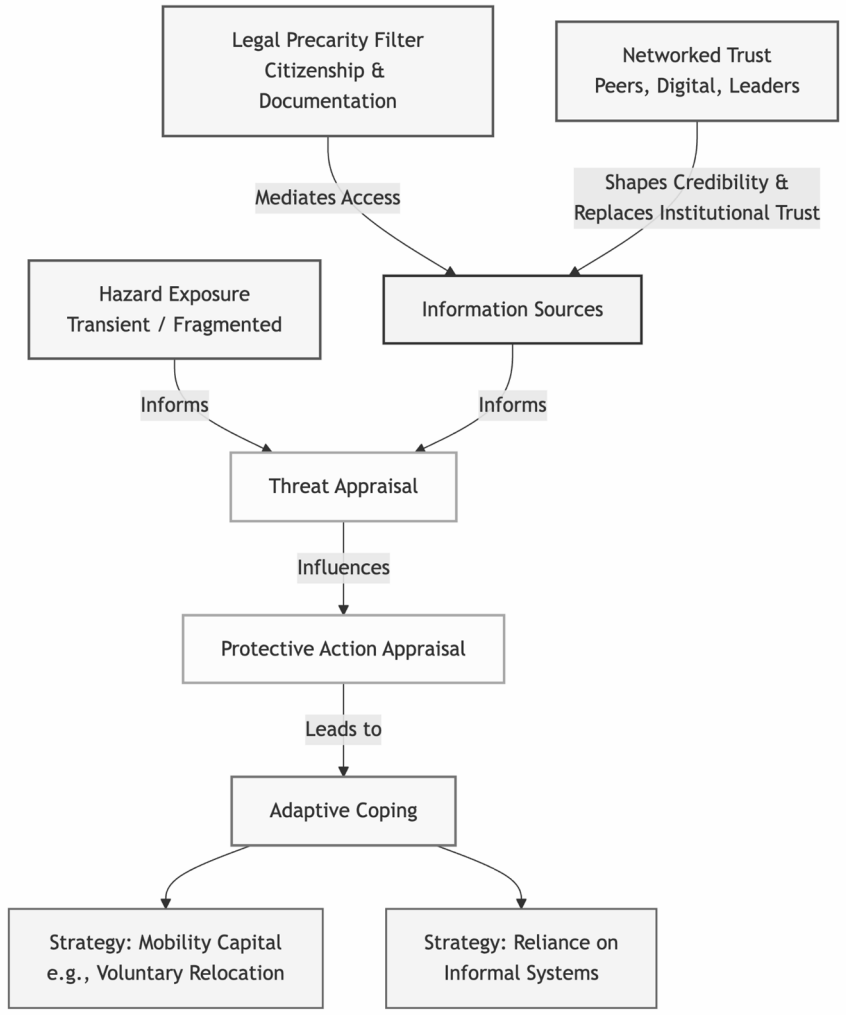


Figure 6. Mobility-Aware Protective Action Decision Model: A Conceptual Framework for Understanding Mobility-Conditioned Protective Action.

The framework represents the decision-making process through which individuals assess flood risk and determine whether household-level preparedness actions are feasible. The figure also illustrates how legal precarity, networked trust, and adaptive coping pathways intervene at different stages of protective decision-making, shaping how hazard information is received, interpreted, and translated into action across mobile populations.

4.3. Agency, Adaptation, and the Limits of Resilience

Despite pervasive structural barriers, participants demonstrated meaningful and contextually grounded forms of agency. These included elevating belongings during the rainy season, establishing informal warning networks, translating alerts across languages, mapping safer routes through flood-prone neighbourhoods, and providing mutual support to neighbours and co-workers. Such practices resonate with broader scholarship on community-led resilience and everyday adaptation among marginalised populations [80]. These everyday adaptations represent the lived expression of the adaptive but constrained coping pathways identified in the Mobility-Aware PADM. They demonstrate agency exercised within the bounds set by the Legal Precarity Filter, where individuals actively respond to risk but do so under conditions of insecure tenure, limited resources, and exclusion from formal protection systems.

This distinction is important because resilience language can obscure the conditions that make informal coping necessary in the first place. These findings also echo broader evidence from disaster-prone communities in low- and middle-income settings, where locally grounded adaptation can reduce immediate harm but remain constrained when tenure insecurity, weak institutional protection, and unequal access to resources remain unaddressed [38,80]. In Chiang Mai, informal warning networks and household-level adjustments helped

participants navigate recurrent flooding, but they did not resolve the deeper vulnerabilities produced through housing insecurity, legal precarity, and uneven access to official risk governance. The evidence therefore supports a relational understanding of resilience. Agency is real and consequential, but it is not evenly distributed and should not be treated as a substitute for institutional protection. Informal coping strategies may reduce immediate losses, but they cannot compensate for insecure housing, inaccessible warnings, or exclusion from formal assistance. Resilience, in this sense, is not an individual attribute or community virtue; it is a condition shaped by governance arrangements, legal positioning, infrastructural access, and the distribution of protection.

4.4. Theoretical Contributions and Transferability

This study contributes to flood preparedness theory by showing that protective action among migrant and mobile populations cannot be explained through risk perception, prior experience, or institutional trust alone. The findings demonstrate that although perceived flood likelihood and institutional trust were associated with undertaking at least one preparedness action, preparedness remained concentrated in low-cost and low-commitment measures, such as saving emergency contacts or seeking information. More substantial actions were constrained by insecure housing, limited resources, legal precarity, language barriers, and uneven access to trusted warning systems. This distinction is theoretically important because it shows that the initiation of preparedness and the capacity to undertake meaningful preparedness are not the same process.

By introducing the concept of the feasible preparedness gap, the paper reframes the awareness-action gap as a problem of action feasibility rather than individual motivation alone. In doing so, it extends the Protective Action Decision Model by placing mobility-related constraints within the decision environment itself. Legal status, housing autonomy, information access, and social embeddedness are therefore not treated as background vulnerabilities, but as conditions that shape whether protective action can realistically be taken.

The Mobility-Aware PADM developed in this study offers analytical transferability beyond Chiang Mai. While the empirical findings are context-specific, the framework is relevant to other urban settings where flood preparedness is shaped by migration, temporary residence, insecure tenure, multilingual risk publics, and digitally mediated governance systems. The theoretical contribution of the paper is therefore to connect behavioural models of preparedness with the structural and governance conditions that determine who is able to act before a flood occurs.

4.5. Implications for Policy and Practice

The findings suggest that improving preparedness among migrant and mobile populations requires more than stronger risk communication. Awareness matters, but it is insufficient where people lack secure housing, trusted information channels, legal protection, or the practical capacity to act [18,32]. Early warning systems should therefore be designed around accessibility rather than administrative visibility. Systems that depend on formal registration, national identification, official-language communication, or government-managed platforms risk excluding precisely those groups most exposed to flood risk [57]. More inclusive approaches require multilingual warnings, multiple communication channels, and dissemination routes that do not rely on legal status or formal documentation [12,56,81].

The findings also highlight the importance of trusted intermediaries. Migrant networks, employers, community organisations, religious institutions, and digital peer groups already play a central role in circulating hazard information, consistent with evidence on the role of trust networks in transnational migrant communities [63] and on trust as a determinant of risk-communication effectiveness [22,82]. Disaster management agencies should work with these actors not as informal substitutes for official systems, but as important partners in reaching populations who may distrust or avoid state channels.

The concentration of vulnerable populations within insecure and flood-prone accommodation further demonstrates that preparedness cannot be separated from housing and urban governance, echoing findings that migration status and housing precarity compound disaster vulnerability elsewhere [11,13,48]. Where exposure is shaped by unequal access to safe housing, awareness campaigns alone are unlikely to produce substantial improvements in preparedness. Inclusive flood preparedness therefore requires closer integration between early warning systems, housing policy, migrant support services, and local planning [60]. In mobility-diverse cities, the central policy challenge is not simply whether people understand risk, but whether they possess the legal, informational, financial, and housing-related capacity to act upon that knowledge.

4.6. Limitations and Future Research

This study has limitations, but they also clarify the agenda for future research on mobility and disaster preparedness. The use of purposive and chain-referral sampling was necessary to reach hidden and mobile

populations who are often absent from official records, but it limits statistical generalisability. The findings should therefore be understood as analytically transferable rather than representative of all migrant and mobile populations in Chiang Mai. The cross-sectional design captures preparedness at one point in time, whereas mobility, legal status, housing security, and institutional trust are dynamic conditions. Longitudinal research is needed to examine how preparedness changes as people move, regularise or lose legal status, shift housing arrangements, or experience repeated flood events.

The study focused on flood risk in one urban context, but the mechanisms identified here are likely to matter across other hazards and governance settings. Further research should test the Mobility-Aware PADM in relation to heatwaves, wildfires, earthquakes, air pollution episodes, and compound hazards, particularly in cities where disaster governance relies on digital platforms, formal registration, and state-linked warning systems. The most important future challenge is to understand how digital governance is reshaping who becomes visible, reachable, and protected in disasters. As warning systems become increasingly platform-based and data-driven, preparedness research must move beyond measuring awareness and behaviour alone. It must examine the legal, linguistic, spatial, and technological conditions that determine who can act before a hazard becomes a disaster.

5. Conclusions

This study examined flood risk perceptions, warning access, and preparedness among migrant and mobile populations in Chiang Mai, Thailand. The findings revealed substantial inequalities in flood exposure, preparedness, and access to risk information across mobility groups. Hidden populations and lower-income migrants were disproportionately concentrated in flood-prone housing, reported the highest levels of direct flood experience, and faced the greatest barriers to preparedness. Although awareness of flood risk was generally high, preparedness levels remained low across the sample, with many respondents relying on low-cost coping measures and nearly one-third reporting no preparedness actions. Access to warnings was also uneven, shaped by language barriers, legal precarity, institutional trust, and reliance on informal communication networks.

These findings demonstrate that preparedness is shaped not only by awareness of risk, but by the conditions that make protective action possible. Legal status, housing access, digital inclusion, institutional trust, and mobility capital influenced those who received warnings, who could act upon them, and who remained vulnerable despite recognising risk. The study therefore identified a feasible preparedness gap, where awareness of hazard risk did not necessarily translate into preparedness because the resources and opportunities required for action were unequally distributed.

To explain these dynamics, the study developed a Mobility-Aware Protective Action Decision Model (PADM), introducing the concepts of the Legal Precarity Filter, Networked Trust, Adaptive Coping Pathways, and the feasible preparedness gap. Together, these concepts provide a framework for understanding how mobility-related inequalities shape preparedness beyond the cognitive processes typically emphasised in behavioural models. By bringing behavioural and vulnerability-based perspectives into closer dialogue, the framework offers a more comprehensive account of preparedness in mobility-diverse urban environments.

The significance of this study extends beyond Chiang Mai. As cities become increasingly mobile, diverse, and digitally governed [62], disaster preparedness can no longer be understood through assumptions of stable residence, universal warning access, or equal capacity to act. Improving preparedness among migrant and mobile populations requires not only greater awareness but also reductions in the legal, housing, informational, and governance barriers that constrain protective action. This reflects the Sendai Framework's emphasis on inclusive, people-centred risk governance [15] and wider calls for more inclusive and transformative approaches to disaster governance [1]. Understanding who can prepare, under what conditions, and with what resources will be essential to building effective disaster risk reduction in an increasingly mobile world.

Author Contributions

I.A.M.: conceptualization, methodology, investigation, data curation, formal analysis, visualization, and writing, original draft preparation; A.Y.: conceptualization, methodology, supervision, interpretation of findings, writing, original draft preparation, and writing, review and editing. Both authors contributed to the development and refinement of the conceptual framework. Both authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was reviewed and approved by the University of Leicester Research Ethics Committee (Ref: ENV-2024-021, 12 June 2025). The research was conducted in accordance with the approved ethical procedures.

Informed Consent Statement

Informed consent was obtained from all participants involved in the study in accordance with the approved ethical procedures of the University of Leicester. Consent was obtained prior to participation and in participants' preferred language.

Data Availability Statement

The data supporting the findings of this study are not publicly available due to ethical and confidentiality restrictions relating to the protection of potentially vulnerable and legally precarious participants.

Conflicts of Interest

The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

During the preparation of this work, the authors used AI tools such as Grammarly AI to support language editing, improve clarity, and refine the presentation of non-essential parts of the manuscript, including the abstract. AI was not used for data analysis or any other aspect of the study, and did not shape or influence the manuscript's findings, interpretation, or conclusions. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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