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Mobile public warning in Japan and the United States: a sister cities collaboration

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Over the last decade, countries have adopted or expanded the use of cell broadcast systems to support mobile public warning for natural and human-caused hazards and disasters. Cell broadcast entails sending short messages simultaneously to multiple mobile devices in a defined geographic area. Japan and the United States have pioneered the development of mobile public warning technology, yet both countries continue to experience problems with the nonuse, misuse, or misunderstanding of these systems. To explore prospects for improving this situation, this study presents thematic analyses of official documents and transcripts from four Japan-U.S. meetings and workshops with researchers, officials, and residents in the "sister cities" of Yamagata, Yamagata Prefecture, Japan, and Boulder, Colorado, USA. The study's boundary spanning, cross-national findings contribute new insights regarding the appropriate level of local adaptation versus global standardization of mobile public warning theory, policy, and practice. These findings can aid officials who are increasingly relying on mobile public warning systems to help keep communities safe amid the intensifying impacts of climate change.

KEYWORDS

cross-boundary communication, public warning, mobile technology, risk communication, alerts, Japan, United States

Introduction

National cell broadcast-based mobile public warning systems have been used in Japan and the United States for more than a decade. Japan launched its Area Mail cell broadcast service in 2007, and the Japan Meteorological Agency (JMA) launched its mobile public warning system in 2013. According to the JMA website, messages are issued in response to "possible catastrophes caused by extraordinary natural phenomena such as heavy rain, earthquakes, tsunami and storm surges" (Japan Meteorological Agency, 2024, para. 2). In addition to routine warnings, a special category of message, "Emergency Warnings," are used to "alert people to the significant likelihood of catastrophes if phenomena are expected to be of a scale that will far exceed the warning criteria" (para. 2). In the United States, the National Weather Service (NWS) is the preeminent user of the Wireless Emergency Alerts (WEA) system (pronounced "we-uh"), a cell broadcast-based system that began nationwide rollout in 2012. According to the Federal Communications Commission (FCC), since its creation, the WEA system has been activated more than 84,000 times to notify millions of people of severe weather or other hazards near them (FCC, 2024).

In the *Washington Post* article, "Emergency phone alerts have saved lives, and caused confusion," Stillman (2023) assesses the advantages and disadvantages of mobile public warning systems. However, media reporting in Japan and the United States tends to focus on the nonuse, misuse, or misunderstanding of these systems (Bean, 2019). Overcoming these

challenges is necessary to improve system effectiveness and reduce death and injury due to inadequate warning. Internationally, officials have described the adoption of effective early warning systems as a priority globally. Global Target G of the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNDRR, 2015) aims to substantially increase the availability of and access to multi-hazard early warning systems. The Sendai Framework states that relevant disaster risk information and assessment must be understandable, usable, and relevant. It seeks to increase the percentage of people who are protected through pre-emptive evacuation following early warning. The Early Warnings for All (EW4All) initiative, launched by the United Nations Secretary-General in 2022, aims to achieve universal access to multi-hazard early warning systems by 2027. Despite considerable challenges (Muhame et al., 2024), mobile public warning technologies are critical in helping achieve the Sendai Framework's Target G and EW4All, and international interest in cell broadcast early warning systems is growing (Acland et al., 2024; Manjusha, 2024).

To engage the cross-national dimensions of mobile public warning, the current study connected stakeholders in the sister cities of Yamagata, Japan and Boulder, Colorado, USA. Yamagata and Boulder were designated sister cities in 1994. A sister city relationship is a form of legal or social agreement between two geographically and politically distinct localities for the purpose of promoting cultural and commercial ties. For example, Boulder's Channel 8 cooperates with the Yamagata Broadcasting Company by exchanging local television broadcast film footage. Residents also organize educational and cultural exchange programs. Yamagata and Boulder are both nestled in mountain settings and attract large numbers of domestic and international visitors year-round. Both areas are also prone to hazards and disasters.

For example, in August 2022, thousands of residents within Yamagata Prefecture were ordered to evacuate as heavy rain flooded homes and roads in the region (heavy rain and flooding occurred again in 2024). In 2011, in the aftermath of the Tōhoku earthquake and tsunami, the subsequent Fukushima Daiichi Nuclear Power Plant disaster prompted officials to measure the radiation levels of homes in Yamagata. While the city itself has been spared from catastrophe (notable historical exceptions notwithstanding, see Abe and Kazama, 1985), significant earthquakes, fires, floods, and evacuations have occurred in recent years in surrounding communities. Boulder County has also endured multiple disasters. In fact, in 2023, the Boulder County Office of Emergency Management (OEM) was renamed the Office of Disaster Management (ODM) in recognition of the area's frequent disasters, including flooding (2013), mass shooting (2021), and wildfire (2016, 2020, and 2021), as well as the need for better support, coordination, and consequence management.

Selection of these sister cities stemmed from the first author's proximity to the 2021–2022 Marshall Fire in Boulder County—the most destructive wildfire in Colorado state history. Engaged in the study of mobile public warning since 2009, the first author interacted with state and local officials in the aftermath of the Marshall Fire disaster to explore systemic improvements. The coauthors had also recently conducted an international workshop in Japan (Bean et al., 2021) and speculated that a "sister cities" approach might generate participation in a cross-national study. Of course, any two cities selected for cross-national comparison would present challenges concerning their representativeness, but this study indicates how Yamagata and Boulder confront mobile public warning challenges like those found throughout Japan and the United States (Bean et al., 2021). Keeping residents and visitors safe from the increasing effects of climate change is a priority for both Japanese and U.S. officials, but little has been done to assess the processes, benefits, or challenges of communities' mobile public warning systems. The present study illuminates them in sister cities toward the goal of improving system effectiveness, as well as public awareness, understanding, and trust in Japan, the United States, and internationally.

In this study, sister cities connections were established at four levels: (1) university researchers working in the area of disaster communication; (2) officials involved in weather-related hazard preparedness, detection, and warning; (3) officials involved in non-weather-related hazard preparedness, detection, and warning, and (4) Yamagata and Boulder residents who have received mobile public warning messages for imminent threats. Establishing multi-level, and cross-boundary connections aimed to deepen mutual understanding and build capacity for future Yamagata-Boulder exchange in the field of disaster communication. This study was the first of its kind to bring together Japanese and U.S. officials and residents in sister cities to address the entire arc of disaster communication in the mobile public warning context: hazard preparedness, detection, warning dissemination, and public response. The remainder of this study first describes the need for boundary-spanning research within the fields of disaster communication and mobile public warning. It subsequently identifies the theoretical and practical questions driving this study, followed by a description of the methods used to answer those questions. It then provides thematic analyses of organizational documents, meeting transcripts, and workshop transcripts to answer the research questions. An "implications" section then explains how stakeholders might leverage this study's findings to help improve mobile public warning policy and practice internationally. A brief conclusion points to next steps in this project.

Disaster communication and the need for boundary spanning mobile public warning research

Mobile public warning systems research is grounded in the field of disaster communication. In the United States, the late Dr. Dennis S. Mileti pioneered the development of disaster communication and was regarded by many colleagues as the world's foremost expert on public warning (Sutton et al., 2024). Mileti's research underwrites several countries' public warning policies and practices (Bean, 2019). For example, Mileti's checklists of the five key content elements that constitute an effective warning message (source, hazard, location, guidance, and time) and five key style factors (clear, specific, accurate, certain, and consistent) are known among practitioners as the "Mileti model" or "Warning Response Model," which now serves as the basis of U.S. Federal Emergency Management Agency (FEMA) public warning tools and training (Sutton et al., 2024). The Mileti model has also drawn the attention of Japanese risk communication scholars. For example, Isao Nakamura's (2021) volume, *Disaster Information and Evacuation: Theory and Practice*, uses the Mileti model to assess examples of Japanese public warning messages. Nakamura discusses the informational needs of foreign residents and the suitability of "easy

Japanese" in crafting warning messages, concluding that community-tailored information, rather than a "one-size-fits-all" is most desirable. The Japanese researchers, officials, and documents we consulted for this project did not indicate any specific theory of public warning underwriting such systems in Japan.

Despite the international influence of Mileti's work, the appropriate level of local adaptation versus global standardization of warning systems remains an open question (Donovan et al., 2023). Neußner (2021) claimed that differences among national early warning systems generated inconsistent public awareness and understanding of the meaning of warning messages. Neußner advocated for more consistency across different countries and hazards. By contrast, Kelman and Fearnley (2021) argued that local customization is necessary, tailoring and adjusting warning systems and messages to the shifting needs of people in each local community. For example, Takenouchi et al. (2021) explored the development of community-driven dissemination of evacuation information ("local switches"). Addressing these divergent perspectives, Bean et al. (2021) surveyed the problems confronting those who seek to develop, deploy, and assess mobile public warning systems and messages internationally. Varying cultural norms and policy orientations emerged as key factors impeding international "harmonization." Cross-national risk, crisis, and disaster communication research is gaining momentum (e.g., Tagliacozzo et al., 2021), and mobile public warning research is ripe for boundary-spanning approaches.

In *Transcending Boundaries: The Innovative Power of Emergent Practices*, Boersma (2022) emphasized the role of boundary-spanning research, suggesting that crises present both dangers and opportunities. Boersma noted that local actors often respond to crises with creativity and initiative despite the limitations imposed by top-down governance systems. Guided by Boersma's perspective, the current study sought to connect local actors in "sister cities" to reveal emergent, bottom-up, mobile public warning practices. By collaborating across academic, weather, non-weather, and resident levels in Yamagata and Boulder, the coauthors sought to facilitate what Boersma calls "networked emergence," that is, the capacity for individuals and organizations to collaborate across boundaries to develop innovative solutions to complex problems (e.g., Grace et al., 2018). The coauthors of the present study served as boundary spanners—individuals who connect otherwise isolated groups. The goal was to help Yamagata and Boulder officials and residents better understand and adapt to shared problems impeding the effectiveness of the mobile public warning systems used in their communities. In so doing, the coauthors attempted to avoid a one-size-fits-all strategy to instead cultivate localized, context-specific responses that harness the creative power of officials and residents while ensuring compliance with national mobile public warning requirements.

Research questions

Drawing inspiration and guidance from the resources described above, the coauthors developed four research questions:

> R1: How do Yamagata and Boulder compare vis-à-vis their weather and non-weather mobile public warning levels, systems, processes and scenarios, public education, and future developments?
>
> R2: What theories of communication and human behavior underwrite weather and non-weather mobile public warning policies and practices in Yamagata and Boulder?
>
> R3: What problems do Yamagata and Boulder *officials* identify regarding mobile public warning for weather and non-weather emergencies in their communities?
>
> R4: What problems do Yamagata and Boulder *residents* identify regarding mobile public warning for weather and non-weather emergencies in their communities?

Methods

This study used an "engaged communication" approach to answer the research questions (Barge et al., 2008). Engaged communication research involves an ethos of care and compassion for others, intentional collaboration, reciprocity, and responsiveness to community concerns, values, and interests. To establish trust and rapport, the coauthors cultivated relationships with participants. Specifically, the first author had previously collaborated with certain Boulder County officials (Bean et al., 2023) and had connections to local resident groups as a result of having lived in the area since 2005. Additionally, staff from Yamagata's International Center had previously worked closely with Boulder's Sister City liaison, providing a level of collegiately that may have been difficult to achieve in absence of sister city ties. Researchers from Japan were either already known to the coauthors or were provided introductions by Yamagata University colleagues. The second author is a meteorologist and researcher based in Japan and has extensive experience interacting with meteorological officials and residents throughout the country. The third author is an international expert and researcher in disaster risk management based at Kyoto University who has lived in Japan since 2010 and has conducted numerous studies throughout the country. However, with qualitative research, it is challenging to know with certainty whether trust and rapport are fulsome enough to mitigate power dynamics and elicit meaningful insights (Denzin and Lincoln, 2011). To help ensure reciprocal exchange, staff from Yamagata's International Center already well-known to Japanese participants accompanied the coauthors to project meetings and facilitated interactions during workshops with officials and residents.

Following Takenouchi et al. (2017), the coauthors used a set of collaborative workshops to engage participants. Specifically, researchers, officials, and residents from Yamagata and Boulder were brought together to discuss the context, timing, format, and content of mobile public warning messages issued in their communities. In January and February 2024, researchers from Japan and public warning officials from Yamagata's Disaster Prevention Section, NWS Denver/Boulder Forecast Office, and BODM (Boulder Office of Disaster Management) agreed to participate. Also in January 2024, 50 residents of Boulder were invited via email to participate. Five of the invitees initially agreed to participate and spoke with the first author about their interest in the project. The low response rate may have been due to participant fatigue (invitees had already participated in previous studies of the 2021–2022 Marshall Fire in Boulder). Yamagata's International Center assisted in publicizing the project among

residents in the area, and six people eventually agreed to participate. The meetings and workshops were scheduled (interpretation was provided), and nearly all activities were conducted in February and March 2024.

To answer R1, the coauthors compared organizational documents, supplemented by discussions with Japanese and U.S. officials. To answer R2, the co-authors convened separately with three Japanese disaster communication researchers. Given Dr. Bean's familiarity with the WEA system and its use in Boulder and throughout the United States, he explained during the meetings how the Warning Response Model's (Mileti and Sorensen, 1990) theory of human behavior underwrites U.S. officials' mobile public warning policies and practices. FEMA's newly released Message Design Dashboard (MDD)—now in use in Boulder and elsewhere in the United States—embeds the assumptions of the Warning Response Model within it. Discussions addressed how mobile public warning content and practices in Yamagata and throughout Japan appear to align with or diverge from the assumptions contained within the Warning Response Model.

To answer R3, from March 6 to 8, 2024, the coauthors conducted a site visit in Yamagata to meet with prospective participants (no site visit was conducted with Boulder officials and residents because the U.S. participants were already known to the researchers and were eager to exchange perspectives with their Japanese counterparts). The purpose of the Yamagata site visit was to establish connections, provide information, answer questions, and confirm the schedule of the subsequent online workshops. The first and second author also met with officials from the Yamagata Meteorological Office. The co-authors convened on Zoom on March 14, 2024, with public warning officials from Yamagata's Disaster Preparedness Section and the Boulder Office of Disaster Management (BODM). For this workshop, each side provided an overview of their mobile public warning systems, highlighted the top problems they experience, and described what they hoped to learn from other side. Follow up questions and comments were exchanged after the workshop. The coauthors also convened on Zoom on March 28, 2024, with public warning officials from the JMA and the NWS Denver/Boulder Forecast Office. Again, for this workshop, each side provided an overview of their mobile public warning systems, highlighted the top problems they experience, and described what they hoped to learn from other side. Likewise, follow up questions and comments were exchanged after the workshop.

Answering R4 entailed two phases. First, following Takenouchi et al. (2017), residents were provided a questionnaire asking them to describe what kind of language they would want used for a mobile public warning message for flood or wildfire evacuation (open-ended). As Takenouchi et al. (2017) explained, it is important to consider how weather information should be viewed from the perspective of residents, who are the ultimate users of it, to improve comprehension of the information and encourage appropriate protective action. The questionnaire also asked residents about information provision and what they wanted to learn from their sister city counterparts. Second, resident participants convened on Zoom on March 27, 2024 (six residents from Yamagata and four residents from Boulder) for a workshop to discuss their experiences and share information. After icebreakers (e.g., introductions and sister cities trivia), each resident was invited to (a) share their experience with mobile public warning and (b) ask questions about the experiences of their sister city counterparts. A summary of the workshop schedule is included in Table 1.

Transcripts of audio files were produced using Google's speech-to-text platform and checked for accuracy by the first author. However, due to Zoom and Google's limited ability to accurately process simultaneous English and Japanese interpretation and speech-to-text, the coauthors mostly conducted the analysis by repeatedly listening to recordings and highlighting comments using an iterative approach (Tracy, 2019). An iterative approach differs from a grounded theory approach in that grounded studies often delay the literature review until after data are collected to help ensure an inductive examination of the data. An iterative approach, by contrast, alternates between emergent readings of the data and use of existing models and theories; it reflects the interests, priorities, and theories the researcher brings to the data (Tracy, 2019). An iterative approach was used to (a) identify participants' utterances that responded to the research questions, and (b) group utterances together using concepts from the research literature (cited above) that might account for the patterned utterances. For this study, the goal was to identify and explain the "problems" and "prospects" associated with mobile public warning that arose among participants. To ensure quality, the coauthors accounted for the range of perspectives offered, used examples of transcript segments for illustration, triangulated between different data types (documents, utterances, and written responses to questionnaires), and asked participants to validate the legitimacy of emerging analytic interpretations (O'Connor and Joffe, 2020; Phillips and Hardy, 2002). However, it is important to acknowledge the challenges of comparability and equivalence in cross-cultural qualitative research (Polsa, 2007). To the extent possible, this study attempted to

TABLE 1 Workshop schedule summary.

Workshop #/topic	Date	Objective
Workshop 1: Researchers	March 1, 2024 March 7, 2024 April 10, 2024	Facilitate cross-national collaboration among researchers to compare theories, policies, and practices of mobile public warning systems in Yamagata and Boulder to identify best practices and innovative solutions.
Workshop 2: Municipal warning officials	March 14, 2024	Enhance mutual understanding between Yamagata and Boulder municipal warning officials regarding the operational challenges and improvements in mobile public warning systems for weather and non-weather hazards.
Workshop 3: Weather warning officials	March 28, 2024	Exchange knowledge and strategies between weather warning officials from JMA and NWS to improve the effectiveness of mobile weather warnings.
Workshop 4: Yamagata and Boulder residents	March 27, 2024	Gather insights from residents of Yamagata and Boulder about their experiences with mobile public warning systems to better align message content and dissemination practices with public needs and expectations.

maintain similarity in settings (Zoom), workshop approaches (discussion topics and flow), researchers (all coauthors participated in the workshops), and research instruments (questionnaires and workshop questions). To address differences in participants' response styles, the researchers gathered both written (questionnaires and answers to workshop preparation prompts) and verbal (workshop utterances) data. Interpretive bias was partially addressed by having both Japanese and U.S. researchers interpret the data to find points of equivalence and difference. The following sections present the themes that arose from analysis of documents and transcripts. Generative AI (Chat GPT 4o) was used to draft the brief overviews of Yamagata and Boulder below (edited for accuracy), two of the summary tables (Tables 2, 3, edited extensively), and an initial list of references based on in-text citations (mostly abandoned due to inaccuracies). The prompts provided to the Generative AI have been included as a Supplementary file.

Yamagata and Boulder weather and non-weather mobile public warning levels, systems, processes and scenarios, public education, and future developments

Table 2 compares Yamagata and Boulder along the dimensions stated in R1.

Yamagata overview

Yamagata is the capital of Yamagata Prefecture, which is in the Tōhoku region of Honshu, Japan. Geographically, the city lies in the southwestern part of Yamagata Prefecture. The city is surrounded by mountains. Heavy snowfall occurs in winter, drawing visitors to its rural resorts, natural beauty, hot springs, and subsequent springtime cherry blossoms. The city's flatlands are used for residential and agricultural purposes. Yamagata's decreasing, aging population and urban migration trends parallel Japan's overall demographic shift. As of 2023, there were 242,260 residents, and 30% were over 65 years old. The population of Yamagata is predominantly ethnically Japanese, with a small percentage of foreign residents.

Mobile weather warning levels in Yamagata

Mobile weather warning in Yamagata and throughout Japan is conducted under the auspices of the JMA. JMA's Emergency Warning System notifies municipal officials of likelihood of catastrophes due to natural phenomena of extraordinary magnitude such as heavy rain, earthquakes, tsunami, and storm surges. In addition to routine warnings, advisories, and other bulletins, JMA issues Emergency Warnings to alert municipal officials to the significant likelihood of catastrophes if a hazard is expected to be of a scale that will far exceed the normal warning criteria (e.g., such as the 2011 Great East Japan Earthquake). The criteria for Emergency Warning issuance to the public are determined by local governments in charge of disaster management, with the exception of earthquakes, tsunami, and volcanic eruptions, which the JMA controls. The JMA provides a 5-level typology, with the topmost level representing an extreme instance of Emergency Warning. The JMA's 5-level typology is widely shared with officials, residents, and visitors.

Under the Disaster Countermeasures Basic Act (1961, revised multiple times), municipalities are required to protect lives and property by providing disaster information and countermeasures to residents. As part of this requirement, municipalities are responsible for developing and improving the communication processes used to distribute disaster information. L-Alert (Local Alert) is one of several rapid, automated, and redundant warning systems that support these responsibilities. Strictly speaking, the JMA does not issue mobile warning messages directly to residents in an affected community. Instead, each municipality issues its own mobile warning messages to at-risk publics, a primary route being L-Alert. L-Alert is a registered trademark for "Disaster Information Sharing System," a system that communicates detailed information regarding local safety and security. The Ministry of Internal Affairs and Communications promotes L-Alert utilization, and the Multimedia Promotion Center, a general incorporated foundation, operates it. Local residents do not have direct contact with L-Alert. Instead, local authorities use the system to issue information via television, radio, internet, and mobile networks. According to "Emergency Alert Email Distribution Guide v. 3.7" (Docomo, 2023) published by Japan's major mobile service providers (NTT Docomo, Inc., KDDI Corporation, SoftBank Corp.,

TABLE 2 Yamagata and Boulder mobile public warning comparison.

Category	Yamagata	Boulder
Mobile weather warning levels	JMA's 5-level typology; local officials issue warnings via L-Alert.	NWS/WEA system direct to wireless subscribers for severe, imminent weather hazards.
Mobile non-weather warning	Officials issue warnings for evacuation and non-weather emergencies, though rarely used.	Non-weather warnings frequently issued via BoCo Alert; WEA for severe and widespread hazards.
Mobile warning systems	Area Mail system delivers information via mobile phones; lacks precise geotargeting.	BoCo Alert (opt-in) and WEA (opt-out) systems used; ReachWell app available in over 100 languages.
Mobile warning processes	Local Disaster Prevention Section handles some hazards; JMA in Tokyo handles earthquake, tsunami warnings.	Boulder officials use Emergency Alert Request Job Aid (in field) for coordinated alert issuance for hazards.
Mobile alert scenarios	Typhoons, landslides, urban fires, public health, and security hazards trigger warnings.	Evacuation orders, shelter-in-place, Red Flag warnings, and law enforcement incidents trigger alerts.
Public education	Online and printed materials, LINE, social media, and flyers are used for public education.	Quarterly community preparedness workshops; online and printed public education materials include graphics in English and Spanish.
Future developments	Yamagata LINE official account service for disaster prevention information across platforms.	New text messaging service for disaster updates.

TABLE 3 Yamagata and Boulder theories of communication and human behavior comparison.

Category	Yamagata	Boulder
Underlying theory of communication	Implicit theory based on practical experience and local adaptation; informal learning across municipalities.	Explicit use of the Warning Response Model (FEMA); socio-behavioral model with structured message design.
Warning response process	People often seek confirmation from family or community (milling) before acting; social pressure may influence action.	Individuals often rely on confirmation (milling) from other sources (social and environmental) before acting.
Message components	Limited formal structure; messages vary depending on local practices; lacking in detailed hazard consequences explanation, leading to lower personalization and understanding.	Messages includes five essential components (source, hazard, location, guidance, and time) to increase personal relevance and risk perception; in practice elsewhere in the USA, most messages are incomplete.
Community preparedness culture	Strong community preparedness culture; people rely on social networks and pre-existing plans.	Less emphasis on community planning; more reliance on official messages for instruction.

and Rakuten Mobile, Inc.), "As a general rule, it is up to the local government to decide whether or not the message they wish to send falls under the category of deliverable items" (slide 9).

Mobile non-weather warning in Yamagata

Yamagata municipal officials are responsible for issuing evacuation orders for weather and non-weather emergencies alike. As a result, the line between weather and non-weather warning is blurred. For the purposes of this study, non-weather warning in Yamagata involves mobile warning messages for hazards that involve evacuation or shelter-in-place, i.e., urban fire, wildfire, or industrial accidents; however, non-weather warning in Yamagata and throughout Japan is infrequent compared to the United States according to the participants and documents consulted for this study.

Mobile warning systems in Yamagata

As elsewhere in Japan, weather and non-weather mobile warning messages in Yamagata are distributed by Area Mail. Seki et al. (2008) explained that Area Mail delivers information about hazards, disasters, and evacuation sites for residents from national and local public safety organizations that have contracted with NTT Docomo. Authorized officials can then access a website for controlling message delivery from a personal computer by using a web browser and input a message of up to 515 characters 15 characters for the title, 500 characters for the main text. From this website, the popup display function on recipients' mobile devices can be enabled or disabled depending on the importance of the message. The areas targeted for cell broadcast message delivery are specified in units of cities, wards, towns, and villages under the jurisdiction of the relevant public safety organization. Based on the entered information, the Area Mail Center broadcasts the message to base stations within the specified delivery areas. Currently, precise geotargeting is not conducted due to national restrictions on the localized use of geofencing technologies. According to JMA officials, earlier citizen complaints regarding imprecise geotargeting and over-alerting led national policymakers to disallow the type of localized geotargeting conducted in the United States. Instead, a mobile public warning message is generally distributed to the entire municipal/regional area under threat. Specific geographic locations at risk are indicated within the text of the message itself (however, certain commercial apps in Japan and the United States can display areas at risk and the route to nearby evacuation centers).

Mobile warning processes and scenarios in Yamagata

In Yamagata, officials in the city's Disaster Prevention Section decide when a warning message should be issued for certain hazards requiring evacuation, such as flood. Earthquake and tsunami warnings come directly to residents. Yamagata officials might send warning messages for typhoon, heavy rain, landslide, wildfire, urban fire, public health, or security hazards.

Public education for mobile public warning in Yamagata

Public education occurs via an array of online and printed materials including websites, LINE accounts, social media pages, flyers, posters, pamphlets, and booklets. The Yamagata Residents' Handbook offers an example of public education for mobile public warning. Specifically, the top portion of the page explains that residents will receive warning messages on compatible mobile devices. No opt-in is necessary, and no fees are charged. An example message is included, along with a link to additional information.

Future developments in Yamagata

In addition to the mobile public warning systems described above, regions and municipalities in Japan occasionally provision mobile device-based applications ("apps") and/or various opt-in systems to residents and visitors. For example, Sakata City near Yamagata is now rolling out a new "Sakata Compo" web service. Disaster prevention information can be received via this web service for citizens in cooperation with the free communication application LINE. Registrants will be able to receive disaster prevention information, and the city can send disaster prevention information via multiple information transmission means, such as the city website, emergency bulletin e-mail, official Facebook, and X (formerly Twitter) in one operation. Recently, local governments are moving forward with providing services via LINE. How this combination of obligatory messages, opt-out and opt-in systems, and apps interact and influence stakeholders' awareness and decision-making with the mobile public warning ecology is a question that confronts stakeholders.

Boulder overview

Boulder, Colorado, is nestled in the foothills of the Rocky Mountains, near Denver, the state capitol. Boulder is known for its picturesque setting. Many residents pride themselves on the area's outdoor lifestyle. The city sits at 5,328 feet (1,624 meters) above sea

level and draws visitors with its abundant hiking, mountain biking, and rock climbing opportunities. The city of Boulder is part of Boulder County and serves as the county seat. Boulder and its surrounding region are known for promotion of environmentalism, outdoor activity, and health consciousness. The University of Colorado Boulder, the largest university in the state, contributes to the mix of students, academics, and professionals working in technology, research, and innovation. Boulder's eastern terrain is agricultural, and residential areas consist of flatlands and slopes that extend into the Great Plains. Boulder Creek flows through the city from the mountains in the west as it travels toward the plains to the east. Given the University, a sizable portion of young adults and a highly educated populace typify the demographics of the roughly 100,000 residents. The population is predominantly White, with Hispanic or Latino, Asian, and African American communities. Boulder maintains a high median household income, but the cost of living in Boulder is also higher than in many other parts of Colorado and the United States.

Weather warning levels in Boulder

The cell broadcast WEA system is an integral part of the United States' emergency preparedness and response infrastructure. According to the FCC, between 2012 and 2023, the WEA system was used more than 84,000 times to issue emergency notifications, severe weather warnings, evacuation and shelter-in place instructions, and alerts for missing and abducted children (FCC, 2024). The National Weather Service (NWS) is by far the most extensive user of the WEA system. WEA messages are character-limited (360 or 90, depending on a mobile device's capabilities) and are accompanied by a distinctive audible tone and vibration.

Conceived in the aftermath of the September 11, 2001, terrorist attacks and the 2005 Hurricane Katrina disaster, the 2006 Warning Alert and Response Network (WARN) Act gave the FCC authority to develop and adopt relevant technical standards, protocols, procedures and other technical requirements needed for the WEA system. Anticipating advances in mobile technology, the WARN Act authorized the creation of a voluntary National Alert System to provide a public communications system capable of alerting the public on a national, regional, or local basis to emergency situations. As of 2024, the WEA system is comprised of five message classes. The first class, "national alerts" are WEA messages designed to be issued only by the President of the United States (or their delegate) during a national emergency. To date, no national alerts have been issued aside from three end-to-end test messages in 2018, 2021, and 2023. Unlike every other WEA message class, mobile device users cannot "opt out" of national alerts via their device settings. The second class, "imminent threat alerts," constitute the bulk of WEA messages issued and include alerts for natural or human-made disasters, extreme weather, active shooters, or other rapid onset emergencies. Designated alerting authorities who have been authorized by FEMA to access the Integrated Public Alert and Warning System (IPAWS) issue imminent threat WEA messages to the public. IPAWS is the federal communications backbone through which WEA messages are validated and distributed. IPAWS alerting authorities include NWS (the largest user of the WEA system), and an array of federal, state, local, tribal, and territorial entities (authorized users of the IPAWS system are listed on the FEMA website).

A third message class, "public safety alerts," began appearing on compatible mobile devices in 2019. According to FEMA, public safety alerts "contain information about a threat that may not be imminent or after an imminent threat has occurred" and "are less severe than imminent threat alerts" (FEMA, 2024). AMBER (America's Missing: Broadcast Emergency Response) alerts, the fourth class, are issued in response to reported child-abduction cases where rapid public notification might help return a child to safety. The final class, "test messages," allow mobile device users to "opt in" to state and local tests of the WEA system, which would otherwise occur without public awareness.

Over the years, WEA systems enhancements, such as the inclusion of "embedded reference" hyperlinks, the creation of the "public safety" message class, and the renaming of the "presidential alert" message class to "national alert," have occurred through various FCC rulemaking processes. Importantly, today, the PBS WARN (Warning, Alert, Response Network) website's interactive online map now displays all active WEA messages broadcasting in real time. NWS pushes its mobile public warning messages to IPAWS. Alerts marked for WEA distribution are checked for Common Alerting Protocol (CAP) technical compliance and then routed to commercial wireless carriers who broadcast the alert from cell towers to all compatible cell phones in the designated hazard area. IPAWS also serves as collection point for non-weather alerts, such as civil and child abduction emergency messages which are issued by other emergency authorities. IPAWS is linked to a variety of other channels for further distribution, such as television/radio stations, sirens, display on highway signs, and desktop and mobile alert software application. WEA messages for weather related emergencies in the Boulder area originate in the NWS Denver/Boulder Forecast Office.

Non-weather warning in Boulder

On February 8, 2024, Dr. Bean met with City of Boulder and Boulder County public warning officials in the Boulder County Communications Center. The 2021–2022 Marshall Fire marked an inflection point in BODM's history. Public outcry concerning the lack of mobile public warning during the Marshall Fire led to significant changes in how first responders, BODM officials, and residents interact before, during, and after an emergency. The information contained in this section reflects the post-Marshall Fire systems currently in use, although some of the policies, processes, and terminology reflect earlier systems. Importantly, BODM's non-weather warning policies and processes are comprehensively addressed in its 2023 Boulder Alert and Warning Annex (not publicly available). The 73-page Annex covers: roles and responsibilities; when and how to issue a public alert or warning; methods and technologies; messaging; alerting coordination; training requirements; and system testing and exercise requirements.

Mobile warning systems in Boulder

The 2023 Boulder Alert and Warning Annex notes that the WEA system and opt-in Everbridge system ("BoCo Alert") are the two primary mobile systems that Boulder County officials use to warn residents and visitors of emergencies. The WEA system, discussed above in the context of weather warning, can also be used to notify at-risk publics of severe threats to their safety due to a variety of non-weather hazards. BoCo Alert is the name of Boulder County's opt-in system, but the system itself is provided by the Everbridge, a commercial provider of emergency notifications via landline or Voice over Internet Protocol (VoIP) phone, cellular phone, email, text

message and telecommunications device for the deaf (TDD). The Annex states, "Any first responder is responsible for ordering the evacuation and coordinating with the communications center or the agency that will be the lead for launching notifications" (p. 37). According to the Annex, Everbridge maintains a database of warning polygons for all-hazards. These polygons have been predesignated by local fire departments, law enforcement and dispatch directors. This system allows residents of the county and all cities within the county to be notified of an emergency in a variety of ways, including on their cell phone, home phone, and work phone and by text message and email (BoCo Alert / Everbridge is not a cell broadcast based system). In addition to BoCo Alert / Everbridge, BODM promotes the use of ReachWell, a mobile application that residents can download to their device and receive alerts issued by all 911 centers in over one hundred different languages.

Mobile warning levels in Boulder

According to the 2023 Boulder Alert and Warning Annex (p. 26), the following three alert levels are used in the county in order of increasing level of severity:

Advisory: Informational message about a situation that is likely to impact one of the addresses listed in an opt-in profile or a registered landline. Advisory messages will not be disseminated on the IPAWS system by dispatch personnel.

Warning: Messaging which encourages recipients to prepare to act due to an emergency in their immediate area. Individuals needing extra time to mobilize due to animals, friends or family members with functional needs issues should consider taking immediate action when a Warning notification is issued. Warning messages will not be disseminated on the IPAWS system (but may be issued via BoCo Alert).

Order: Messaging intended to have the recipient take the listed required action immediately due to an imminent threat to life (issued via IPAWS and BoCo Alert).

Mobile warning processes and scenarios in Boulder

According to the Annex, officials in the field can use the "Emergency Alert Request Job Aid" to initiate mobile public warning processes. Use of the Job Aid can help "ensure the proper alert or warning language is used, proper message information is provided to the dispatcher and the correct warning system is utilized to warn the public" (p. 20). Only extreme hazards will trigger the issuance of WEA messages. Once initiated, all relevant agencies will work to coordinate efforts when using the county's alert and warning systems. According to the Annex (p. 13), scenarios that could involve the issuance of mobile public warning messages (a "warning" or "order") include but are not limited to: evacuation orders (including evacuation routes, shelter info, key information, etc.); locations of points of distribution (for food, water, medicine, etc.); direction to climb to higher ground; shelter in place orders for situations like HazMat and law enforcement incidents; Red Flag warnings; weather alerts; lockdown; and shelter-in-place guidance.

Public education for mobile public warning in Boulder

Boulder County's "Community Preparedness Plan" (version 2/9/2024) includes the objective, "Strengthen community understanding of alert and warning systems" (p. 3). To meet this objective, BODM has engaged in online and offline public educations efforts. Online efforts include website content and social media posts. Emergency alert resources are available in Spanish, Mandarin, Korean, Vietnamese, and Russian. All materials are available at https://boulderodm.gov/preparedness/resource-library/. Offline efforts center on quarterly community preparedness workshops held at public institutions (such as the local library). Public education materials are provided by BODM through various channels. To improve public understanding, awareness, and instruction, BODM has also developed the "Emergency Alert Actions" graphics in multiple languages.

Future developments in Boulder

In the aftermath of the 2021–2022 Marshall Fire BODM has become a national leader in efforts to improve mobile public warning. BODM officials routinely participate in related FEMA trainings and workshops, attend academic and practitioner conferences, contribute to FCC deliberations, and advise federal, state, and local officials about Boulder's experiences and evolution. On July 10, 2024, BODM added a new text messaging service to the ways community members can choose to stay informed during a disaster. The new and optional keyword text messaging system will provide incident updates, community resources, road closures, sheltering information, and information about other community impacts. Having redundant systems for emergency notification is a public warning best practice, but how such text messages will integrate with BoCo Alert and/or WEA public safety messages remains to be seen in practice.

Theories of communication and human behavior that underwrite weather and non-weather mobile public warning policies and practices in Yamagata and Boulder

Table 3 identifies the main differences and similarities in researchers' perceptions of the communication and behavioral theories that influence how mobile public warnings are received and acted upon in Yamagata and Boulder (R2).

Transcripts of the workshop with Japanese disaster risk communication experts revealed differences and similarities in Japan and the United States's underlying theories of communication and human behavior. Officially, FEMA uses the Warning Response Model for designing effective public warning messages (Sutton et al., 2024). In practice, however, only a fraction of WEA messages issued between 2012 and 2022 were "complete" by the standards of the Warning Response Model (Olson et al., 2024). This socio-behavioral model emphasizes that messages must include five essential content elements: source, hazard description, location, guidance, and time. The model also highlights that individuals process these warnings through stages: understanding, belief, personalization (relevance to the individual), and action or inaction.

By contrast, Japan's Cabinet Office has distributed the "Emergency Alert Email Distribution Guide" since 2005, but there is no explicit public warning theory used across Japan, and local public safety officials rotate through municipal departments. Due in part to the structure and processes of Japanese municipal bureaucracy, there

seems to be an "implicit model" based on practical experience and local adaptation. As one workshop participant stated, "[I] have never heard [of] the [Mileti] model … I'm not so sure, but most of the local municipality people here, [do] what the other municipality do… there seems to be some model exists, but we would say 'implicit' model, not 'explicit.'" Another participant stated, "Municipal offices do not have to like… make a decision by themselves; just they are followers of the JMA." Given that municipalities often follow what other municipalities do, informal learning across regions may occur, rather than use of a structured theory akin to the Warning Response Model.

In 2023, U.S. public warning researchers and FEMA officials launched the Message Design Dashboard (MDD), an online tool designed to help local public warning officials generate messages that are more easily understood and effective. While Japan's "Emergency Alert Email Distribution Guide" offers examples of desirable messages, this study's coauthors did not locate any resources in Japan analogous to the MDD, nor any explicit references to risk communication theory that should guide the message content and style. We therefore conclude that the "family resemblance" of Japanese public warning messages included in the "Emergency Alert Email Distribution Guide" to example messages included in FEMA's MDD training is coincidental. It may therefore be in Japan's interest to investigate whether officials should formally identify the risk communication theory that should underwrite the content and style of public warning messages. Yet, it must be acknowledged that meaning is not "objective" or independent of context. Meaning is always a "local, situated, and transient accomplishment" (Taylor and Munoz, 2016, p. 2). Therefore, some level of local adaptation of mobile warning message content and style will always be necessary to promote optimal response.

In both Yamagata and Boulder, after receiving warning messages, individuals often seek confirmation by "milling" (Wood et al., 2018) — checking with others (family, neighbors, or digital sources or groups) before deciding to act. The importance of including the "why" in warning messages, that is, providing a reason for the need to take immediate action with reference to specific, localized risk information, is a critical component that can improve response. As one Japanese participant explained, "The information [in Japan] is lacking this point … so the message did not explain the hazard so much … this kind of making of behavior [why] is what is quite critical." In discussing a case where a disaster victim was criticized for wanting more information before acting, this participant noted, "The criticism from the public of her was 'you do not need such information just follow the instruction.'" This anecdote revealed a tension in the Japanese public warning context: social pressure to follow protective action instruction irrespective of one's level of risk perception and personalization.

Relatedly, discussion emphasized how Japan's strong community preparedness culture (Kitagawa, 2019) plays a significant role in public response. In Japan, individuals often rely on social connections and planning (e.g., family groups) to take action, whereas in the United States, officials appear to presume that people will be more reliant on the message itself for instruction. As one participant noted, "[Whether or not we] receive perfect information, we have to move and do something. But what to do? That's why … an individual has to make a predetermined plan [for] when they receive the information, otherwise, they recognize, 'Oh, we have to move,' but no idea [what to do, unless there's a plan]." Another participant agreed, "In Japan, there is much more focus on community-level action. People have plans in place and know what to do when they get the warning. It's not just the message; it's the collective preparedness that makes the difference." Another participant stated, "Local community people often take action by themselves, checking the height of water or other information." In sum, Japanese and U.S. culture, official policy, community norms, and disaster communication practices differ in substantial ways, making a one-size-fits-all approach to mobile public warning problematic.

Mobile public warning problems that Yamagata and Boulder officials identify for weather and non-weather emergencies

Table 4 compares Yamagata and Boulder along the themes arising is response to R3.

The discussion in this section is restricted to mobile public warning issues, but Yamagata and Boulder officials face broader challenges in terms of the mass media and social media systems used to reach at-risk populations. Comparing the problems that Yamagata and Boulder officials identify regarding mobile public warning for weather and non-weather emergencies reveals several similarities and differences. In terms of weather warning, the organizations that issue warning messages to mobile device users differ considerably. According to one Japanese official, JMA previously issued mobile public warning messages directly to device users but ceased doing so due to public complaints. Today, device users must use the J-Alert app to directly receive JMA weather warning messages. This official observed, "Japanese residents and high ranking government officials take greater issue with false alarms and unnecessary alerts. While a handful of U.S. residents may complain about false alarms/unnecessary alerts, there has been no significant policy change in which alerts are sent directly to the residents and by whom. The authority and ability of the U.S. NWS to issue these alerts has never been called into question or changed since the WEA [system] began." While warning message origination differences exist, participants in this study did not identify origination, by itself, as a problem. Where origination may become a problem is in terms of alerting fatigue (as explained below).

In Yamagata, weather warning messages are issued to residents by the municipal Disaster Preparedness Section, which is, in turn, guided by JMA's alert levels. Geotargeting is restricted to municipal or neighborhood levels, creating uncertainty among some residents about whether they reside in the area at risk. By contrast, NWS issues WEA weather warning messages directly to mobile device users through the IPAWS/WEA system, and geotargeting can (in theory) be restricted to just a few city blocks. In practice, however, distribution of WEA messages outside the designated hazard area remains problematic. In terms of non-weather warning, Yamagata's Disaster Preparedness Section also issues related messages (which are rare), and no separate opt-in system is used. By contrast, in Boulder, non-weather warning is more frequent, and trained staff members in the Sherriff's Communication Center and City of Boulder can use either the WEA system or the area's opt-in "BoCo Alert" system.

Officials in Yamagata and Boulder note that weather warning platforms and messages are multiplying, creating a potentially cluttered information environment. One JMA official noted that "it is difficult to prioritize which information should be sent as [mobile] push

TABLE 4 Yamagata and Boulder mobile public warning problems (officials' perspectives).

Category	Yamagata	Boulder
Geotargeting	Weather warnings are issued on a municipal basis. Evacuation information can be limited to a specific area within information content.	WEA distribution outside the designated hazard area remains problematic, constraining certain uses.
Over-alerting	Frequency of weather warning could contribute to warning fatigue.	Multiple types of mobile public warning messages reach residents: WEA, BoCo (if opted in), AMBER, law enforcement, national test, etc., potentially contributing to warning fatigue.
Warning thresholds	Yamagata office in JMA sets thresholds for weather-related warnings and Yamagata's Disaster Prevention Section issues the weather warning message.	NWS officials differ in identifying when weather hazards meet "imminent" and "severe" thresholds for WEA message issuance.
Supporting access and function needs populations	How those with mental disabilities might be negatively affected by warning message tones is a concern.	Boulder officials are at the forefront of advancing Colorado's approach to "inclusive" alerts.
Public education	Motivating the public to take appropriate protective action remains challenging.	Motivating the public to take appropriate protective action remains challenging.

notifications." In Boulder and throughout the United States, weather warning is only one type of message a device user might receive; other types of messages may include AMBER alerts for missing and abducted children, law enforcement notifications, and system test messages. As one JMA official observed, "In Japan, there seems to be a focus on narrowing down the information that is sent through emergency alert emails [mobile device messages], while the U.S. appears to be utilizing this method to send a variety of information. I feel this is the biggest difference. I speculate that this may reflect differences in what is the most commonly used means of obtaining information." Despite having more types of warning messages, the U.S. approach limits the issuance of official weather warning messages to NWS. As one official explained, "The decision was made a long time ago that the NWS is the sole authority for alerts that reach the public/residents. [For example,] AccuWx can send alerts to its clients, and those alerts can be different and specific to clients' needs. They can technically alert the public through their app if the public downloads their app, but it will not say 'warning' in it. AccuWx retransmits NWS warnings on their app, but they do not issue 'warnings' that reach the public on their app." Nevertheless, NWS officials acknowledge that mobile device users can receive an abundance of messages that could, in theory, contribute to alerting fatigue.

Officials in Yamagata and Boulder likewise share concern about how mobile warning issuance thresholds are determined. Technically speaking, Japanese municipal officials are not required to issue mobile warning messages at the thresholds advocated by the JMA (commentators noted this situation in the aftermath of the 2021 Atami landslide disaster). Although WEA system policy restricts issuance to warnings that meet "severe" and "imminent" thresholds, weather warning officials may differ in their perception of when weather hazards have reached those conditions. As one NWS participant noted, meteorological thresholds are well established (e.g., "Hail needs to be 1" (25 mm) in diameter to be considered severe") but the decision to warn is inconsistent: "122 offices [in the United States] can issue weather alerts for their area of responsibility.... [A] forecaster may think a storm looks more severe than a forecaster in another office because when the warning is issued, we typically do not have confirmation of hail size or wind gust." In terms of non-weather warning, Yamagata officials seldom use the mobile public warning system because hazards that would rise to the level of message issuance are rare. No application to higher authority is needed for issuing non-weather warning messages in Yamagata. By contrast, in Boulder (and throughout the United States) FEMA tightly controls and regulates municipal/organizational access to the WEA system. Municipal users of the WEA system, such as Boulder County, must also pay a commercial, FEMA-approved vendor for access to a WEA system technical interface. Boulder police, fire, and emergency services personnel in the field can request mobile warning message issuance using a specialized "job aid" (an intervention that may be unique to Boulder). In Yamagata, mobile warning message issuance is wholly controlled by the Disaster Preparedness Section in collaboration with the Mayor's Office.

Another concern for Yamagata and Boulder officials is how to best support access and functional needs populations (the preferred moniker in the United States). One JMA official noted, "Since this information is life-threatening, we want to make sure that everyone can understand it, but we are not able to do that." An NWS official replied, "We try to tailor/retransmit alert information in the best way possible for people to understand it, and that includes non-English versions of all our alerts. For WEA, we do Spanish translation for sure. We have hearing impaired alerts, and visually impaired alerts which depend on a third party equipment or app, but the alerts are able to be repackaged to help those communities. But we have not yet explored ways to help those with mental disabilities." Colorado has become a leader in the provision of inclusive alerts, creating an opportunity for Yamagata officials to explore new approaches for reaching access and functional needs populations (Natural Hazards Center, 2024). It is important to note, however, that the term "disability" is culturally constructed; Japanese officials treat "elderly people" in ways that access and functional needs populations are treated in the United States.

Among the top priorities for Boulder weather warning officials are to improve geolocation for WEA messages, expand WEA message categories to include "fire warnings," and improve the WEA system's ability to include graphics as a way to dissect/digest probabilistic information. As one NWS official stated, "Like in Japan and the United States, there is a character limit for mobile alerts, but I think an expansion of the character limit is necessary to convey more accurate information at once. Also, I would like to know how you [Japanese officials] smoothly and reliably use URLs to guide users to websites, maps, etc." Ideally, answers to such questions might help improve public response. As one Boulder County official noted:

> I perceived that Yamagata has a more disciplined public regarding responding to alert and warning. There is no choice to opt out, and … the public there seems to follow what the messaging says. The Boulder County population tends to operate with freer will when responding to alert and warning. One good example to illustrate this is the fact that almost as many people drove into the evacuation polygon as evacuated during the NCAR fire in 2022. This is why we have worked hard to draw precise polygons and post links to the message and map. Additionally, it appeared that Yamagata did not use alert and warning for law enforcement events like we do.

A final shared challenge involves public education. Both Japanese and U.S. wireless subscribers are provided minimal information on their mobile devices concerning the meaning of the toggle switches found in their notification settings. Some U.S. subscribers may inaccurately presume that the toggle switches are associated with local opt-in systems (Bean, 2019). Device-based public education is needed to better inform subscribers of the meaning of the toggle switches, the availability of local opt-in systems and apps, and the consequences of opting out of the national cell broadcast warning system. As one Yamagata official stated, "Additionally, the challenges we face in raising disaster prevention awareness among residents are common between us, and I realized that we need to address them as future tasks. By learning about the differences between Boulder and Yamagata City, I think I have identified areas that require improvement in the future. Not just for this workshop, but I believe that regularly exchanging information will lead to better disaster prevention measures." A Boulder official echoed this sentiment, "I think there is a great opportunity to expand public education in the county. The resources we have … do a great job but are limited in number. Because the public can operate in a free will manner, it is important that we (public safety officials) communicate to them in detail our limitations and their responsibility to remain safe during emergencies."

The problems that Yamagata and Boulder residents identify regarding mobile public warning for weather and non-weather emergencies

Table 5 compares Yamagata and Boulder along the dimensions stated in R4.

The problems that Yamagata and Boulder residents identify regarding mobile public warning for weather and non-weather emergencies are similar. Amplifying and extending the categories of information noted in Table 5, residents in both communities also identified timeliness, geotargeting, and trust as top concerns. In terms of timeliness, one Yamagata resident stated, "I want to know what kind of information I will receive at what time." A Boulder resident asked, "Is the information timely?" Another remarked, "The alert arrived, but officials did not know [the details] and it [the hazard] was changing rapidly." Timeliness overlapped the issue of specificity. One Yamagata resident noted, "It would be helpful to have specific instructions on evacuation locations and routes." Another asked, "Does the message include what to do, such as how to evacuate?" Similarly, one Boulder resident stated, "I would like to know where I should evacuate, or be given a direction of where to go." Another asked, "I want to know what to do. Which way should I go? How far do I need to go?" Regarding geotargeting, both groups questioned whether the mobile warning message they received were relevant to their specific area. Yamagata residents sought clearer instructions on actions specific to their location. One resident observed that "it would be helpful to have specific instructions on evacuation locations and routes." A Boulder resident asked, "I want to know if it is really for me. Is it really *my* area?" Another noted, "In the [2021–2022] wildfire, we were unsure where to head but chose to go west… A route of open roads would have helped." Both communities expressed concerns about the legitimacy and trustworthiness of mobile warning messages. This included distinguishing between official messages and other types of notifications. One Yamagata resident was unsure whether the warning messages she'd received had come from Yamagata City or other organizations. One Boulder resident asked, "I also frequently get spam messages, so how does an evacuation message establish its legitimacy to receivers?" Another noted, "Now that I am on the [BoCo Alert] list, I get a lot of AMBER alerts, elderly [missing], it's not specifically aimed toward me or where I am living."

Residents in both communities were asked to imagine scenarios where they received mobile warning messages for flood and wildfire directing them to evacuate and the types of information they hoped to receive. The residents' responses displayed consistency. Both communities emphasized the importance of knowing where to evacuate and how to get there, with specific routes and visual aids being requested. One Yamagata resident sought highly specific information, "Evacuate to the east of the mountain for a distance of several kilometers… I would like to know information on traffic congestion on roads, detour routes." One Boulder resident similarly stated, "I would like to know where I should evacuate, or be given a direction of where to go." Another remarked, "In both scenarios [flood and wildfire], I would want evacuation routes so I know which route to take." Both groups also wanted updates on the location, size, and progression of the disaster to inform their decision-making. One Yamagata resident sought information such as, "Where the fire is located, how big the fire is, and how fast it is spreading." A Boulder resident stated, "I would be interested in being able to figure out where the flood is happening relative to where I am." Both communities sought clear and unambiguous instructions about what actions they should take, whether to evacuate, and how to respond. One Yamagata

TABLE 5 Yamagata and Boulder mobile public warning problems (residents' perspectives).

Category	Yamagata	Boulder
Message specificity	Lack of specific disaster conditions and evacuation information.	Lack of clarity on specific evacuation routes and destinations.
Actionable instruction	Unclear instructions on what actions to take.	General, vague alerts without actionable steps.
Over-alerting	Information overload during heavy rain.	Concerns about receiving alerts too frequently, leading to alert fatigue.
Need for visual enhancements	Desire for visual aids (maps, diagrams) and specific instructions.	Desire for real-time updates and integration with GPS/navigation tools.

resident sought a visual aid, "I want concrete information… it will look like the picture in xx minutes." One Boulder resident wanted clear instruction, "I want to know what to do. Which way should I go? How far do I need to go?" Both groups thought it would be helpful to receive visual representations, such as maps or diagrams, to better understand the situation and guide evacuation (Liu et al., 2017).

These shared themes indicate a strong desire among Yamagata and Boulder residents for practical, location-specific, and actionable information that is easy to understand and act upon in real-time during disasters. Wordcount limitations in this article do not permit cross-boundary comparisons of residents' and officials' perspectives. Such investigations could, ideally, lead to interventions designed to improve public education and awareness and would be a natural next step in this project. For example, a cursory review of resident and officials' perspectives indicates shared concerns for message specificity and actionability. Both groups fear the consequences of over-alerting. However, the groups differ in terms of proposed solutions, with residents emphasizing the need for visual aids like maps and diagrams, while officials are focused more on improved geotargeting.

Implications

The sections above highlighted the problems and prospects confronting mobile public warning stakeholders in Yamagata and Boulder (and by extension, throughout Japan, the United States, and internationally). The study engaged residents in both communities to understand the alignment between their perspectives and officials' concerns (Societal Resilience Cluster, 2023). Ideally, residents and officials in Yamagata and Boulder (and throughout Japan and the United States) can learn from each other in ways that help them better prepare for, create, use, and respond to mobile public warning systems and messages before, during, or after a disaster. Yamagata could benefit from Boulder's advanced geotargeting capabilities, which allow for more precise alerts that (in theory) reach only those directly affected by a hazard, reducing the potential for alert fatigue. Although JMA abandoned geotargeting long ago, technological advances might compel public warning officials to reconsider it. Boulder, in turn, can learn from Yamagata's strong community preparedness culture, where residents often rely on pre-established plans and social networks to respond to emergencies. This fosters more collective action during disasters, as opposed to relying heavily on government-issued warning messages. Both communities face challenges with over-alerting and the need for clear, actionable instructions. Officials can jointly explore emerging practices of integrating real-time updates, maps, and GPS tools to provide residents with more specific evacuation routes and visual aids. Boulder's quarterly preparedness workshops and educational materials in multiple languages could inspire Yamagata to enhance its public education efforts. Similarly, Boulder can look to Yamagata's childhood and adult preparedness education efforts for helpful ideas and approaches.

Ultimately, however, the relevance of this study should be judged in terms of whether it (somehow) helps reduce death, injury, and loss from the non-use, misuse, or misunderstanding of mobile warning systems in Japan, the United States, or elsewhere in the world. To do this, mobile public warning stakeholders would need to apprehend how this study's cross-national findings might help them improve public warning technologies, organizational policies, messaging practices, as well as public education, awareness, and response. That is no easy task. Considerable economic, political, technological, and cultural challenges confront mobile public warning stakeholders globally. Based on our thematic analyses, we have identified a need to develop an international community of practice.

Amplifying Boersma's (2022) emphasis on boundary-spanning communication, we find that the field of mobile public warning is ripe for the creation of a discourse that supports theoretically guided interventions designed to improve knowledge, policy, and practice. This project marks the first time (that we are aware of) that Japanese and U.S. mobile public warning officials and residents have come together to engage each other. One result has been the ability of stakeholders to identify and critique underlying assumptions and contribute new ways of talking about mobile public warning. For example, the shared goal of creating mobile public warning systems and messages that are easily understood, actionable, and effective relies on commonplace assumptions about what the concepts of "understanding," "action," and "effectiveness" mean in the first place, as well as the interactions and influences among them. Examining these assumptions in this study, we find they are based upon subtle, culturally specific attitudes, values, and beliefs, as well as historically produced notions of disaster communication expertise, authority, responsibility, and accountability (see also Bean et al., 2021). For example, the Japanese concept of tsunami-tendenko, which encourages people to prioritize their own safety over helping others during a tsunami, has no direct equivalent in the United States.

One JMA official noted following the workshop, "The differences between Japan and the U.S. are not about one being appropriate and the other inappropriate, but rather that both have evolved according to their respective societies and cultures. I had already felt this way, but the workshop further strengthened this belief. By learning about these differences, I was able to find many points that should be referenced, making it extremely valuable." Focusing more attention on how stakeholders talk about mobile public warning can help draw such cross-boundary similarities and differences to the forefront of disaster communication research and practice internationally.

Despite differences in language, culture, and history, there is striking similarity among the problems confronting Japanese and U.S. officials who issue mobile public warning messages for weather and non-weather emergencies. Participants pointed to the benefits of learning how their sister city counterparts responded to those problems. For example, one JMA official stated, "It was highly valuable to learn that both Japan and the U.S. face similar challenges, such as excessive warnings and prioritizing information [sent to residents]. Understanding that different approaches are taken in other countries despite facing similar issues allowed me to consider mobile alerts from a different perspective. I am truly grateful for this opportunity." Developing an international community of practice could help facilitate future exchange and learning. Toward this end, this study demonstrates how "sister cities" might serve as an established mechanism to facilitate cross-national collaboration to improve disaster communication.

Aggregation of international research concerning mobile public warning could help as well. Specifically, Japan's Mobile Society Research Institute publishes studies of weather and non-weather alert and warning systems and technologies and is a valuable resource for public warning stakeholders. Japanese researchers conduct routine studies of the JMA warning system and related preparedness, response, and recovery technologies and activities (Mobile Society Research Institute, 2024). For example, a January 13, 2023, report from NTT Docomo, published by Mobile Society Research Institute, is titled "Awareness and Experience of Receiving Area Mail and Emergency Alert Mail Both on the Rise – Reception During Disasters is Highest in Tohoku, Kanto, and Kyushu, While Reception During Training is Highest in Kansai." Survey results showed that people's awareness rate increased by 21 points in 4 years to 80% and the number of people who had experienced receiving messages increased by 18 points in 4 years to just under 70%. The Mobile Society Research Institute publishes studies of weather and non-weather alert and warning systems and technologies and is a valuable resource. In the United States, FEMA is emerging as an analogous clearing house for public warning research. Yet, the U.S. research landscape is fragmented among government and commercial websites and academic journals. The United States could therefore benefit from the creation of an organization similar to the Mobile Society Research Institute, which was "established with the objective of broadly examining both the positive and negative aspects of mobile phones from a free and independent standpoint" (2024, para. 1). Boundary spanning organizations, such as UCL's Warning Research Centre, could help create a repository of international, multilingual research studies.

Conclusion

Experts in disaster communication are expected to help solve problems and bring about a safer, better world by promoting improved disaster risk management and public warning. International interest in cell broadcast early warning systems is expanding. However, mobile public warning is a challenging arena for disaster communication research because those who suffer most from its inadequacy are those who are injured or killed during a disaster. How many people have died during disasters who might otherwise have survived had mobile public warning systems and messages been more effective is a troubling—but largely unanswerable—question. Fortunately, in Japan and the United States, the number of persons killed by weather and non-weather disasters is declining (Ritchie and Rosado, 2024). Nevertheless, the nonuse, misuse, and misunderstanding of public warning systems and messages in both countries creates problems for officials, residents, and visitors (Bean et al., 2021). Public warning stakeholders can and should do better. Our admonition to "do better" may seem idealistic, but it is born out of a decade-long frustration of witnessing injury and death in Japan and the United States that might have been avoided had more effective mobile public warning systems and messages been in place. This study sought to identify what officials and residents in Yamagata and Boulder (and throughout Japan and the United States) could learn from each other that might help them better prepare for, create, use, and respond to mobile public warning systems and messages during an emergency. While the previous sections of this study have provided answers to that question, the small number of participants requires stakeholders to view those answers as preliminary and in need of further exploration. Ultimately, however, we conclude that the creation of an international community of practice might be the most impactful outcome of this project. Ideally, the creation of a community of practice can generate concrete and specific improvements for each locality.

As climate change accelerates, and as weather-related disasters intensify, there is an increasing need to understand what mobile public warning system elements (including messages) are equally suitable to everyone regardless of cultural background and which require local, cultural adaptation. Stakeholders will likely find, as we have in this study, that the concepts of understanding, action, and effectiveness are themselves neither natural nor universal phenomena. This study has thus pointed to the need for the future cross-boundary study of who produces knowledge of mobile public warning, what knowledge is prioritized, and how that knowledge informs (or not) public policy and practice.

Data availability statement

The datasets presented in this article are not readily available because data will be supplied upon reasonable request. Requests to access the datasets should be directed to hamilton.bean@ucdenver.edu.

Author contributions

HB: Writing – original draft, Writing – review & editing. KT: Writing – original draft, Writing – review & editing. AC: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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