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Chapter 8

'Balancing human needs with technology'—a design-led approach for exploring an earthquake early warning system in Aotearoa New Zealand

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8 'Balancing human needs with technology'[1]—a design-led approach for exploring an earthquake early warning system in Aotearoa New Zealand

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Introduction

Aotearoa New Zealand lies in a highly active seismic zone. GNS Science—New Zealand's geological survey—records over 20,000 earthquakes yearly through its seismic networks. Around 150 earthquakes are large enough to be felt by the people living across New Zealand (GNS Science n.d.). The country's population has the potential to experience intense ground shaking caused by earthquakes, exposing them to elevated risks of loss of life, injury, property damage, and economic costs.

Such disaster impacts can be reduced through multiple ways, such as land-use planning, engineering, emergency preparedness and planning, and warning systems (Becker et al. 2020a). Many locations worldwide have *public-facing* earthquake early warning (EEW) systems, such as in Japan, Mexico, Taiwan, South Korea, and the West Coast of the United States of America (Chung et al. 2020). These public EEW systems can warn people of strong shaking up to tens of seconds before it occurs. The public can use the few seconds to take protective actions such as Drop, Cover, and Hold.

Two interesting concepts make it possible for EEW systems to send alerts to people ahead of ground shaking. First, information can travel faster than seismic waves. Second, seismic waves move at different speeds. For locations further from the earthquake's epicenter, the secondary waves or surface waves—which cause the most damage, will arrive much later than the primary waves (Cremen and Galasso 2020).

EEW systems' potential in mitigating losses caused by earthquakes aligns with the United Nations (UNDRR 2015) Hyogo Framework and Sendai Framework for Disaster Risk Reduction. These frameworks emphasize the importance of developing people-centered early warning systems as an integral part of disaster risk reduction. However, despite the high seismicity in Aotearoa New Zealand, there is no official public EEW that will warn the general population in real time of incoming ground shaking from earthquakes. A nationwide public EEW system as a mitigation measure for earthquake risks is still in its early consideration.

Assessing the feasibility of EEW requires understanding of the technical, social, and cultural issues. It entails engagement with a broad set of stakeholders from different sectors, including research institutions, government, emergency management, other sectors, and community groups (Tan et al. 2021). Initial scoping studies in New Zealand show that the various sectors and the public have positive views of a potential EEW system

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(Becker et al. 2020a; Becker et al. 2020b). At these early stages of consideration, there is an opportunity to design and develop a genuinely people-centered EEW system in New Zealand.

Warning systems should be technologically sound to warn about hazards efficiently and consistently. However, it is also critical that warning systems are designed to reflect individuals' and communities' needs and their capacities to respond or not respond to the warnings (Fallou, Finazzi, and Bossu 2022; McBride et al. 2022). The disconnect between warning systems and their stakeholders can lead to costly consequences. During the 2013 super typhoon Haiyan in the Philippines, the public underestimated the warning issued by authorities leading to under preparation and poor response causing massive casualties and injuries (Otto et al. 2018). International bodies are increasingly emphasizing the need for people-centered systems, including integrating indigenous knowledge, catering to users' contexts, and considering broad information channels to reach target audiences, among others (UNISDR 2005).

Most literature on EEW systems discusses the systems' technical capability and performance (Velazquez et al. 2020). Rarely discussed is the process of design and development of EEW systems. Any aspect of design or development often focuses on testbeds, network optimization, and prototype evaluation; and does not include the development process of creating the systems (e.g. Iannaccone et al. 2010). Even rarer are articles discussing a people-centered approach to developing these EEW systems. An identified research gap is in the design of EEW systems toward earthquake resilience for communities (Tan et al. 2022).

This chapter discusses a design-led approach used to engage with the public to investigate the feasibility of an EEW in New Zealand.[2] It puts a people-first lens on a public EEW system. It recognizes that a warning system is as much about people and their behaviors as the technical infrastructure. The next parts of the chapter discuss (1) the overarching design science approach used by an EEW research in New Zealand, (2) a particular focus on the participatory design in engaging communities, (3) and finally, the voices and views resulting from the community workshops.

A design science approach for EEW research

> You're not just doing it for yourself, you're doing it for the community. Sometimes you'll benefit from it and sometimes you might not, but it's about the bigger picture.
>
> – EEW workshop participant

Design science involves designing an artifact (e.g. system, product, or process) with people who want to address a real-world problem and contribute to finding solutions (Hevner and Chatterjee 2010; Peffers et al. 2007). Design science research is iterative. Figure 8.1 illustrates the cyclical processes involved. The three cycles of design science ensure that the research project is relevant to its environment (*relevance cycle*), that it is rigorously grounded on scientific knowledge (*rigor cycle*), and that the design is iteratively re-evaluated and refined on both environmental context and knowledge (*design cycle*) (Hevner and Chatterjee 2010).

This chapter particularly focuses on the *relevance cycle*, highlighting participatory engagement as a part of the design science approach that elevates a people-centered methodology. Through the *relevance cycle*, the team engaged with stakeholders using various approaches, including initiating a *community of practice* (Tan et al. 2021) and

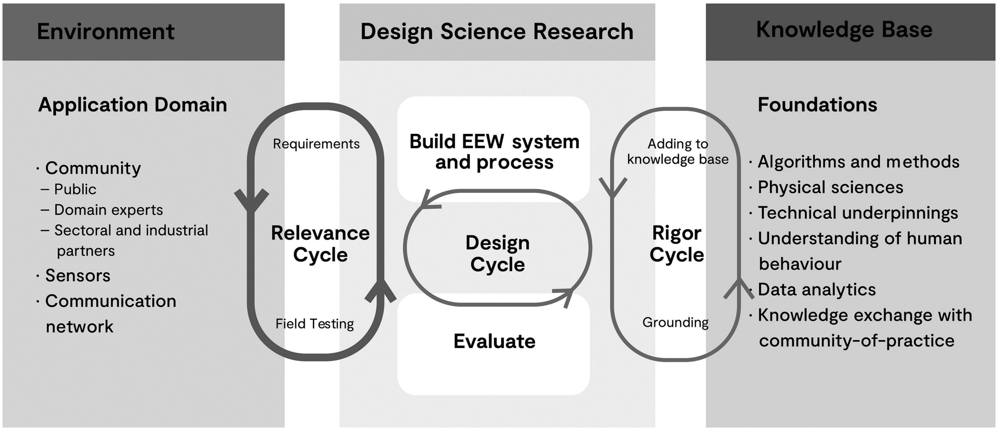

Figure 8.1 The research framework applied to investigating the feasibility of EEW in New Zealand, using the design science three-cycle view (adapted from Hevner and Chatterjee 2010). The focus of this chapter is on using a participatory method to engage the community as part of the relevance cycle.

facilitating *community engagements* with the public—as will be discussed in this chapter. Insights gained from the *community of practice* and *community engagements* have provided inputs to the prototype design of a low-cost EEW system (Prasanna et al. 2022), which is currently being field tested in Wellington, New Zealand.

The knowledge needed for this EEW research is multidisciplinary, involving geophysical sciences, seismology, information technology, telecommunications, social sciences, data science, participatory design, and others. As part of the relevance cycle, the intention of engaging with the community of practice was to create an open environment for researchers, emergency managers, government, and private industry players to discuss EEW in New Zealand (Tan et al. 2021). A community of practice comprises members who share a common concern and regularly interact to improve learning, research, and practice. Discussion forums with the community of practice were held to understand the expectations, perceptions, and concerns about establishing an EEW system in New Zealand (reported in Tan et al. 2021).

An area for further action was to ask who is not yet included in the EEW conversation. The *relevance cycle* for designing a people-centered EEW system must go beyond the community of experts. The public must be part of the conversation. A *participatory design* approach was used to engage the public to understand their perceptions of EEW. Participatory design enables the exploration and understanding of everyday people's lived experiences to positively affect the system's design (Schuler and Namioka 1993).

Participatory design in engaging with communities

> It is important to have continuous dialogue and to provide quality information. Things like — 'This is what we have found out' and 'We are moving ahead because of these findings…' This will give me more trust and confidence. And as the project moves forward, I'd be more engaged with the whole process seeing that the country is getting some benefit out of it.
>
> – EEW workshop participant

Engaging with communities is crucial for all parts of building, implementing, and using an EEW system. Participatory approaches build community capacity, participation, and ownership (Marchezini et al. 2018). People's views, behaviors and needs are essential to ensuring the uptake and value of such a system. This project investigates EEW's feasibility while consciously embedding a participatory lens from the outset.

Participatory methods are useful in gauging citizen attitudes and community perspectives on topics. The participatory design explores everyday people's lived experiences, bringing them to bear on policy, service, and technological project designs. Participatory methods are 'must-haves' to bringing about greater participation in, and more effective responses to, system implementation, service design, and community-led and informed responses (Mark and Hagen 2020).

Who did we engage?

To study community perspectives for this project, eight workshops were conducted in four distinct environments across New Zealand, including a major city, four coastal towns, two urban in-land cities, and a small in-land rural community recently affected by a magnitude 7.8 earthquake. The recruitment approach was through making connections and introductions—for four workshops, the first contact came through arrangements with local Civil Defense groups, and for the rest of the workshops, the research team contacted and initiated meetings with various community leaders. The participants were from various affinity groups and community providers, including indigenous affiliations, migrant communities, surf clubs, retired individuals, urban residents, rural communities, and subject matter experts on earthquake engineering. The community engagements consisted of eight in-person workshops and 140 participants.

Conducting research in Aotearoa New Zealand also involves recognizing and supporting indigenous Māori knowledge and designing a clear engagement pathway with Māori (Kaiser and Saunders 2021). Cultural inclusion means increasing recognition of indigenous viewpoints and bodies of knowledge to foster changes and policies that are genuinely effective, such as seen in the culture-based approaches in the climate change adaptation space (Kenney and Phibbs 2021). The engagement included a workshop held at a marae with the kaumātua of a Māori community.[3,4] There is also a need for authentic engagement with Māori in developing effective early warning systems, as one of the Māori elders in one of the EEW community workshops mentioned:

> Māori need to be a part of any conversations like this. Otherwise, you only get half the story. An Earthquake Early Warning network based solely on sensors should not be the starting point for this.
>
> – EEW Workshop participant

Using 'The Comfort Board' method for the workshops

Within participatory design sits an established set of practices, tools and techniques to explore and understand the lived experience of everyday people (Schuler and Namioka 1993). For this project, the team chose to use their own proven participatory method—The Comfort Board—to plan, deliver and engage with community groups. The Comfort Board is an approach that enables meaningful conversations with communities on a specific topic (Brown et al. 2019). It is especially useful when exploring projects that are not fully realized or implemented, as it uses narrativized scenarios that model future situations (such as an earthquake). The method provides a platform for the participants to deliberate, find common ground consensus, and design potential solutions or recommendations to the issues described. Most importantly, participants narrate the key themes in their own words, within their world views and according to their community's needs and aspirations.

The Comfort Board method is delivered via a two-hour workshop encouraging discussion among the participants. The deliberative process provides an avenue for participants

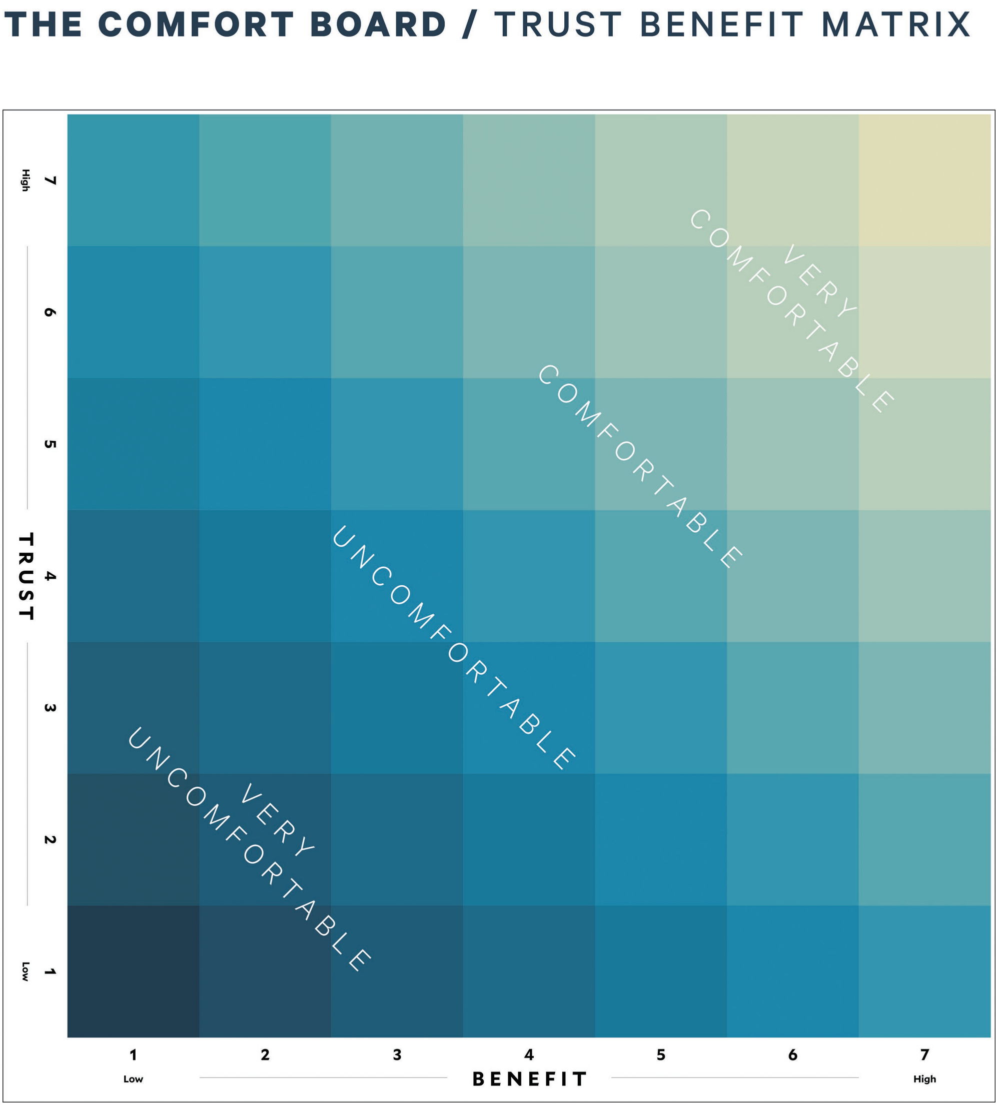

Figure 8.2 A comfort board with trust and benefit as its axes. The corresponding diagonal position reflects the participants' comfort scale (Toi Āria 2020).

to receive and exchange information, examine an issue critically, and agree on points that will inform decision-making (Fearon 1998). The 'gameboard' has two axes on a matrix—trust and benefit—which creates a corresponding 'comfort scale', as illustrated in Figure 8.1. The process starts by inviting all participants to consider their levels of trust and benefit in a scenario and position themselves on the life-size trust-benefit matrix (see Figures 8.2 and 8.3).

Scenarios

The Comfort Board uses scenarios that model real-life situations to gather from participants a *range* of attitudes and experiences to a particular issue or problem based on their own life experiences or life views. To investigate people's thoughts on EEW, five hypothetical scenarios were used, each scenario building on the next, spanning a time frame of ten years. The five scenarios (A–E) tackle distinct topics relating to EEW implementation through to long-term use. The first workshop scenario begins with a topic header of 'earthquake early warning system', to introduce the concept of EEW to the unfamiliar audience:

> **Scenario A**: The government is rolling out a new Earthquake Early Warning system. Public facilities (such as libraries, schools, community centers, and parks) have been fitted with earthquake sensors. With these sensors, the system may be able to give warning when it detects incoming ground shaking from an earthquake. This system has been publicized through radio, TV, newspapers, and social media. The government's campaign has several key messages: (1) that everyone with a smartphone is encouraged to download the free app; (2) that there are, however, limitations to the EEW system, populations near the epicenter will not receive a warning, but those

Figure 8.3 Participants placing themselves on their comfort level on the life-size Comfort Board (Photo credit: Alicia Cui).

further out may receive the warning; (3) if you receive a warning take action: 'Drop, Cover, and Hold'.

Central to the scenario progression is the introduction of prompts to explore different conditions for an EEW system across three stages: before, during, and after an earthquake. Each scenario explores different social and technical variables contributing to the implementation of an EEW in New Zealand (See Table 8.1 for a summary of the scenarios). Figure 8.4 illustrates how the scenarios are visually presented to the participants. The workshop groups share and discuss their views as each scenario is presented.

Conversations

On completing all five scenarios, the final workshop task asks participants to collectively identify and prioritize the common ground themes and concerns voiced across the workshop conversations that they consider most important to increasing comfort. See Figure 8.5 for an example of a group's collective summary. The communities, through the process, built consensus on what parameters should be in place or what actions could be taken to increase comfort, thus improving people's potential acceptance and use of an EEW system in New Zealand.

Analysis

Twenty-two group summaries of EEW issues were collected after conducting the eight workshops. Each table conversation was also recorded and transcribed for further analysis. The analysis anchored on the broad question, 'What are the most important things that will increase your comfort with EEW in Aotearoa New Zealand'. The facilitators summarized the data from each workshop into reports organized by table and scenario. The reports included group summaries and transcribed conversations. These

Table 8.1 Summary of scenarios and the corresponding themes explored in the workshop

Scenario	*Timeframe*	*Themes explored*
A Initial rollout of a nationwide EEW system	Initial rollout	EEW system (sensors) and concept introduced to the public. Mobile App defined as a channel for receiving an EEW alert. Action to take upon receiving the alert.
B Installation of sensors into homes for a subsidized cost	Six months later	Install sensors in homes to support network. Cost and resources involved.
C Monitoring and use of data from phones and sensors	One year later	Data collection and integration from phones and sensors. Use of data by researchers.
D App updates, alert thresholds, and notification	Two years later	Length of warning and shaking thresholds for alerts. False alert tolerance.
E EEW system and preparedness in New Zealand communities	Ten years later	Prevalence of EEW in society. Expected behavioral response to alerts.

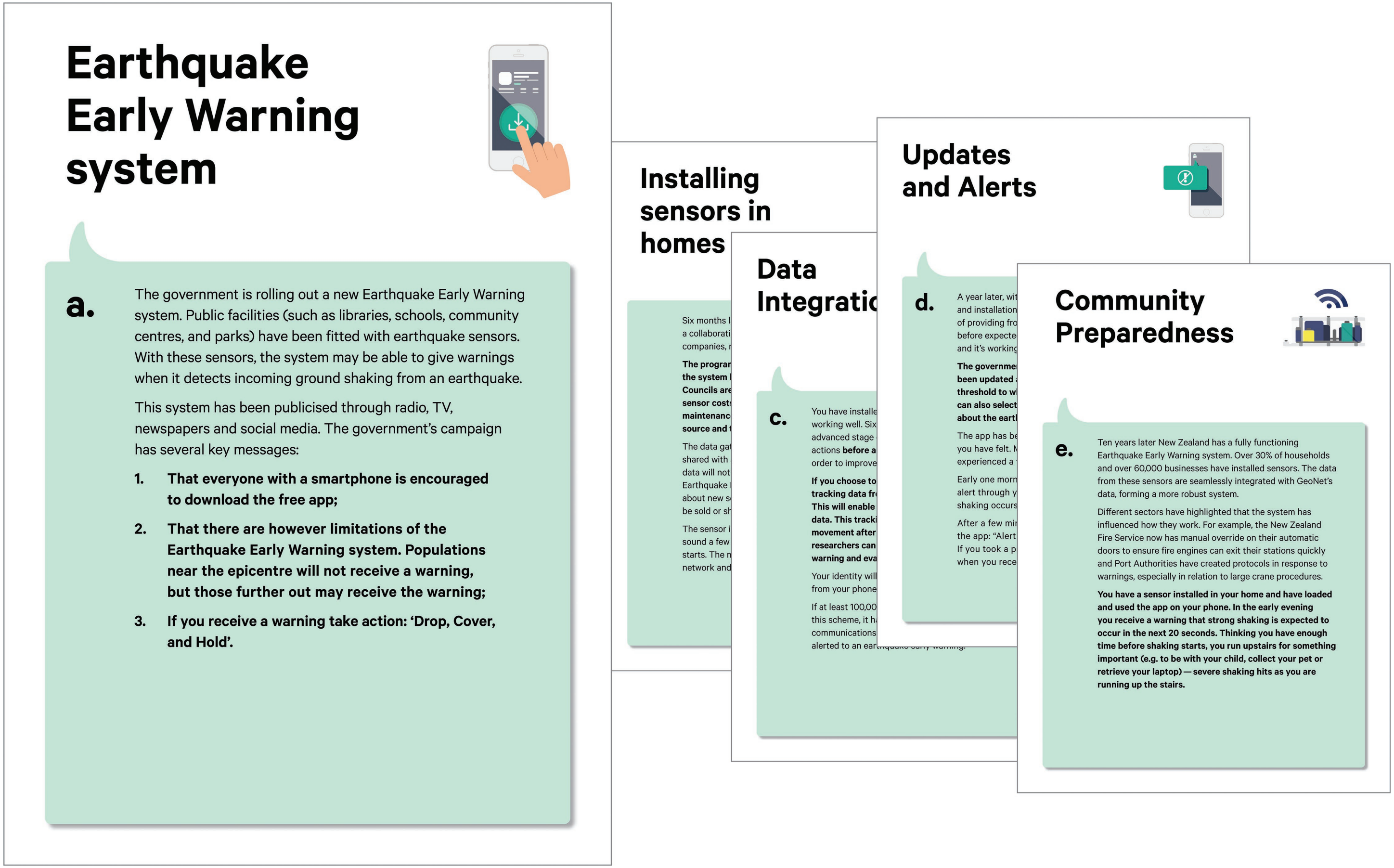

Figure 8.4 Scenario sheets used for the Comfort Board workshops. Each scenario is written succinctly within 200 words or less and presented to the participants in a sheet of A4 paper.

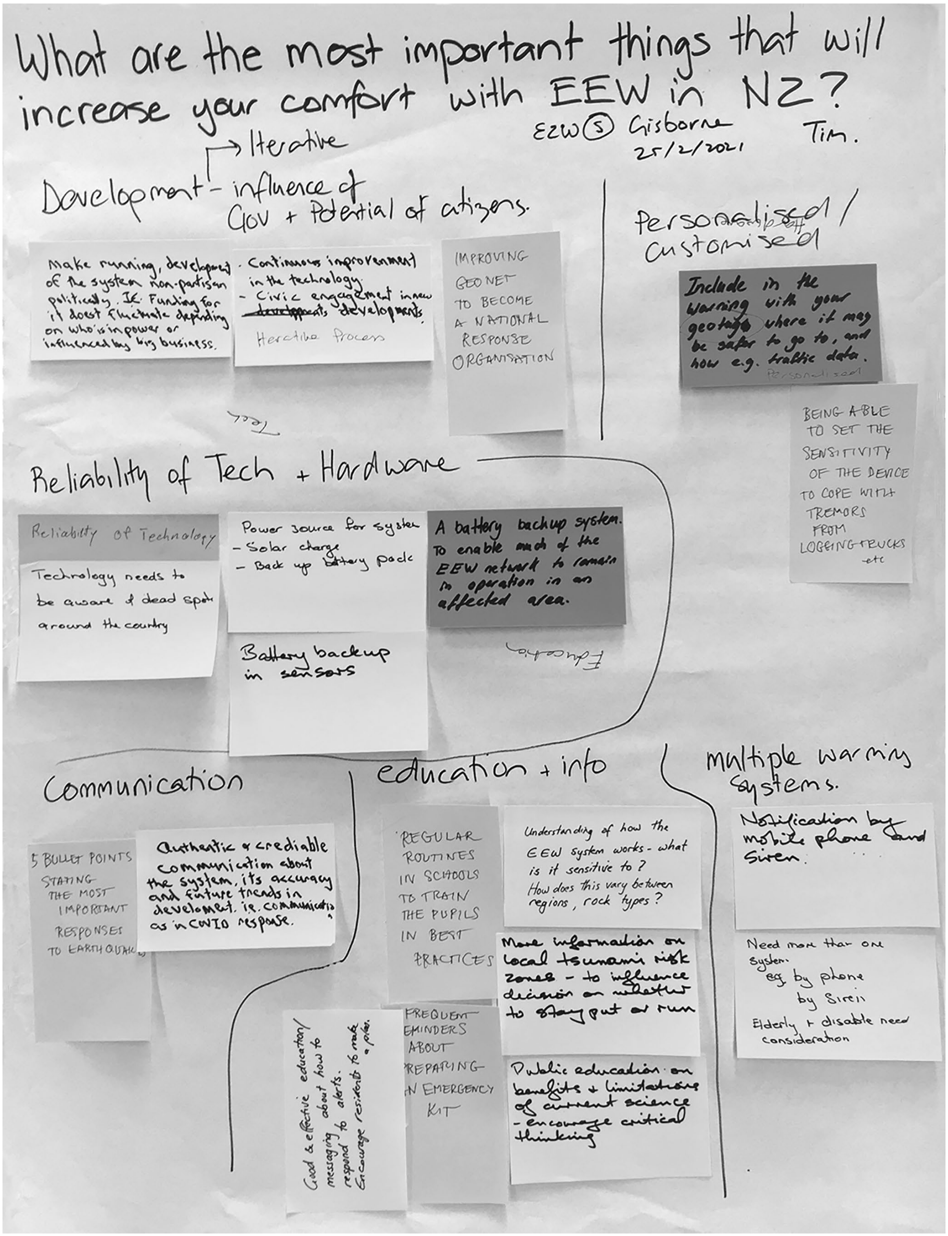

Figure 8.5 An example of a group's collective summary of the issues explored at an EEW workshop held in Gisborne, a seismically active city on the east coast of the North Island of New Zealand.

reports were then shared with the broader research team to review and thematically code and analyze (following Flick 2018; Gibbs 2012). Then the research team came together for a 'synthesis day' to assess and compile the findings and draw conclusions from the workshop data.[5]

Conducting these workshops provided a platform for a collective process of reflection-in-action where the project team and the communities articulate mutual aims and define appropriate methods to attain them. The workshops are an essential part of the *relevance cycle*; they ensure that the process of designing an EEW system is contextualized appropriately in its environment and connected to community needs.

Voices and views on EEW

> It's great getting all of this data but if you don't care about the people out there and if they're not ok — then what's the point. If you're going to all of this expense then include the people. Take a holistic approach that balances human needs with technology.
>
> – EEW workshop participant

The community workshops revealed a central principle of 'People, Place, and Protection'—that a New Zealand-based EEW system should protect people in the context of where they live. The participants emphasized the need for a holistic approach considering the intersections between (1) services and technology, (2) communication, and (3) human behavior. Figure 8.6 shows the conceptual framework for an inclusive, evidence-based, informative approach to a people-centered EEW system.

Overall, the participants who engaged in the workshop were supportive of an EEW system. Although there were caveats for how EEW would respond to community needs, participants still felt that the potential for any form of prior warning for an imminent earthquake would be better than no warning. They also understood that the development of warning systems would be iterative over time. The following two quotes from workshop participants highlight their views on the concept of EEW:

> I like that [this system] gives me the opportunity to prepare and [...] to be ready. Any forewarning allows for a ready-ing of your emotions. Anything's better than nothing, potentially.
>
> You have to start somewhere. There are always pros and cons but considering all the pros; I put my trust in it. The cons I expect to be addressed in the future.

EEW was a newly introduced concept for most participants, but they understood the importance of a robust technology system. The participants highlighted the need for public engagement, transparency, and inclusion to ensure the community will benefit from an EEW system. Certain groups also highlighted their community contexts and needs for EEW. We highlight these findings below.

Public engagement

Participants did not always understand the technical constraints of EEW (e.g. blind zones—areas near the epicenter where it is impossible to issue alerts). A workshop participant expressed it like this

> The people who need it most are the ones at the epicenter because they're gonna be the ones affected. I think that's kind of 'reverse' letting everyone else know that this is happening to these people... I just think the ones that are going to be affected the most should be notified. I mean, it's a good initiative; I'm not sure how effective it is.

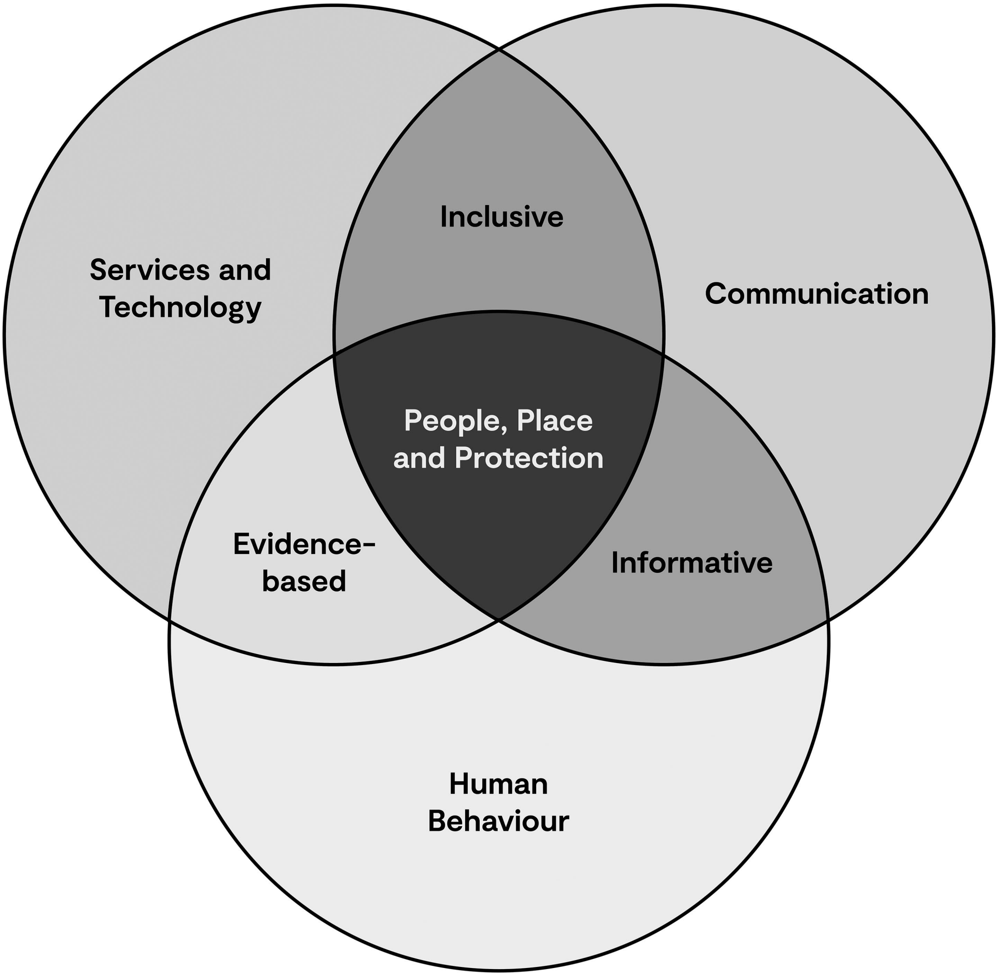

Figure 8.6 Toward a people-centered approach to an EEW system in New Zealand.

The participants' difficulty understanding the limitations shows the need for clear communication about the system, its capabilities, and the actions required after a warning for sustained public uptake. The participants emphasized the importance of an education program for the public that is informative and ensures communities can integrate EEW into their established ways of preparing for disasters.

Many participants spoke of the need for education and proper messaging to inform the public about what actions were advisable (or not advisable) within the early warning window:

> I think it's about some sort of training or education, for example, dry-runs, even from the young years, to teach them how to respond. So the sensor is just one of the many ways we educate people.
>
> In the same way that we're taught drop-cover-hold [on feeling earthquake shaking], there needs to be clear communication and public awareness about the actions you should take if you have more time.

Insights, such as these, show that the design of a successful EEW system would need to include a broader education and training framework and a public engagement strategy.

Transparency

Participants also discussed that the EEW system reliability is not just about eliminating alerting errors but also about the system transparency. Participants expressed tolerance for potential false alarms and teething issues, especially at the early stages of implementation. People accepted that errors would occur in the early stages of implementation and that quick acknowledgment and follow-up information would mitigate user drop-off:

> I'm much more likely to trust when [...] something goes wrong that it's acknowledged and responded to. If there were a number of false alarms, I'd get pissed off, and my trust would go down. But if you're willing enough to say, 'this isn't perfect, there's been a mistake,' then I'm all good with that as long as we all find out what sat behind it.

Engaging with the communities will help design a system to generate users' trust. An EEW system in New Zealand should be designed to optimize reliability and ensure that embedded communication strategies exist to rectify and address errors quickly and clearly.

Inclusion

Findings from the workshop showed that communities in New Zealand are diverse and encompass a wide range of ethnicities, ages, and abilities. Some of the workshop participants voiced concerns representing different communities. A number of the participants felt that developing nationwide public systems often exclude particular community groups:

> There's an exclusion happening here. Māori are always excluded from these conversations happening between companies, institutions, agencies, and the public, from participating in this kaupapa [initiative].
>
> My daughter is special needs, autistic, so that's a concern for me. I can see the benefits of an early warning system, but some groups do get overlooked in their response to things like this.
>
> I don't like the idea that old people like me would be ignored. How do you make sure that we're included? Most have got basic phones to communicate with family, but they are not downloading apps and things like that.

For other the migrant community, they felt that some people in their group do not even have the basic knowledge of earthquake hazards:

> It's different for my migrant community because their resilience levels are different because they don't see the issue as being as serious as it is. The information hasn't gone to that community enough.

The participants highlighted that an inclusive EEW system means that a range of people should be consulted in developing the technology and system. This includes the communication aspects of promoting the system and educating people about how to respond in the event of an alert.

Specific needs for different communities

The more nuanced findings from the workshops show the need to explore multiple distribution methods for EEW alerts, especially considering designing for demographics such as the elderly, people with disabilities, and migrant communities. Participants suggested that an EEW system be treated as a part of larger and more holistic earthquake response initiatives, including community support and care:

> People that know their neighbors have a higher rate of survival – so it would be interesting to see a bigger focus on community going hand-in-hand with the focus on technology. A full package that connects people with people – especially those that are isolated. That's the real issue. Not surviving the earthquake but surviving after the earthquake. This needs to be the full package.

In workshops with coastal communities, participants expressed heightened concerns about tsunami risks associated with earthquakes. Tsunami is a crucial consideration since not all EEW systems have tsunami warnings. Many of New Zealand's population live in coastal areas. Participants expressed the view that for people to have higher trust and uptake of an EEW system in New Zealand, the system must also consider tsunami risk warnings:

> I'm talking about the tsunami, that's all I'm worried about. I couldn't give a damn about the earthquake. If I come through it, great. But the real thing is the tsunami. This seems to be an 'after the event' device to measure what happened. So if there's an earthquake […], we get to know about [tsunami].
>
> Living here, if it isn't somehow linked to a tsunami warning, i.e. This is an earthquake, well, you need to hit the hills now; what use is it?
>
> This has to be linked to Tsunami for those living at the coast. Tsunami is a bigger fear than earthquake. I've lived through a big earthquake here. My house, I didn't think it was going to exist, was twisting and shaking like this. I was […] upstairs. Yeah. I'm sure I […] remember thinking, I hope I survive. Yes. But the biggest fear was Tsunami. So [linking this to tsunami] would increase […] benefit.

The most positive responses to the proposed system were from participants in a workshop in Seddon, a community with lived experience of the Magnitude 7.8 (Mw) 2016 Kaikōura earthquake and its aftershocks. Their personal experiences of severe ground shaking provided a powerful sentiment: *any kind of warning is better than nothing*. A participant shared that an alert would motivate them to act immediately rather than wait to see whether the earthquake's magnitude was sufficient enough to act.

There were also negative responses to the concept of EEW. One representative from a northern iwi (tribe—a place-specific sub-group of Māori) expressed it like this:

> I saw no relevance [in this system] for myself. I come from […] [an iwi] in Taupō. We read our environment, which lets us know what's going on. So by the time this has all happened, we've already moved or done what we need to do or stayed put

> because we know we're going to be okay. This type of warning system then doesn't have any relevance, whether that's good or bad, it's just irrelevant.

The Māori participant pointed out that in a Māori-worldview, the starting point for a conversation about community safety and education would not begin with an EEW network based on sensors. The participant recommended having an indigenous approach from the outset to ensure appropriate cultural knowledge frames are considered and, where appropriate, applied. Having these conversations also opens pathways for compromise and understanding. Another Māori participant suggested bringing together old knowledge (indigenous) and new knowledge (science and technology) for a safer future:

> If we can find a way to develop a warning system that integrates the old and the new and integrates local knowledge systems that are of benefit, we will have a way to prepare for this. We have a [thousand] years of geoscience done from indigenous brainwork. It's knowledge where the earthquakes have struck before and how they have impacted and that sort of information feeding into risk analysis.

These varying perspectives show the complexity of a nationwide EEW system. The impacts of EEW may have different influences on regions, cultures, and groups. Designing a nationwide system must carefully explore, capture, and integrate the contexts of the communities. More in-depth engagement with Māori, and other communities, is vital to have a New Zealand EEW system embedded with cultural relevance, equity, and shared knowledge. Furthermore, engagements should happen throughout the EEW system design, including in various stages of prototype, implementation, evaluation, improvements, and future iterations.

Discussion and conclusion

EEW research increasingly recognizes the need to integrate more social sciences into the development of EEW systems, particularly involving public perspectives into the discourse (Tan et al. 2022; Velazquez et al. 2020). However, few academic publications have shared the role that design-led approaches can provide for people-centered public-facing EEW systems. This chapter contributes to the research conversation by sharing an overarching design science approach toward investigating the feasibility of EEW. It provides a snapshot of a participatory design method used to engage in discussion with communities on the topic of EEW.

Engaging with the eight Aotearoa New Zealand communities was an enriching process that enabled the research team to learn from various community voices and views on EEW. The workshops set out to explore the views of people regarding implementing an EEW system and to better understand the needs, opportunities and challenges of establishing such a system. The workshops confirmed the sentiments from past research that the New Zealand public has a positive outlook toward EEW (Becker et al. 2020a; Becker et al. 2020b). The workshops, however, have shown that despite the positive views, there are challenges to overcome to ensure that a public EEW system will achieve its intended benefits. The participants envisaged a holistic EEW system for New Zealand that considers the intersections between services and technology, communication, and human behavior. They expected that this holistic system would have a suitable level of public engagement, transparency, and inclusion to ensure that it would benefit the population—balancing human needs with technology.

The community workshops have highlighted three design considerations for developing a public-facing EEW in Aotearoa New Zealand. First, a public engagement strategy should be designed as part of the EEW system. Public education should be prioritized in communicating the system, the appropriate responses, and its role in overall earthquake preparedness for the country. Second, the system should be designed for transparency when dealing with alerting errors. The community workshops have shown that the public generally accepts missed and false alerts, but the designers and custodians of the EEW system must be transparent about its limitations. Third, design considerations should be made for special interests—for instance, integrating tsunami warnings and actions is seen as critical for New Zealand coastal communities. Designing an EEW system is complex and multi-faceted. It may not be possible to address all the needs. Still, these conversations are essential to help prioritize which challenges must be overcome to help deliver an EEW that will ultimately benefit the public.

EEW projects in other countries can benefit from this participatory method to gain insights appropriate to their contexts. The method is particularly helpful for locations that do not yet have an EEW system in place and for participants with no technical background in EEW. The conversations in the community workshops were participant-focused rather than expert-led, with the aim to provide a space for open, non-intimidating, and honest conversations about community concerns for a future technological innovation.

The community workshops and other *relevance cycle* activities ensure that this EEW feasibility research project is relevant to its environment. Using the findings from this study and supported by the other parts of the design science approach, the next step is to ensure that the design of an EEW system is rigorously grounded on scientific knowledge—the *rigor cycle*. The prototype design of a low-cost EEW system (Prasanna et al. 2022) is currently being field-tested in Wellington, New Zealand. The feasibility research will also undergo the *design cycle*, which will be iteratively evaluated and refined on both environmental context and knowledge. Designing an EEW system involves a cyclical process that requires continuous learning and re-evaluation. The design-led approach described in this chapter puts people at the center, encouraging a close engagement with communities to inform the development of relevant and trusted future technological solutions.

Notes

1 This title is taken from the views expressed by a workshop participant.
2 In 2020, the New Zealand Earthquake Commission (EQC) and Massey University funded a research project to investigate the use of low-cost sensors for EEW in New Zealand. This research project is used in this chapter to illustrate a design-led approach in supporting its research.
3 A marae, a place of cultural significance, is a meeting ground that belongs to a Māori tribe, sub-tribe, or family, a place where they stand and belong. Marae are used for meetings, workshops, celebrations, funerals, and other cultural events.
4 Kaumātua are elders and leaders of a Māori tribe, sub-tribe, or family, that are held in high esteem.
5 A public report summarizing the workshop themes and participant quotes, including those used in this chapter, is available to read at https://mro.massey.ac.nz/handle/10179/16735.

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