10-15-2023

The Public's Perception of an Earthquake Early Warning System: A Study on Factors Influencing Continuance Intention

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International Journal of Disaster Risk Reduction 97 (2023) 104032

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

The public's perception of an earthquake early warning system: A study on factors influencing continuance intention

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1. Introduction

Aotearoa New Zealand is in a seismically active region between the Pacific and Australian plates. The country records around 20,000 earthquakes each year, of which about 250 are strong enough to be felt [1]. Significant damaging earthquakes have occurred in New Zealand's recent history, including the 2010–2011 Canterbury sequence and the 2016 Kaikōura-Hurunui earthquake, impacting lives and properties [2,3]. Given the high frequency and severity of earthquakes in New Zealand, there is a need to develop a range of mitigation tools to reduce earthquake impacts.

An earthquake early warning (EEW) system is one possible mitigation measure for New Zealand to consider [4,5]. A public-facing EEW system aims to warn users early about an impending earthquake, allowing them to take appropriate action to protect themselves before ground shaking arrives. EEW in New Zealand is in its infancy but evolving [4,5]. Although, as of writing, there is no official EEW system to warn the public in New Zealand, several technological products and systems already exist in New Zealand that can provide EEW services [4,6]. One such system is the Android Earthquake Alert (AEA) System [7,8].

Receiving EEW alerts is a relatively new experience for most New Zealanders, with the AEA system being the first to be easily accessible by the public through Android devices. The AEA system was launched in New Zealand on April 28, 2021 [9]. Since then, Android device users in New Zealand have the capacity to receive EEW alerts, informing them in advance of incoming ground shaking.

Understanding the public's continuance intention toward the AEA system is crucial at the early stage of EEW in New Zealand, as it can provide insights into broader long-term public perception and adoption of EEW in the country. Continuance intention refers to a person's decision to continue using a particular technology or product over time [10–12]. It is a key factor in the adoption and long-term success of technology products and services [11,13].

Although the concept of continuance intention is often applied in commercial technological services and products (e.g. Refs. [14,15]), its relevance also extends to critical contexts such as health services (e.g. Refs. [10,16]). However, only a few studies have investigated continuance intention in the disaster management technology context [17]. Research in the New Zealand context has delved into continuance intention, particularly in disaster apps, aiming to clarify how enhancing usability factors relates to users; inclination to continue using these apps [12].

The current study aims to fill this gap by examining whether the concept of continuance intention applies to the EEW context in New Zealand. Specifically, it investigates the factors that influence the continuance intention of the New Zealand public towards the newly introduced AEA system.

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https://doi.org/10.1016/j.ijdrr.2023.104032
Received 18 June 2023; Received in revised form 17 September 2023; Accepted 20 September 2023
Available online 26 September 2023

2. Background and Theory

Past studies have argued that the success of EEW relies heavily on how well it is adopted and used by the public [18,19]. Studies on the United States (US) West Coast have found that systems can give more robust warnings with longer average warning times for lower ground motion thresholds (i.e. users want to be alerted at a weaker ground shaking level) [18,20]. EEW systems have been deemed successful from seismological and technological standpoints, where alerts are evaluated regarding accuracy and timeliness [21]. However, the end-users' reactions to warnings are also crucial to the EEW system's effectiveness [21,22]. After all, the objective of public EEW systems would be for the public to use the information to take protective action [23,24]. However, despite the potential utility of EEW, fewer than expected numbers take action when receiving an EEW alert [19]. To achieve the desired behaviour and promote public participation in EEW, it is crucial to understand the factors that influence users' intention to continue using the system over time. This paper investigates factors influencing people's decision to continue opting-in to the AEA system after receiving their first few alerts. The study focuses on the context of New Zealand, where the system was launched in 2021.

2.1. Android Earthquake Alert system

The AEA System is built directly into the Android smartphone devices' operating systems [8]. On the US West Coast, AEA partners with the US Geological Survey's ShakeAlert network [7,8]. However, outside California, Washington, and Oregon (where ShakeAlert operates), AEA uses a crowdsourced approach of using Android phones to detect earthquakes [7]. The AEA system, which provides EEW service to its users in Greece, New Zealand, Kazakhstan, Australia, and some Pacific islands, uses the accelerometer sensors in the devices to detect earthquakes and send an alert to users who may be in the affected areas [7]. Android smartphone users do not opt-in to the service as it is built into their phones but may choose to turn off receiving alerts through their phone settings.

The AEA system issues two alerts: the 'Be Aware' and Take Action' alerts [7]. The 'Be Aware' alert gives users a heads-up for light shaking; this is delivered as a normal notification and is not intrusive as it respects the volume, do-not-disturb (DND), and phone notification settings. Users can get more information if they tap the notification [7,25].). The 'Be Aware' alert is only sent to users for expected shaking of MMI 3 or 4 and earthquakes of magnitude 4.5 or greater. On the other hand, the 'Take Action' alert is designed to grab attention by lighting up the phone screen and sending out a loud sound; this alert will override the DND setting of a user's phone [7,25].). The 'Take Action' alert is sent for expected moderate or heavy shaking (MMI 5 or higher) for earthquakes of magnitude four or greater.

2.2. AEA in New Zealand in 2021

Since the release of the service in April 2021, some members of the research team, who are based in Wellington, have been monitoring the earthquake alerts received. For the year 2021, we have experienced receiving "Be Aware" alerts on five occasions. Fig. 1 A-E provides details showing earthquake information from GeoNet, the official source of geological hazard information in New Zealand, for the earthquakes that occurred on 2 August, 5 August, 12 October, 22 October, and 7 November.[1] At the same time, the right side of the figures illustrates screenshots of the messages from the AEA system received by the researchers on these occasions.

The earthquake events on 2 and 5 August occurred early in the morning and had comparably smaller magnitudes than the other events in 2021. Only 2790 and 5906 felt reports were submitted to GeoNet (see Fig. 1 A & B). These August events, however, were the earliest records of AEA alerts being sent out to the public. Comparably, the events later in the year were larger in scale and felt more widely, with 17,552 and 24,738 felt reports for the 12 and 22 October events, respectively. The 12 and 22 October events (Fig. 1C & D) are the focus of this study.

2.3. A post-acceptance continuance intention model

Most Android smartphone users have the AEA system built into their phones [8]. It is enabled by default on compatible Android phones. Some users may not be aware of this service and may only become conscious of it after receiving their first alert. Users, however, can choose to disable or turn off the alerting feature if they prefer not to receive earthquake alerts in the future. After learning of the service, users' perceptions and experiences may influence their subsequent intention to discontinue receiving alerts and opt-out of the AEA system.

To decide to continue or disable the AEA service relates to the concept of continuance intention – an intention of current users to keep using the system into the future [26]. The intention results from a rational decision to use technology based on beliefs, expectations, or experience with the technology [27]. Android smartphone users already have the AEA system built-in; thus, they do not necessarily make an initial decision for acceptance of the technology. However, users still have the option to disable the service, making continuance intention an important concept to consider.

It can be argued that Bhattacharjee's [11] continuance intention model (See Fig. 2) is appropriate for this study as it already assumes users' acceptance and focuses on their intention to continue using the technology. Therefore, this study utilises the continuance intention model [11] to investigate factors influencing continuance intention (i.e. users' decision to continue or disable the AEA service) after receiving their first few alerts.

Fig. 2 illustrates the three factors that affect continuance intention according to the continuance intention model: perceived usefulness, confirmation, and satisfaction [11].

[1] Earthquake details can be found in the GeoNet website: https://www.geonet.org.nz/earthquake/2021p574445 (2 Aug 2021), https://www.geonet.org.nz/earthquake/2021p582866 (5 Aug 2021), https://www.geonet.org.nz/earthquake/2021p767783 (12 Oct 2021), https://www.geonet.org.nz/earthquake/2021p794366 (22 Oct 2021), https://www.geonet.org.nz/earthquake/2021p838207 (7 Nov 2021).

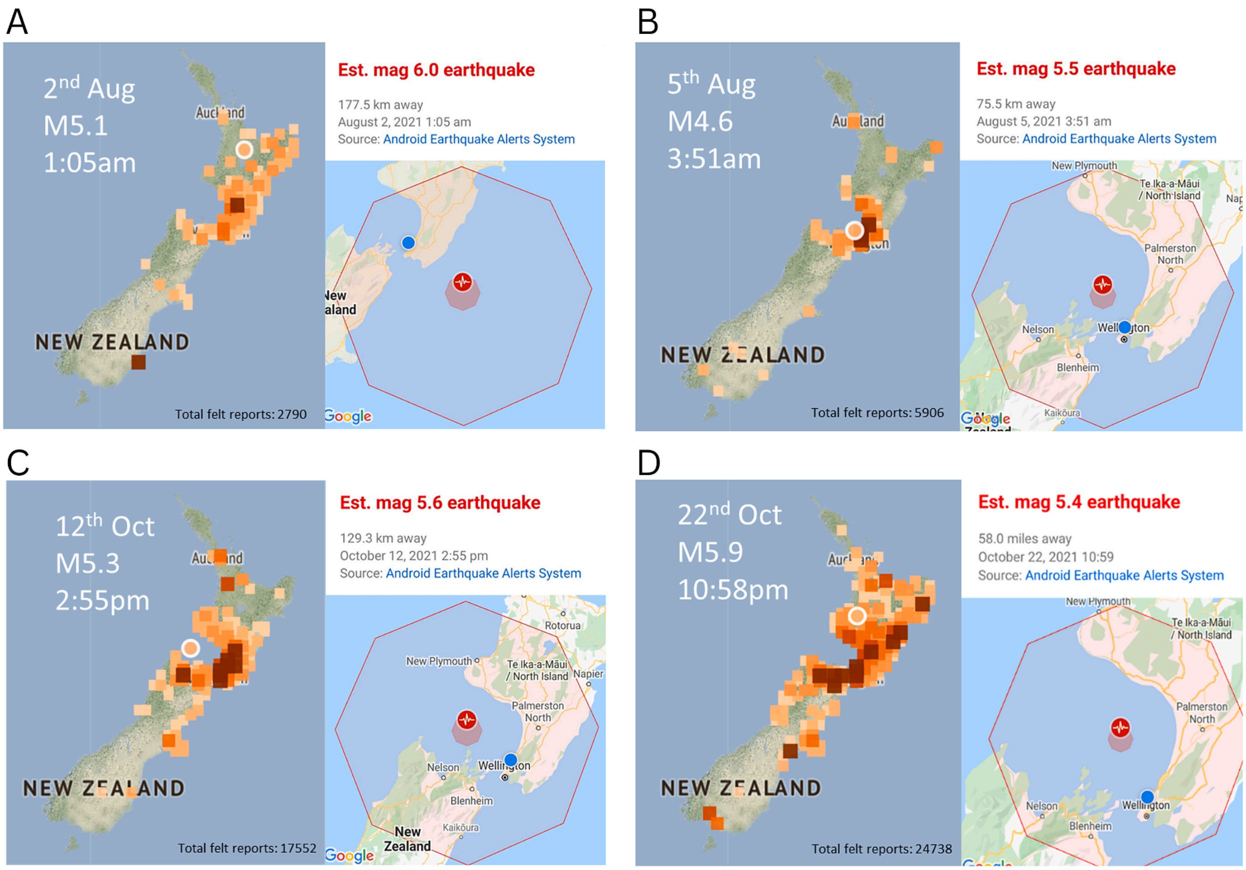

Fig. 1. A – D. Significant earthquakes were felt widely in New Zealand in 2021, leading up to and including the data-gathering period for the study, where AEA system alerts were sent out. The left-hand side of the figures shows the official date and time of the occurrence and magnitude as recorded by GeoNet, the corresponding shake map illustrating where people reported felt shaking, and the total number of felt reports. The right-hand side of the figures shows screenshots of the messages received by the researchers corresponding to the earthquake events. The screenshot contains the estimated magnitude, the distance of the epicentre from the location of the user, the date and time, the source of the alert, a map showing the location of the user and the expected location of the epicentre, and a polygon where expected shaking will occur.

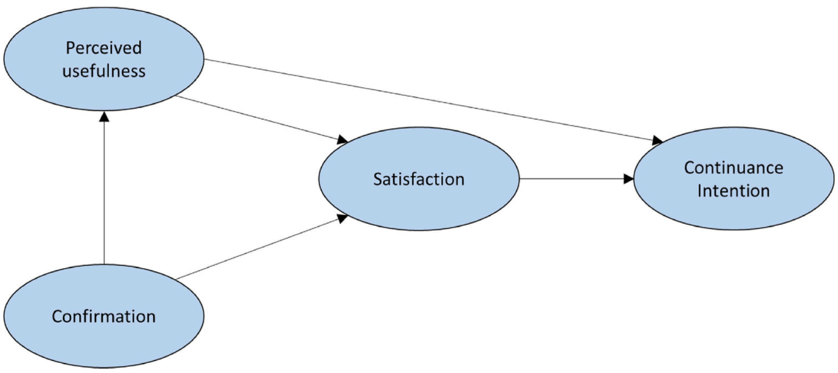

Fig. 2. [11] Post-acceptance continuance intention model.

- **Perceived usefulness** refers to users' perception of the technology's expected benefits [11], which in the context of EEW systems relates to the extent to which users perceive the system can provide benefits such as potentially life-saving information.
- **Confirmation** is the extent to which users perceive the congruence between the expectation and the actual performance of the technology [11]. In the EEW context, confirmation can be understood in terms of the system's capability to warn users of earthquakes effectively.
- **Satisfaction** refers to the user's overall sense of satisfaction with the technology [11], which, in the EEW context, relates to the overall sense of contentment and positive evaluation of the system.

2.4. Examining satisfaction as a construct for warning technologies

Emergencies and disasters present unique challenges for understanding user behaviour and intentions about technological products and services. The use of technologies during crises can differ significantly from day-to-day applications [28]; [12]. This distinction becomes particularly relevant when examining the determinants of users' intentions to continue using disaster-related technologies, such as EEW systems.

Recent research has raised questions about the applicability of satisfaction as a determinant of users' intentions in the context of crisis technologies. This includes EEW systems designed to provide timely warnings and ensure public safety during seismic events. Theories that incorporate hedonic factors, such as satisfaction, may not adequately capture the complex dynamics and motivations driving users' intentions in the context of crisis technologies [17].

However, despite the questions raised regarding the significance of satisfaction as a factor in non-hedonic technologies, it is important to retain it as a variable in the model to explore its potential contribution and better understand its role, if any, in influencing users' intentions to continue using the EEW system. By including satisfaction in the analysis, we can examine whether it interacts with other factors or manifests differently in the EEW context, providing valuable insights into the multidimensional nature of users' perceptions and behaviours.

2.5. Trust as an additional construct

In studying continuance intention, researchers have modified models to include additional constructs relevant to the specific technology being investigated. For example, perceived service quality and perceived trust were additional factors to consider for the study of mHealth services [10]. Perceived service quality and perceived trust have strong conceptual linkages to the continuance intention in the context of mHealth. Their findings, where the R^2 of endogenous variables are greater than 0.60, showed that perceived trust has significant explanatory power for the model and superior prediction capability for continuance intention [10].

Perceived trust is an important factor for high-risk technologies such as those related to health and finance, as the failure or misuse of such technologies can have impactful consequences (e.g. Refs. [29,30]). This study follows the same line of thought by considering perceived trust as an additional construct in the research model for EEW's continuance intention. Users with a higher trust perception towards the early warning system may be more likely to continue using it.

It is well known that for messages about natural hazards such as earthquakes to be effective, the audience must have trust in the source [31]. Trust in earthquake alert warning systems is particularly relevant as the population receiving the warning may not be entirely familiar with the system or may not have experienced receiving an alert [32]. If people do not trust the warning system, they may not follow the warning advice to take protective measures or may disable the alert services entirely [33,34]. Mistrust may also result in poor future responses to future warnings [33].

In information systems studies, it is important to note that perceived trust applies to an overall perception of the brand or company, not simply the trust in the product itself. Perceived trust is defined as the user's confidence that the provider will fulfil its obligations reliably and with integrity [10,35]. Perceived trust refers to an individual's belief that the provider will deliver its promise and often reflects the relationship of users with the firm or organisation [10,36]. Similarly, trust in EEW relates to the credibility of the source and the channel, i.e. the warning system as a whole [20].

Perceived trust can also have a relationship with confirmation [10,37]. Users' perceived trust can increase when expectations are met or exceeded (i.e. confirmed). Confirmation's influence on perceived trust may especially be important in the EEW context. Users may have expectations when receiving an EEW alert, influencing their trust perception of the system. During the Ridgecrest earthquakes in California, many Los Angeles residents felt shaking and had expected to receive an alert; the lack of an alert (as the expected shaking was below the MMI 4 threshold for alert issuance) led to negative public reaction surrounding the system [38,39]. Conversely, suppose an alert is issued for an impending earthquake, and the users feel the shaking; in that case, their expectations will be confirmed, potentially leading to increased trust in the system.

2.6. Research model and hypotheses

After considering the appropriateness of including perceived trust as an additional construct, Fig. 3 illustrates the research model proposed for this study and the hypotheses to be tested.

The modified research model follows the original [11] model but extends to include perceived trust as a construct. In conceptualising a continuance intention model for EEW systems, we hypothesise that perceived trust can be crucial in determining the user's continuance intention. Furthermore, disappointments may occur when public expectations are not matched when it comes to alerting, thus reducing the public's trust in the system [20]. We, therefore, also hypothesise that confirmation links with perceived trust.

The following are the hypotheses for the study:

- H1: Satisfaction has a significant positive influence on continuance intention,
- H2: Perceived usefulness has a significant positive influence on continuance intention,
- H3: Perceived trust has a significant positive influence on continuance intention,
- H4: Perceived usefulness has a significant positive influence on satisfaction,
- H5: Confirmation has a significant positive influence on satisfaction,
- H6: Perceived trust has a significant positive influence on satisfaction,
- H7: Confirmation has a significant positive influence on satisfaction, and
- H8: Confirmation has a significant positive influence on perceived trust.

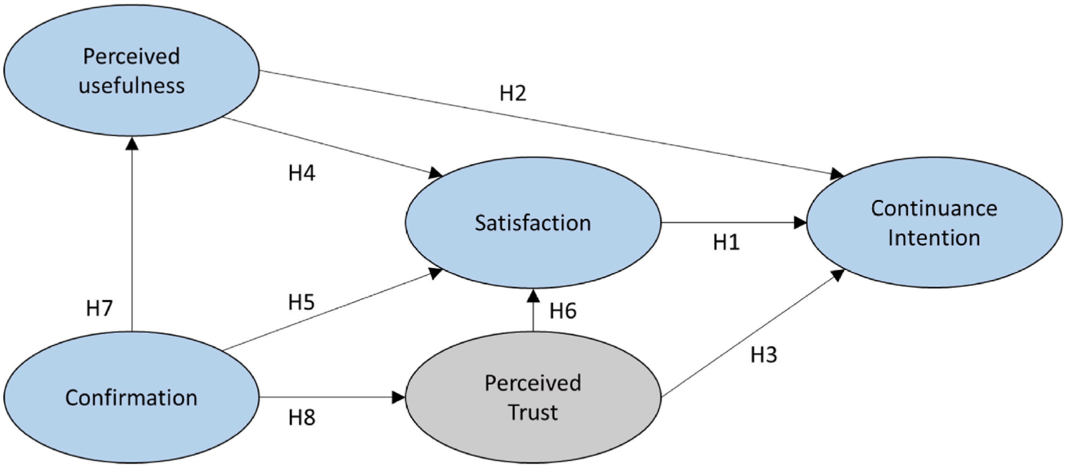

Fig. 3. The proposed research model for EEW continuance intention, with perceived trust as an additional factor.

The proposed model will be tested using structural equation modelling (SEM) on data collected from two separate earthquake events that occurred on 12 October and October 22, 2021. For ease of interpretation, hypotheses are labelled [a] for the 12 October event and [b] for the 22 October event in the results section.

3. Method

This study uses SEM to examine the relationships between the factors of perceived usefulness, confirmation, satisfaction, and perceived trust and their influence on continuance intention for the two earthquake events (12 October and 22 October). The two datasets were modelled separately to potentially identify the impacts of the earlier alert on the response to the latter alert.

3.1. Instrument

The online questionnaire was developed and deployed through Qualtrics Survey Software. The questionnaire included measurement items that reflected the constructs of the extended model, including perceived usefulness, confirmation, satisfaction, perceived trust, and continuance intention. Items developed for the questionnaire were adapted based on constructs drawn from Bhattacharjee [11] and [10]. A total of 20 items were asked to reflect the model constructs. Each item asked the respondents' level of agreement with the statement using a 7-point Likert Scale. Table 1 shows the items used.

Trust in EEW relates to the credibility of the warning system as a whole, including the source of the alert [20]. Therefore, to understand the factor of perceived trust further in the context of EEW in New Zealand, we also asked a question on who the respondents thought was the source of the alert.

Table 1
Reflective items used in the questionnaire.

Factor	Statement	Item ID
Continuance intention	I intend to keep the earthquake alert feature enabled on my phone.	CI1
	My intentions are to keep the earthquake alert feature enabled rather than disabled.	CI2
	I would like to disable the earthquake alert feature on my phone.	CI3
	I will not disable the earthquake alert feature on my phone.	CI4
Satisfaction	How do you feel about your overall experience of the earthquake alert? (answered on 4 different 7-point semantic scales)	
	Very dissatisfied/very satisfied	S1
	Very displeased/very pleased	S2
	Very frustrated/very contented	S3
	Absolutely terrible/absolutely delighted	S4
Perceived usefulness	Having the earthquake alert on my phone improves my overall earthquake preparedness.	PU1
	I believe the earthquake alert on my phone will increase my resilience to earthquakes.	PU2
	Having the earthquake alert on my phone enhances my ability to respond to earthquakes.	PU3
	Overall, I find the earthquake alert on my phone useful.	PU4
Confirmation	My experience with the earthquake alert was better than what I expected.	C1
	The earthquake alert's performance was better than I anticipated.	C2
	My expectation from the earthquake alert was satisfied as a whole.	C3
	Overall, most of my expectations from the earthquake alert were confirmed.	C4
Perceived Trust	I trust the information given by this earthquake alert.	PT1
	The earthquake alert is trustworthy.	PT2
	This earthquake alert provides reliable information.	PT3
	I trust that the earthquake alert has dependable features.	PT4

The following were the response options for the alert source: Google, GNS Science, GeoNet, the National Emergency Management Agency (NEMA), and local civil defence groups. The respondents could also provide an answer outside these options with a choice to select “others” with an open text entry. We included these options for the following reasons.

- Google is the AEA System provider [40].
- GNS Science, New Zealand's Geological Survey, is a geoscience research organisation. It is involved in geological hazard monitoring and works closely with other government agencies and industries to understand and mitigate geological hazards in New Zealand [41].
- GeoNet, operated by GNS Science, is New Zealand's national geological hazards monitoring service and the official source of geological hazard information in New Zealand [42]. GeoNet focuses on real-time monitoring of geological hazards.
- NEMA, formerly known as the Ministry of Civil Defence and Management, is responsible for sending official alerts, including for tsunami and COVID-19 alert level changes [41,43].
- Local civil defence groups are regional authorities that can send warnings to their communities [41,44].

3.2. Data collection

The data collection targeted adults aged 18 or older in Aotearoa New Zealand, who would have received the alert through their mobile phones. A screening question in the survey asked whether they received the alert to ensure data analysis only includes respondents with experience with the AEA system after an earthquake.

Recruitment through social media was deemed the most appropriate, as it can be distributed across wide geographic regions to collect rapid responses from the target population after an alert is sent out. Social media platforms are beneficial in collecting interested and affected parties' concerns on emerging technologies [45]. A key advantage of recruitment through social media is immediacy [46]. Especially in the context of perceptions of the alerts, social media recruitment allows for a way to rapidly distribute and collect people's perceptions and experiences closer to the alert event.

The survey was developed in anticipation that future earthquakes may generate an alert from the AEA system in New Zealand. The study received peer-reviewed approval under the Massey University code of ethical conduct for research involving human participants.

The distribution strategy was to share a link to the online survey through the research team's social media accounts and request promotion and endorsement through affiliated emergency management-related organisations. In addition, posting in online groups (e.g., Facebook community noticeboards) was utilised to maximise the reach in affected alerting areas. Utilising groups is a social media recruitment strategy that can reach potential participants effectively; invitations through existing groups can be thematically suited for planned surveys [47].

A Magnitude 5.3 earthquake occurred on October 12, 2021, 80 km north of the French Pass in New Zealand. The deep earthquake (depth at 150 km) meant that shaking was felt widely across the central part of New Zealand. 17,552 people reported they felt the earthquake on the GeoNet platform.[2] The AEA system also sent a ‘Be Aware’ alert, so the pre-prepared questionnaire was distributed online soon after the event for data collection. A total of 524 responses from the 12 October event survey were useable for SEM analysis. Of the 524 responses, 500 answered the question regarding the source of the alert.

Another earthquake event occurred on October 22, 2021. The Magnitude 5.9 earthquake was located 30 km southwest of Taumarunui. It was another deep earthquake at 210 km depth, this time more widely felt throughout New Zealand, with 24,738 reporting they felt the earthquake via GeoNet.[3] An AEA ‘Be Aware’ alert was also sent out for this event. We gathered data from this earthquake event through a separate, event-specific online questionnaire. A total of 671 responses from the 22 October event survey were useable for SEM analysis. Out of the 671 responses, 619 responded to the question regarding the source of the alert.

3.2.1. Participants

Of the 524 respondents from the 12 October survey, 59% identified as women and 35% as men, 2.6% as non-binary or gender fluid, and 2.7% declined or did not answer. Of the 524 respondents, 1.1% did not answer the question on age, but of those who responded, the median age was 33.4 years. Fig. 4 shows the age distribution of the 12 October survey respondents. Respondents could select multiple options for ethnicity; 58.4% selected New Zealand European, 34.9% New Zealander, 7.4% as Māori, 6.5% Asian, 1.7% Pacific Islander, and 11% other.

Of the 671 respondents from the 22 October survey, 73.3% identified as women, 24.4% as men, 0.5% identified as non-binary or gender fluid, and 1.5% declined to answer. Of the 671 respondents, 0.3% did not provide their age, but of those who responded, the median age was 39.1 years. Fig. 5 shows the age distribution of the 22 October survey respondents. Respondents could select multiple options for ethnicity; 52.9% selected New Zealand European, 46.7% New Zealander, 12% as Māori, 2.5% Asian, 1% Pacific Islander, and 7% other.

Like other online studies that primarily use social media for recruitment, our study's participants' demographic characteristics may not perfectly mirror those of the broader study population. In both of our samples, there is an overrepresentation of women, while the representation of Māori individuals is lower than the national average of 17% [48]. Additionally, the median age (33.4 years) of respondents from the 12 October survey is younger than the national median age of 36.7 years. In contrast, the median age (39.1 years) of respondents from the 22 October survey is slightly older.

[2] https://www.geonet.org.nz/earthquake/2021p767783.
[3] https://www.geonet.org.nz/earthquake/2021p794366.

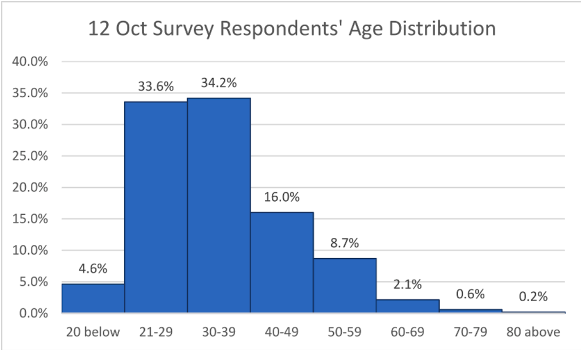

Fig. 4. Respondents' age distribution -- from the 12 October survey.

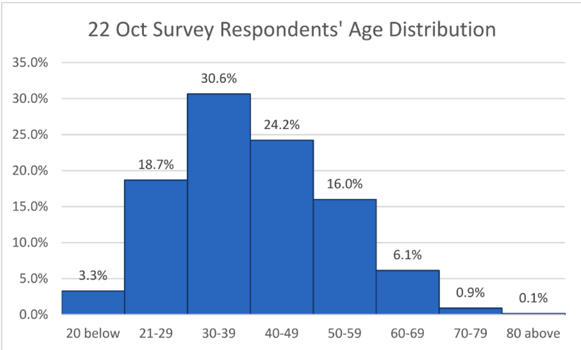

Fig. 5. Respondents' age distribution – from the 22 October survey.

While it's crucial to acknowledge the inherent limitation of representativeness in our data, it's essential to consider that the novelty of EEW alerts in New Zealand introduces unique data collection challenges. As the alerting service was new during the data collection period, the actual population of users, which was unknown, could have demographic characteristics different from those of the wider New Zealand population. The value of this study lies in the ability to gain insights from this data collection approach for understanding user perceptions of a new EEW service. In this context, the benefits of rapidly gathering responses through online recruitment outweigh the limitations. In future research, more representative sampling methods could be employed. However, these often come with increased costs and longer time requirements, which may compromise the data's timeliness and reliability.

3.3. Data analysis

The datasets from the 12 October and 22 October events were analysed separately using SEM via EQS version 6.4. Specifically, a maximum likelihood method with robust methods corrections were performed for both datasets. The endogenous factors were continuance intention, satisfaction, perceived usefulness, and perceived trust. Model identification was not a concern since $p^* = 210$ (based on 20 variables) exceeded $q = 45$ (based on 20 equations and 25 variances) [49]. The goodness-of-fit indicators are the Comparative Fit Index (CFI) and the Root Mean-Square Error of Approximation (RMSEA) [49].

We also looked at the results for respondents' perception of the source of the alert. We conducted mean comparisons using one-way analysis of variance (ANOVA) to determine whether the source perception to determine whether key factors (perceived trust and continuance intention) varied between perceived message sources. Although separate entities, GeoNet and GNS Science have overlapping activities and responsibilities as GeoNet sits within GNS Science; they are officially responsible for monitoring geohazards in New Zealand [41,42]. To simplify the analysis, we have combined the data from these two groups into one 'GeoNet/GNS' group. To be confident with this decision, we further conducted independent samples *t*-tests; results showed no significant differences in the continuance intention and perceived trust of participants between those who perceived GeoNet and GNS Science as the source of the alert (See Table 2). As such, GeoNet and GNS Science were combined into one GeoNet/GNS group for the ANOVA.

4. Results

This research aimed to investigate the factors influencing the continuance intention of the New Zealand public towards the newly introduced AEA warning system. SEM was conducted to analyse both datasets collected from the 12 October and 22 October earthquakes, respectively, to gain insights. Results from both datasets are shown below. To investigate the respondents' perception of trust, we also provide descriptive results on who the respondents thought was responsible for issuing out the alert and inferential testing of differences in perceived trust and continuance intention between perceived message sources.

Table 2
Independent Samples t-tests Results.

	12 October			22 October		
	GeoNet (*N* = 150)	GNS Science (*N* = 51)	*t*	GeoNet (*N* = 214)	GNS Science (*N* = 61)	*t*
	M (SD)	M (SD)		M (SD)	M (SD)	
Continuance Intention	6.42 (0.86)	6.45 (0.72)	0.82	6.31 (0.98)	6.39 (0.79)	0.58
Perceived Trust	5.65 (1.09)	5.69 (0.93)	0.85	5.76 (1.15)	5.71 (0.91)	0.74

4.1. Results from 12 October datsaset

Fig. 6 shows the standardised path coefficients for each path in the model, the standardised coefficients, and the fit indices for the 12 October dataset.

The model had a CFI value of 0.93 and an RMSEA value of 0.06, indicating a good model fit, and overall explained approximately 39% of the variance in continuance intention. The results from the 12 October dataset fully support the hypotheses raised. The results confirmed H1 [a], H2 [a], and H3 [a], that satisfaction, perceived usefulness, and perceived trust all had significant direct effects on continuance intention. Perceived usefulness had the strongest effect, with a coefficient of 0.41. In comparison, satisfaction and perceived trust had lower but still significant effects at coefficients of 0.19 and 0.15, respectively. The results also supported the hypotheses regarding the indirect effects of the factors on each other. For H4 [a], perceived usefulness had a significant positive effect on satisfaction, positively affecting continuance intention. Similarly, significant positive results were also observed with the relationships between confirmation and satisfaction (H5 [a]), perceived trust and satisfaction (H6 [a]), confirmation and perceived usefulness (H7 [a]), and confirmation and perceived trust (H8 [a]).

The results from the 12 October dataset support all eight hypotheses. The results for this dataset provide evidence that perceived usefulness, satisfaction, and trust significantly affect continuance intention towards the newly introduced AEA system in New Zealand.

4.2. Results from 22 October dataset

The same SEM analysis was conducted on the 22 October dataset. Fig. 7 displays the standardised path coefficients for each path in the model, the standardised coefficients, and the fit indices for the 22 October dataset. The results are generally similar between the two datasets, but there are notable differences in the role of satisfaction in the model.

The confirmatory factor indices for the second dataset were consistent with a good model fit, with a CFI of 0.94 and an RMSEA of 0.05, and approximately 26% of the variance in continuance intention explained. This dataset's path coefficient between satisfaction and continuance intention was insignificant (H1 [b]), perhaps contributing to the lower proportion of variance in continuance intention explained in this model compared to the former. The results for the 22 October dataset also indicate no significant relationship between perceived trust and satisfaction (H6 [b]), in contrast to the results from the 12 October dataset, where a significant positive relationship was found. The results suggest that the relationship between satisfaction and continuance intention, and the role of perceived trust to satisfaction, varies across the contexts of the two datasets.

The remaining six of the eight hypotheses are supported for the 22 October dataset. The results demonstrated that perceived usefulness and perceived trust significantly influence continuance intention in the same direction as the 12 October dataset (H2 [b] and H3 [b]). Similarly, perceived usefulness also had significant direct effects on satisfaction (H4 [b]) and continuance intention (H5 [b]). H7 [b] and H8 [b] exhibited a significant positive direct effect of confirmation on perceived usefulness and trust, respectively.

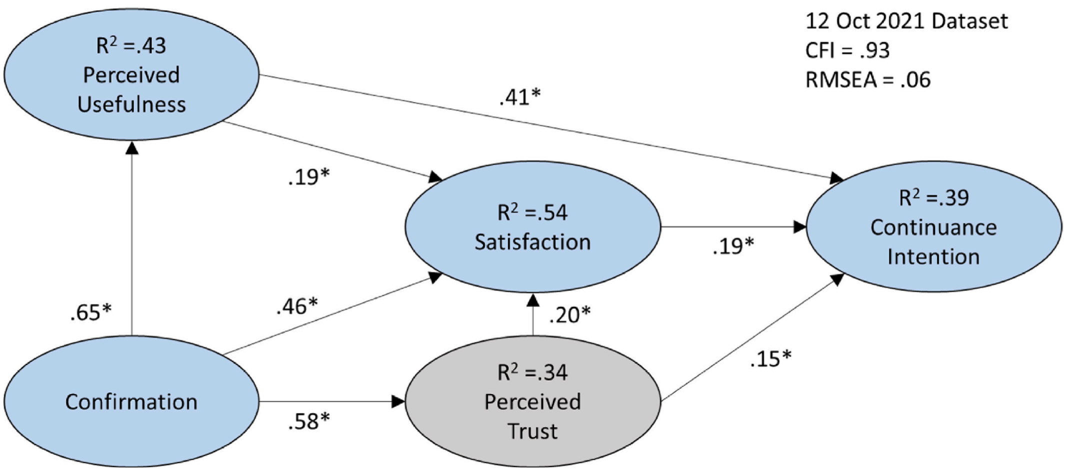

Fig. 6. Results from the October 12, 2021 dataset.

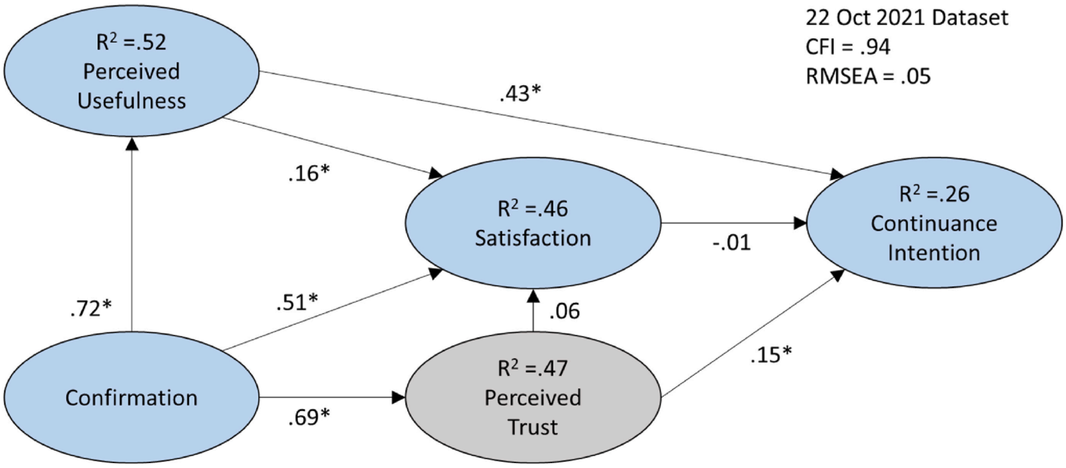

Fig. 7. Results from the 22 October dataset.

Overall, the results from both datasets suggest that satisfaction, perceived usefulness, and perceived trust are important factors that influence continuance intention. However, the role of satisfaction varied across the models from the two datasets.

4.3. Source of the alert

Across the two samples, as illustrated by Fig. 8, GeoNet/GNS Science, Google, and NEMA were the top responses for who the respondents thought issued the alerts. For the 12 October dataset, almost equal numbers thought the alert came from GeoNet/GNS Science and Google (40% of respondents each), while the remaining 20% thought NEMA issued the alert. For the 22 October dataset, the largest proportion of the respondents (44%) thought that the source of the alert was GeoNet/GNS Science. Only 34% of respondents to the second survey correctly identified that the alert was from Google, notably a lower percentage compared to the previous earthquake alert event. Twenty-one per cent of the 22 October dataset respondents thought the alert came from NEMA. None of the respondents chose local civil defence groups or others as their answers. These results show that, in both datasets, less than half of the respondents identified the correct alert source. It also shows that most respondents associate the alert with official alerting agencies (GeoNet/GNS Science or NEMA).

Mean comparisons using these groupings were conducted using one-way ANOVA for both datasets, particularly the respondents' answers to continuance intention and perceived trust questions. There was no significant difference in the average score for continuance intention and perceived trust for the 12 October dataset (See Table 3). For the 22 October dataset, there was also no significant difference in perceived trust (See Table 4). However, results showed that there were significant differences in continuance intention. Post-hoc analyses using the Games-Howell procedure showed significant pairwise differences between the groups (See Table 5). These results show that the respondents had similar levels of perceived trust in the EEW system, regardless of their perception of the

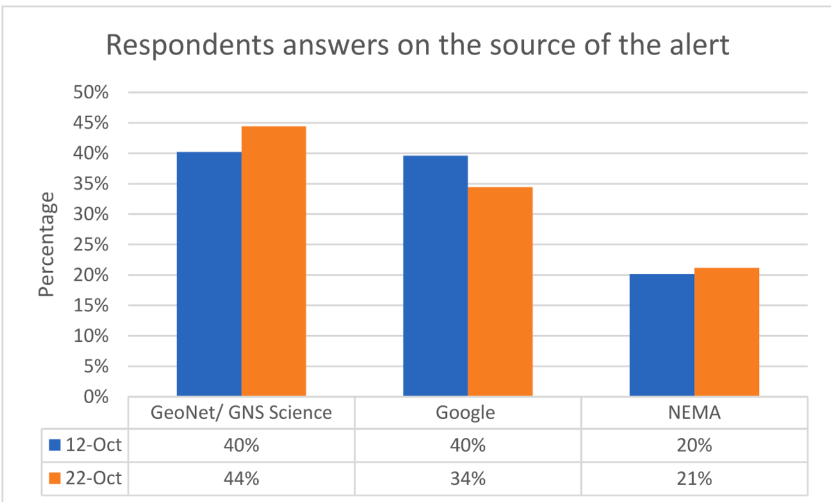

Fig. 8. Source respondents thought responsible for the alerts.

Table 3
ANOVA results for the 12 October dataset.

	GeoNet/GNS Science ($N = 201$)	Google Alert ($N = 198$)	NEMA ($N = 101$)	
	M (SD)	*M (SD)*	*M (SD)*	*F*
Continuance Intention	6.42 (0.82)	6.43 (0.71)	6.30 (0.80)	1.03
Perceived Trust	5.66 (1.05)	5.57 (1.04)	5.62 (1.08)	0.41

Table 4
ANOVA results for the 22 October dataset.

	GeoNet/GNS Science ($N = 275$)	Google Alert ($N = 213$)	NEMA ($N = 131$)	
	M (SD)	*M (SD)*	*M (SD)*	*F*
Continuance Intention	6.33 (0.94)	6.51 (0.66)	6.27 (1.01)	3.77*
Perceived Trust	5.75 (1.10)	5.63 (0.96)	5.73 (0.99)	0.90

Note. * = $p < .05$.

Table 5
Post-hoc analysis of continuance intention of the 22 October dataset.

Agency 1	Agency 2	Mean Difference	95% Confidence Interval of the Difference
GeoNet/GNS Science	Google Alert	−0.17587*	−0.35, −0.01
GeoNet/GNS Science	NEMA	0.06282	−0.19, 0.31
Google Alert	NEMA	-0.23869*	0.00, 0.47

source of the alert. However, continuance intention was higher if the perceived source of the alert was Google Alert compared to GeoNet/GNS Science and NEMA.

5. Discussion

This study aimed to examine the applicability of continuance intention in the EEW context, specifically investigating factors influencing the continuance intention of the New Zealand public towards the newly introduced AEA system. Analysis of the two datasets from the 12 October and 22 October earthquakes revealed that the continuance model applies to some extent, especially to the significance of perceived usefulness and perceived trust to continuance intention. However, the results from the two datasets showed varying results for satisfaction's relationship with perceived trust and continuance intention. In this section, we delve further into the insights from the findings.

5.1. Satisfaction and perceived trust in EEW systems

All eight hypotheses were supported in the 12 October dataset, confirming the direct effects of satisfaction, perceived usefulness, and perceived trust on continuance intention. The 22 October dataset yielded similar results but with some notable differences. While perceived usefulness and perceived trust continued to exert significant direct effects on continuance intention, the relationship between satisfaction and continuance intention was found to be non-significant. Additionally, the relationship between perceived trust and satisfaction differed between the two datasets, with a significant positive relationship observed in the 12 October dataset and no significant relationship in the 22 October dataset.

These results suggest further investigation is needed to understand the role of satisfaction and perceived trust. In the subsections below, we discuss some potential reasons for the non-significance of satisfaction, such as contextual factors and context applicability. We also discuss the importance of prioritising trust-building efforts, including addressing perceptions of alert sources.

5.1.1. Potential contextual factors influencing satisfaction

It is important to consider the context of data collection to understand possible reasons for the different results on satisfaction from the two datasets. As expected, the recency of events between the 12 and 22 October earthquakes may have shaped participants' perceptions and attitudes towards the AEA system.

In the first dataset (12 October event), the respondents may have experienced the AEA for the first time or have been a few months since receiving an alert. Before the 12 October event, the last widely felt earthquake with a record of AEA being sent out was in early August 2021. The novel experience might have influenced their responses. In contrast, during the 22 October earthquake, some participants may have received the EEW alert just ten days before. The 12 October event and AEA system were also reported in national media outlets in New Zealand (e.g. Refs. [50,51]).

This repeated exposure to the system might have influenced attitudes differently for the data collection after the 22 October event. Recent experience or knowledge may have led to the non-significant relationship between perceived trust and satisfaction, and satisfaction and continuance intention. These findings suggest that the relationships between satisfaction, perceived trust, and continuance intention can be context-dependent on the recency of events. Further research is needed to understand the mechanisms of these relationships fully and to explore other potential contextual factors that may have contributed to the variation of the results.

5.1.2. Applicability of satisfaction as a determinant for EEW continuance intention

The lack of significance of satisfaction as a factor in the model may be attributed to the specific nature of the technology under study and the applicability of the factor in the model. Recent research has raised doubts about the suitability of satisfaction as a determinant of users' intentions to continue using disaster-related technologies, including EEW systems [17]. This study's results support this notion, as satisfaction did not exhibit a significant relationship with continuance intention in the second dataset. EEW systems are primarily designed to provide timely and reliable alerts for impending ground shaking, prioritising the promptness of warnings over delivering a satisfying or pleasurable user experience.

Although satisfaction did not significantly impact continuance intention in the second dataset, its inclusion in the model allowed for a comparative analysis of its influence alongside other factors. The findings indicate that respondents' perceptions of usefulness and trustworthiness consistently influence continuance intention more than satisfaction. These insights suggest that future research should delve deeper into understanding the roles of usefulness and trustworthiness and explore alternative determinants that better capture the unique characteristics of crisis technologies.

5.1.3. Building trust in EEW systems

The results of this study have demonstrated that perceived trust is a significant factor influencing respondents' intention to continue using the AEA system. This finding highlights the importance of prioritising trust-building efforts in the context of EEW systems. Consistent with previous research on warning technologies, trust has been identified as a critical factor for user acceptance and engagement [52,53]. In particular, studies on EEW systems have emphasised the need to establish trust holistically in both the warning messages and the sources delivering those messages [20].

Interestingly, the results from this study indicate that trust levels do not vary significantly depending on the perceived source of the alerts. Most respondents across both datasets believed the alerts originated from official agencies such as NEMA, GeoNet, and GNS Science. This finding suggests the New Zealand public generally trusts warning information regardless of source. However, it also raises concerns regarding potential confusion about broadcast warning messages, especially if the public does not differentiate the source. This finding highlights the potential inclination of the population to have high trust in broadcast messages. A study on wireless emergency alerts (WEA) in the US also showed conflation of WEA messages, and despite the lack of public understanding of the message classification and options of the WEA, a substantial proportion of respondents trust the WEA [54].

Trust in official information is crucial for effective disaster response. However, if users experience incorrect, false, or missed alerts from the EEW system, their trust in the warning messages and sources may be compromised. This mistrust might develop for EEW and other critical alerts during crises and disasters. Trust in the source is not solely about reliability but also relies on the absence of mistrust [55]. This is an important question to consider, given the large number of participants who thought the alert came from official agencies. If the public loses trust in the alert system following incorrect alerts, they may also lose trust in the *perceived* source. Follow-up communication is critical, especially for missed and false alerts [32]; developed post-alert messaging for ShakeAlert for different alert scenarios to help engender trust. It is critical that in times of crisis, such as an earthquake, the public has trust in their official geoscience and emergency management agencies. Therefore, false or missed alerts from the AEA system could have the unintended impact of jeopardising trust in and adherence to official information. Furthermore, legal and ethical implications can arise when warning systems are operated by multiple organisations, particularly when errors occur. Questions surrounding responsibility and liability become increasingly important in such scenarios, especially for EEW.

5.1.4. Continuance intention based on the perception of the alert source

The results from the study showed that respondents' continuance intention differs based on their perception of the source of the alert. The respondents were likelier to not opt out of the AEA if they perceived that the alert came from Google. Note that 40% and 34% of respondents correctly identified Google as the alert source. Their increased likelihood for continuance intention may be tied to their knowledge of the service. However, further research is required to confirm the role of prior knowledge or experience in continuance intention. This finding highlighted that perception of the alert's source might influence the AEA system's continuance intention.

5.2. Practical implications

Results from the study have practical implications for designing and implementing public-facing EEW systems. First, satisfaction is not a strong determinant factor for continuance intention. Hence, more emphasis should be put on enhancing perceived usefulness and trustworthiness. Instead, the study's results highlight the importance of focusing on perceived usefulness and perceived trust when designing and implementing EEW systems. EEW developers and policymakers behind warnings should focus on the system's reliability and how the system will be used and trusted by the public. This could mean ensuring consistent performance of the system through accuracy and reliability, and clear and transparent communication about the system, its functioning, maintenance, and who is responsible for issuing alerts. The study findings complement EEW studies that have emphasised the importance of trust (e.g. Refs. [20,56]) and the challenges of overreliance on EEW systems without fully understanding their limitations [57,58].

Second, contextual factors affect continuance intention. There is a need for EEW systems to address the changes in contexts and to maintain trust and engagement. The study highlighted other factors outside the model, such as the recency of events and perception of the source of the alert, which may influence satisfaction and continuance intention. This suggests the need for EEW systems to adapt to varying contexts and user expectations. As EEW is developed and implemented, responsible parties should consider the contextual dynamic, such as the frequency of alerts, recent earthquake events, and users' familiarity with the system. Monitoring and evaluating user perceptions is essential to identify any changes and make necessary adjustments to maintain trust and engagement.

Finally, the findings showed potential confusion with the perception of the source of the alert. This underscores the importance of effective communication strategies to ensure clear and consistent messaging. The study reiterates findings from social science studies conducted on EEW in New Zealand and across the globe on the importance of coordination and public education (e.g. Refs. [59,60]. Coordination between agencies and organisations responsible for issuing alerts is a must-have and, therefore, crucial to avoid conflicting or contradictory information. Clear guidelines and protocols should be established to address potential issues related to alert messaging, sources, and responsibilities. Public awareness campaigns should play a significant role in educating the public about the EEW system, its sources, types of alerting, and the appropriate protective actions when receiving EEW alerts [59–61].

The study highlights that respondents were confused regarding the source of the alert, which may lead to potential legal and ethical implications. It also raises future questions regarding the responsibility and liability associated with EEW systems. This is aligned with ongoing considerations between necessity and legal responsibility for territories with or developing EEW systems [61]. A review of socio-organisational components of EEW by Ref. [62] highlighted gaps in accountability and liability policies in EEW implementation. Politics and governance can come into play, especially in addressing the liability of releasing warnings and resolving conflict between various EEW players in the public and private sectors [22]. Stakeholders involved in the development and operation of EEW systems should carefully consider legal frameworks, liability issues, and ethical guidelines to ensure accountability and minimise potential risks. Collaboration between public agencies, private organisations, and legal experts can help navigate these complexities and ensure EEW systems' effective and responsible operation. It is essential for public-facing EEW systems to address potential errors to establish mechanisms to handle such situations (e.g. Ref. [32]).

5.3. Limitations and future directions

Despite the valuable insights gained from this study, several limitations must be acknowledged. Firstly, the study focused on examining the continuance intention of the New Zealand public towards the AEA system in the aftermath of two specific earthquakes. Longitudinal studies can also be conducted to track users' perceptions and intentions as they become more accustomed to the AEA system. The findings provide insight into user perception of the first publicly accessible EEW system in New Zealand but may be hard to generalise for EEW more broadly. Furthermore, as EEW technologies evolve and user adoption and familiarity increase, the factors influencing continuance intention may change over time. Future studies could consider longitudinal research designs that span multiple earthquake events to assess the stability and generalisability of the findings over time.

Secondly, the study focused on individual-level factors influencing continuance intention, such as confirmation, satisfaction, usefulness, and trust. Socio-cultural factors may also influence the continuance intention of EEW systems; these are not accounted for in the model. Future research could investigate socio-cultural factors such as social norms and risk conceptualisations. Several studies have looked at various factors such as dominant response and social norms for responding to alerts (e.g. Refs. [59,63]) or understanding end-users from a risk-based perspective (e.g. Refs. [64–66]); similarly, these concepts could also be investigated for their roles in technology adoption and continuance intention of EEW. Further exploration of user acceptance and continuance intention between different social or cultural contexts is also needed.

Lastly, the study relied on self-reported data collected through online surveys, which may introduce response biases and limitations in the generalisability of the responses. Future research could consider incorporating alternative data sources to investigate EEW perceptions further, including data from EEW providers, social media, and interviews or focus group discussions with the public.

Overall, while this study provides valuable insights into the factors influencing the continuance intention of the New Zealand public towards the AEA system, it is important to recognise and address the limitations outlined above. By acknowledging these limitations and conducting further research, we can advance our understanding of user acceptance and engagement with EEW systems and contribute to their continuous improvement and effectiveness in mitigating the impact of earthquakes on individuals and communities.

6. Conclusion

This study aimed to understand the continuance intention of the New Zealand public towards the newly introduced AEA system. The results revealed that perceived usefulness and perceived trust had significant direct effects on continuance intention, highlighting their importance in shaping user behaviour towards EEW. However, the relationship between satisfaction and continuance intention was found to be non-significant for the 22 October dataset, suggesting that satisfaction may not be a strong determinant in the context of EEW systems. This finding challenges the traditional perspective that satisfaction plays a central role in the continuance intention of technological products and services. This highlights that hedonic factors like satisfaction may not be appropriate for technologies in warning and crisis environments.

Furthermore, the study findings indicated contextual factors that may influence the relationship between satisfaction, perceived trust, and continuance intention. The participants' experience and knowledge of the AEA system and the recency of earthquake events may impact their perceptions. These findings underscore the need for further investigation into the role of satisfaction and perceived trust, considering the evolving nature of EEW technologies and users' familiarity over time.

Perceived trust emerged as a critical factor influencing continuance intention, emphasising the importance of trust-building efforts in EEW systems. Clear and reliable communication channels, coupled with trust in both the warning messages and the sources delivering those messages, are crucial for effective disaster response and public acceptance of EEW systems. The study also raised concerns about potential confusion from multiple sources and opportunities to address responsibility and liability for organisations designing and implementing public EEW systems.

Overall, this study contributes to understanding continuance intention in the EEW context and provides insights into the public's perception of the AEA system in New Zealand. The findings have implications more broadly for EEW systems' design, implementation, and communication strategies.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Marion Lara Tan reports financial support was provided by QuakeCoRE. Raj Prasanna reports financial support was provided by Toka Tū Ake EQC. Marion Lara Tan reports financial support was provided by Resilience to Nature's Challenges.

Data availability

Data will be made available on request.

Acknowledgements

This research was funded by the Toka Tū Ake EQC, New Zealand: EQC Project No 20794. Te Hiranga Rū QuakeCoRE, an Aotearoa New Zealand Tertiary Education Commission-funded Centre, partially supported this project. This is QuakeCoRE, publication number 869. This project was also supported by the Resilience to Nature's Challenges.

References

[1] GeoNet, Earthquake Statistics, 2023. https://www.geonet.org.nz/earthquake/statistics_long.

[2] J.R. Stevenson, H. Kachali, Z. Whitman, E. Seville, J. Vargo, T. Wilson, Preliminary observations of the impacts the 22 February Christchurch earthquake had on organisations and the economy: a report from the field (22 February - 22 March 2011), Bull. N. Z. Soc. Earthq. Eng. 44 (2) (2011) 65–76, https://doi.org/10.5459/bnzsee.44.2.65-76.

[3] J.R. Stevenson, J. Becker, N. Cradock-Henry, S. Johal, D. Johnston, C. Orchiston, E. Seville, Economic and social reconnaissance: kaikōura earthquake 2016, Bull. N. Z. Soc. Earthq. Eng. 50 (2) (2017) 343–351, https://doi.org/10.5459/bnzsee.50.2.343-351.

[4] J.S. Becker, S.H. Potter, R. Prasanna, M.L. Tan, B.A. Payne, C. Holden, N. Horspool, R. Smith, D.M. Johnston, Scoping the potential for earthquake early warning in Aotearoa New Zealand: a sectoral analysis of perceived benefits and challenges, Int. J. Disaster Risk Reduc. 51 (2020) 1–16, https://doi.org/10.1017/CBO9781107415324.004.

[5] J.S. Becker, L.J. Vinnell, S.K. Mcbride, K. Nakayachi, E.E.H. Doyle, S.H. Potter, A. Bostrom, The effects of earthquake experience on intentions to respond to earthquake early warnings, Frontiers in Communication 7 (2022) 1–14, https://doi.org/10.3389/fcomm.2022.857004.

[6] R. Prasanna, C. Chandrakumar, R. Nandana, C. Holden, A. Punchihewa, J.S. Becker, S. Jeong, N. Liyanage, D. Ravishan, R. Sampath, M.L. Tan, "Saving precious seconds"— a novel approach to implementing a low-cost earthquake early warning system with node-level detection and alert generation, Informatics 9 (25) (2022) 1–32, https://doi.org/10.3390/informatics9010025.

[7] C.A. Cardno, Android phones now offer earthquake detection, alerts, Civil Engineering Magazine Archive 90 (10) (2020) 34–36, https://doi.org/10.1061/ciegag.0001543.

[8] A. Tripathy-Lang, From ShakeAlert to smartphones: earthquake early warning now and beyond, in: Temblor, 2022, https://doi.org/10.32858/temblor.290.

[9] P. Voosen, New Google effort uses cellphones to detect earthquakes, Science (2021), https://doi.org/10.1126/science.abj2298.

[10] S. Akter, P. Ray, J. D'Ambra, Continuance of mHealth services at the bottom of the pyramid: the roles of service quality and trust, Electron. Mark. 23 (1) (2013) 29–47, https://doi.org/10.1007/s12525-012-0091-5.

[11] A. Bhattacherjee, Understanding information systems continuance: an expectation-confirmation model, MIS Q. 25 (3) (2001) 351–370.

[12] M.L. Tan, R. Prasanna, K. Stock, E.E.H. Doyle, G. Leonard, D. Johnston, Usability factors influencing the continuance intention of disaster apps: a mixed-methods study, Int. J. Disaster Risk Reduc. 50 (2020) 1–12, https://doi.org/10.1016/j.ijdrr.2020.101874.

[13] S. Halilovic, M. Cicic, Antecedents of information systems user behaviour-extended expectation-confirmation model, Behav. Inf. Technol. 32 (4) (2013) 359–370, https://doi.org/10.1080/0144929X.2011.554575.

[14] B. Nascimento, T. Oliveira, C. Tam, Wearable technology: what explains continuance intention in smartwatches? J. Retailing Consum. Serv. 43 (July) (2018) 157–169, https://doi.org/10.1016/j.jretconser.2018.03.017.

[15] A.P. Oghuma, C.F. Libaque-Saenz, S.F. Wong, Y. Chang, An expectation-confirmation model of continuance intention to use mobile instant messaging, Telematics Inf. 33 (1) (2016) 34–47, https://doi.org/10.1016/j.tele.2015.05.006.

[16] K.H. Kim, K.J. Kim, D.H. Lee, M.G. Kim, Identification of critical quality dimensions for continuance intention in mHealth services: case study of onecare service, Int. J. Inf. Manag. 46 (December 2018) (2019) 187–197, https://doi.org/10.1016/j.ijinfomgt.2018.12.008.

[17] D. Fischer-Preßler, D. Bonaretti, K. Fischbach, A protection-motivation perspective to explain intention to use and continue to use mobile warning systems, Business and Information Systems Engineering 64 (2) (2022) 167–182, https://doi.org/10.1007/s12599-021-00704-0.

[18] S.E. Minson, M.A. Meier, A.S. Baltay, T.C. Hanks, E.S. Cochran, The limits of earthquake early warning: timeliness of ground motion estimates, Sci. Adv. 4 (3) (2018) 1–11, https://doi.org/10.1126/sciadv.aaq0504.

[19] K. Nakayachi, J.S. Becker, S.H. Potter, M. Dixon, Residents' reactions to earthquake early warnings in Japan, Risk Anal. 39 (8) (2019) 1723–1740, https://doi.org/10.1111/risa.13306.

[20] A. Bostrom, S.K. McBride, J.S. Becker, J.D. Goltz, R.-M. de Groot, L. Peek, B. Terbush, Maximilian Dixon, Great expectations for earthquake early warnings on the United States West Coast, Int. J. Disaster Risk Reduc. 82 (September) (2022) 103296, https://doi.org/10.1016/j.ijdrr.2022.103296.

[21] M.L. Tan, J.S. Becker, K. Stock, R. Prasanna, A. Brown, C. Kenney, A. Cui, E. Lambie, Understanding the social aspects of earthquake early warning : a literature review, Frontiers in Communication (2022) 1–17.

[22] G. Pescaroli, O. Velazquez, I. Alcántara-Ayala, C. Galasso, Integrating earthquake early warnings into business continuity and organisational resilience: lessons learned from Mexico City, Disasters 47 (2) (2023) 320–345, https://doi.org/10.1111/disa.12551.

[23] Y. Fujinawa, Y. Noda, Japan's earthquake early warning system on 11 March 2011: performance, shortcomings, and changes, Earthq. Spectra 29 (2013) 3–25, https://doi.org/10.1193/1.4000127.

[24] B.R. Wu, N.C. Hsiao, P.Y. Lin, T.Y. Hsu, C.Y. Chen, S.K. Huang, H.W. Chiang, An integrated earthquake early warning system and its performance at schools in Taiwan, J. Seismol. 21 (1) (2017) 165–180, https://doi.org/10.1007/s10950-016-9595-3.

[25] Google. (n.d.). Android early earthquake warnings: How Andriod Earthquake Alerts System work. Crisis Response Google. Retrieved May 25, 2023, from https://crisisresponse.google/android-alerts/.

[26] A. Bhattacherjee, C.P. Lin, A unified model of IT continuance: three complementary perspectives and crossover effects, Eur. J. Inf. Syst. 24 (4) (2015) 364–373, https://doi.org/10.1057/ejis.2013.36.

[27] A. Ortiz de Guinea, M.L. Markus, Why break the habit of a lifetime? Rethinking the roles of intention, habit, and emotion in continuing information technology use, MIS Q. 33 (3) (2009) 433–444.

[28] R. Prasanna, T.J. Huggins, Factors affecting the acceptance of information systems supporting emergency operations centres, Comput. Hum. Behav. 57 (2015) 168–181. https://doi.org/10.1016/j.chb.2015.12.013.

[29] K. Anil Kumar, S. Natarajan, An extension of the Expectation Confirmation Model (ECM) to study continuance behavior in using e-Health services, Innovat. Market. 16 (2) (2020) 15–28, https://doi.org/10.21511/im.16(2).2020.02.

[30] A.W. Dhia, M.N. Kholid, Explaining E-wallet continuance intention: a modified expectation confirmation model, Jurnal Minds: Manajemen Ide Dan Inspirasi 8 (2) (2021) 287, https://doi.org/10.24252/minds.v8i2.23592.

[31] G. Wachinger, O. Renn, C. Begg, C. Kuhlicke, The risk perception paradox-implications for governance and communication of natural hazards, Risk Anal. 33 (6) (2013) 1049–1065, https://doi.org/10.1111/j.1539-6924.2012.01942.x.

[32] S.K. McBride, A. Bostrom, J. Sutton, R.M. de Groot, A.S. Baltay, B. Terbush, P. Bodin, M. Dixon, E. Holland, R. Arba, P. Laustsen, S. Liu, M. Vinci, Developing post-alert messaging for ShakeAlert, the earthquake early warning system for the West Coast of the United States of America, Int. J. Disaster Risk Reduc. 50 (June) (2020) 101713, https://doi.org/10.1016/j.ijdrr.2020.101713.

[33] C. Garcia, C.J. Fearnley, Evaluating critical links in early warning systems for natural hazards, Environ. Hazards 11 (2) (2012) 123–137, https://doi.org/10.1080/17477891.2011.609877.

[34] R.M. Stokoe, Putting people at the centre of tornado warnings: how perception analysis can cut fatalities, Int. J. Disaster Risk Reduc. 17 (2016) 137–153, https://doi.org/10.1016/j.ijdrr.2016.04.004.

[35] A. Giovanis, C. Assimakopoulos, C. Sarmaniotis, Adoption of mobile self-service retail banking technologies, Int. J. Retail Distrib. Manag. 47 (9) (2018) 894–914, https://doi.org/10.1108/IJRDM-05-2018-0089.

[36] R.M. Morgan, S.D. Hunt, The Commitment-Trust Theory of relationship marketing, J. Market. 58 (3) (1994) 20, https://doi.org/10.2307/1252308.

[37] G. Do Nguyen, M.T. Ha, The role of user adaptation and trust in understanding continuance intention towards mobile shopping: an extended expectation-confirmation model, Cogent Business and Management 8 (1) (2021), https://doi.org/10.1080/23311975.2021.1980248.

[38] A.I. Chung, M.A. Meier, J. Andrews, M. Böse, B.W. Crowell, J.J. McGuire, D.E. Smith, ShakeAlert earthquake early warning system performance during the 2019 Ridgecrest earthquake sequence, Bull. Seismol. Soc. Am. 110 (4) (2020) 1904–1923, https://doi.org/10.1785/0120200032.

[39] J.K. Saunders, B.T. Aagaard, A.S. Baltay, S.E. Minson, Optimizing earthquake early warning alert distance strategies using the July 2019 Mw 6.4 and Mw 7.1 Ridgecrest, California, earthquakes, Bull. Seismol. Soc. Am. 110 (4) (2020) 1872–1886, https://doi.org/10.1785/0120200022.

[40] R.M. Allen, M. Stogaitis, Global growth of earthquake early warning, Science 375 (6582) (2022) 717–718, https://doi.org/10.1126/science.abl5435.

[41] K.C. Wright, G.S. Leonard, A. Beatson, R. O'Sullivan, M.A. Coomer, B. Morris, D. Freire, Public alerting options assessment: 2014 update, vol. 66, in: GNS Science Report, GNS Science, 2014 Issue October.

[42] T. Goded, M.L. Tan, J.S. Becker, N. Horspool, R. Huso, J. Hanson, D.M. Johnston, Using citizen data to understand earthquake impacts: Aotearoa New Zealand's earthquake Felt Reports, Australas. J. Disaster Trauma Stud. 25 (3) (2021) 61–78.

[43] A. Dhellemmes, G.S. Leonard, D.M. Johnston, L.J. Vinnell, J.S. Becker, S.A. Fraser, D. Paton, Tsunami awareness and preparedness in Aotearoa New Zealand: the evolution of community understanding, Int. J. Disaster Risk Reduc. 65 (2021) 102576, https://doi.org/10.1016/j.ijdrr.2021.102576.

[44] M.L. Tan, R. Prasanna, K. Stock, E. Hudson-Doyle, G. Leonard, D. Johnston, Enhancing the usability of a disaster app: exploring the perspectives of the public as users, in: Z. Franco, J.J. Gonzalez, J.H. Canos (Eds.), Proceedings of the 16th International Conference on Information Systems for Crisis Response and Management (ISCRAM), s. 2019-May, 2019, pp. 876–886.

[45] T. Webler, M. Holewinski, B. Orrick, R. Kaur, Toward a method for the rapid collection of public concerns and benefits of emerging energy technologies, J. Risk Res. 23 (1) (2020) 35–46, https://doi.org/10.1080/13669877.2018.1485174.

[46] D.B. King, N. O'Rourke, A. De Longis, Social media recruitment and online data collection: a beginner's guide and best practices for accessing low-prevalence and hard-to-reach populations, Can. Psychol. 55 (4) (2014) 240–249, https://doi.org/10.1037/a0038087.

[47] Z. Zindel, Social media recruitment in online survey research: a systematic literature review, Methods, Data, Analyses (2022) 42, https://doi.org/10.12758/mda.2022.15.

[48] N.Z. Stats, Māori Population Estimates: at 30 June 2021, 2021.

[49] J.F. Hair, W.C. Black, B.J. Babin, R.E. Anderson, Multivariate Data Analysis, seventh ed., Pearson Education Limited, 2014.

[50] K. Hall, Google's Earthquake Early Warning System Proves Worth in NZ, October 16, 2021 1News. 1News. https://www.1news.co.nz/2021/10/16/googles-earthquake-early-warning-system-proves-worth-in-nz/.

[51] M. Kilpatrick, Android Earthquake Early Warning System Alerted Kiwis Ahead of 5.3 Magnitude Shake, Newshub, 2021 October 12.

[52] D. Fischer, J. Putzke-Hattori, K. Fischbach, Crisis warning apps: investigating the factors influencing usage and compliance with recommendations for action, 52nd Hawaii International Conference on System Sciences 6 (2019) 639–648, https://doi.org/10.24251/hicss.2019.079.

[53] M.L. Tan, R. Prasanna, K. Stock, E.E.H. Doyle, G. Leonard, D. Johnston, Understanding end-users' perspectives: towards developing usability guidelines for disaster apps, Progress in Disaster Science 7 (2020) 100118, https://doi.org/10.1016/j.pdisas.2020.100118.

[54] H. Bean, N. Grevstad, Wireless emergency alerts: public understanding, trust, and preferences following the 2021 US nationwide test, J. Contingencies Crisis Manag. March 2022 (2022) 273–288, https://doi.org/10.1111/1468-5973.12438.

[55] D. Fischer-Pressler, D. Bonaretti, Fischbach, Effective use of mobile-enabled emergency warning systems, in: European Conference on Information Systems (ECIS), 2020, pp. 1–15 March.

[56] L. Fallou, F. Finazzi, R. Bossu, Efficacy and usefulness of an independent public earthquake early warning system: a case study—the earthquake network initiative in Peru, Seismol Res. Lett. 93 (2 A) (2022) 827–839, https://doi.org/10.1785/0220210233.

[57] Y. Nakamura, J. Saita, T. Sato, On an earthquake early warning system (EEW) and its applications, Soil Dynam. Earthq. Eng. 31 (2) (2011) 127–136, https://doi.org/10.1016/j.soildyn.2010.04.012.

[58] F. Tajima, T. Hayashida, Earthquake early warning: what does "seconds before a strong hit" mean? Prog. Earth Planet. Sci. 5 (1) (2018), https://doi.org/10.1186/s40645-018-0221-6.

[59] S.K. McBride, H. Smith, M. Morgoch, D. Sumy, M. Jenkins, L. Peek, A. Bostrom, D. Baldwin, E. Reddy, R. De Groot, J. Becker, D. Johnston, M. Wood, Evidence-based guidelines for protective actions and earthquake early warning systems, Geophysics 87 (1) (2022) WA77–WA102, https://doi.org/10.1190/geo2021-0222.1.

[60] L.J. Vinnell, M.L. Tan, R. Prasanna, J.S. Becker, Knowledge, perceptions, and behavioral responses to earthquake early warning in Aotearoa New Zealand, Frontiers in Communication (2023), https://doi.org/10.3389/fcomm.2023.1229247.

[61] C. Valbonesi, Between necessity and legal responsibility: the development of EEWS in Italy and its international framework, Front. Earth Sci. 9 (August) (2021) 1–16, https://doi.org/10.3389/feart.2021.685153.

[62] O. Velazquez, G. Pescaroli, G. Cremen, C. Galasso, A review of the technical and socio-organizational components of earthquake early warning systems, Front. Earth Sci. 8 (October) (2020) 1–19, https://doi.org/10.3389/feart.2020.533498.

[63] T.J. Huggins, L. Yang, J. Zhang, M.L. Tan, R. Prasanna, Psychological effects of dominant responses to early warning alerts, Int. J. Ambient Comput. Intell. (IJACI) 12 (3) (2021) 1–15, https://doi.org/10.4018/ijaci.2021070101.

[64] A.Y.E. Ahn, H. Takikawa, E. Maly, A. Bostrom, S. Kuriyama, H. Matsubara, T. Izumi, T. Torayashiki, F. Imamura, Perception of earthquake risks and disaster prevention awareness: a comparison of resident surveys in Sendai, Japan and Seattle, WA, USA, Int. J. Disaster Risk Reduc. 66 (September) (2021) 102624, https://doi.org/10.1016/j.ijdrr.2021.102624.

[65] G. Cremen, C. Galasso, Earthquake early warning: recent advances and perspectives, Earth Sci. Rev. 205 (2020), https://doi.org/10.1016/j.earscirev.2020.103184.

[66] G. Cremen, C. Galasso, A decision-making methodology for risk-informed earthquake early warning, Comput. Aided Civ. Infrastruct. Eng. 36 (6) (2021) 747–761, https://doi.org/10.1111/mice.12670.