The same but different: Cross-country comparison of national earthquake policies and societal perspectives of seismic risk in Israel and Switzerland

Abstract

National earthquake policies aim to mitigate earthquake risk by minimizing the potential damage to lives, property, and infrastructure and by preparing the population to carry out recommended behaviors when an earthquake is felt or a warning heard. In this research, we compare two earthquake-prone countries, Israel and Switzerland, to examine how citizens react to the national earthquake policies in terms of their perceived risk of earthquakes and their preparedness. We examine four national-level earthquake policy components—risk assessment, mitigation regulation, early warnings system, and risk communication with the public—to analyze the differences between citizens' responses in the two countries to the implementation of these policy components. We find that centralized national-level policy in Israel, which includes regulated building codes, a nationwide early warning system, and national awareness campaigns, does lead to higher levels of reported awareness and preparedness. Similarly, in high-risk cantons in Switzerland, which apply these policies (except for the warning system), citizens were also more prepared than in low-risk cantons. We suggest that earthquake policies should include collaboration with local authorities and the population through a more decentralized and localized approach, which includes drills, training, and information dissemination.

Keywords: Earthquake preparedness; seismic hazard and risk; cross-country comparison; earthquake mitigation policies; risk communication

1. Introduction

Earthquakes are considered to be a major hazard, capable of having devastating short- and long-term effects on specific areas and on entire countries. It is important to distinguish between *seismic hazard* which refers to ground-shaking/seismic waves caused by the seismic event (i.e., the earthquake itself) and earthquake risk, which is associated with the consequences of the shaking (i.e., fatalities, damage to property, economic losses, etc.). Risk management, which is reflected in mitigation, preparedness, response, and recovery policies, prioritizes actions to save lives and protect property taking into account financial constraints, public interest, distributive justice, and feasibility.

In the disaster management process, given that recovery is the costliest and lengthiest phase, efforts should be focused on damage prevention and risk mitigation. As avoiding fatalities is the most critical objective, risk mitigation efforts should include: i) the national design, implementation, and enforcement of buildings codes; ii) the retrofitting of existing buildings and infrastructure facilities; and iii) the establishment of warning systems that will save lives by increasing awareness and enhancing behavioral responses to earthquakes among individuals. Warnings also help mitigate the cascading effects of earthquakes, which are secondary hazards/emergencies that can occur after an earthquake. Warnings could, for example, lead operators of infrastructure and critical services, including railway networks, bridges, and hazardous materials plants, to reduce speed or capacity to minimize the potential harm to people and structures. As such policies are usually planned for and implemented at the national level, it can be challenging for countries to apply them at the local and the individual levels [1].

The root cause of mortality from earthquakes is collapsing buildings and falling objects. Given the impossibility of strengthening all buildings in a country, the public need to be encouraged to comply with behavioral instructions to protect themselves and their property. Research has shown that, although earthquake risk is perceived as fairly high, people tend to not take any protective action against one occurring [1]. This reflects a basic dilemma among earthquake policymakers, namely how to strike a balance between the operational mitigation actions that can and should be taken and how to harness public collaboration and compliance with instructions, and thus minimize fatalities.

To gain a better understanding of how earthquake mitigation and preparedness policies are implemented and reflected by citizens' attitudes and behaviors, we compare two earthquake-prone countries: Switzerland and Israel.[1] This cross-national comparison allowed us to identify how different policy implementations address the trade-offs between national and local level constraints and influence people's perception (of risk). Our main assertion is that earthquake mitigation and preparedness policies require the cooperation of the public. Risk mitigation activities established by policymakers should be communicated to the public by all possible means and the focus should be on designing a collaborative approach that will also incorporate the public's knowledge and capabilities. In view of the different levels of earthquake preparedness among the public at large, the main challenge is how to communicate these messages and how best to integrate the desired safety behavior into people's daily routine. Our research question is thus: how can two earthquake-prone countries—Israel and Switzerland—implement earthquake mitigation and preparedness policies and ensure that these policies are recognized and internalized by their citizens?

The comparison and analysis are as follows. **First,** we present a model of national earthquake preparedness components, which includes the three main actors: i) the federal or central government (decision-makers and policy creators); ii) the operational forces (who implement the policy and enforce it); and iii) the citizens ("end users" of the policy actions). **Second,** we compare earthquake preparedness policies and mitigation efforts in Israel and Switzerland

[1] See appendix 1 for a description of the last three major earthquakes in these two countries.

based on the model. **Third,** we compare the results of national surveys conducted in both countries to show citizens' attitudes and self-reported behaviors. **Finally,** we suggest a framework for earthquake policy analysis based on our results.

2 Materials and Methods

The comparison between the two countries, Israel and Switzerland, is based on their similar seismic hazard levels, that is, the low frequency of strong earthquakes (M>6) in the last 100 years. We applied a case study approach to obtain an in-depth appreciation of seismic risk governance [2] in the two countries—Israel and Switzerland [3]. We chose this approach because our findings should enable the principles and lessons learned to be applied to other countries, leading to transferability [3]. Appendix 2 presents country-level indicators of both countries. Although the size of the population is fairly similar (approx. 9 million citizens in each country), there are significant differences between the countries in terms of geographical size and gross domestic product (GDP). Both countries have advanced emergency response systems that provide healthcare and civil and environmental protection.

Israel's population, however, is composed of various ethnic groups and thus more culturally diverse than Switzerland. These similarities and differences are crucial and lead to challenges when citizens' ability to comply with the government policies is being considered. For example, a dynamic hazard and risk communication is needed with citizens in multilingual communities; people living in low socioeconomic settlements could need financial support to reinforce their homes. For the in-depth comparison, we analyzed official documents from the national seismological services, civil protection, and earthquake preparedness organizations. To compare the public's risk awareness, attitudes, and preparedness levels, we used insights from recent public surveys conducted in both countries [4,5]. Appendix 4 details the characteristics of each sample and descriptive statistics.

3. Theory

3.1. National earthquake preparedness components

National earthquake mitigation and preparedness policies aim to save lives, maintain operational continuity after an earthquake, and prepare the ground for the response phase by boosting first responders' knowledge, skills and training, resources, and contingency planning. Taking preventive actions to mitigate the risk before the disaster occurs and to reduce the vulnerability of places and communities is critical [6, 7] and it is also complementary to increasing preparedness capabilities to respond during the disaster.

As an earthquake has the potential to harm a large area of a country, preparedness and especially mitigation efforts should be directed by the central government through policies. The methodology that should be used to implement such policies encounters significant systemic barriers at the local level due to controversies over land use, low prioritization of preventive actions, local political constraints, and budgeting constraints [8, 9]. Further, the citizens themselves may not cooperate with these efforts being, for instance, unwilling to reinforce their private property against potential earthquakes either because they have inadequate knowledge of the structural modifications required or they lack the financial means to carry out the work [1]. The federal or central government should thus collaborate with both state and local authorities to design policies that focuses on i) the type of partnership needed (general and regulated, or more cooperative) [1]; ii) the level of freedom assigned to local authorities with respect to planning earthquake reinforcement work; and iii) the budgetary and other incentives to plan and implement planning [9]. These planning tensions are critical, as any inter-organizational lack of coordination before a disaster occurs could lead to similar and more severe reactions in the response phase [10, p. 6].

To examine these tensions and analyze current earthquake policies, we assembled four components which represent earthquake mitigation and preparedness dimensions and also incorporate the three "players" in the mitigation and preparedness domains (central, local, individual):

1. Risk assessments for locations, populations, communities;
2. Mitigation of building and infrastructure collapse risk;
3. Warnings; and
4. Hazard and risk communication with the public.

We assert that these four dimensions are key to risk mitigation efforts by governments, local and national operational forces, and citizens and that they contribute to better coping and higher levels of resilience. The four dimensions represent the interdependence of the three partners and the critical need for their collaboration. For example, risk assessment for specific areas will allow local authorities to prepare their local response efforts in a more efficient and effective manner, and provide solutions for the needs and conditions in that specific risk zone. Furthermore, consistent hazard and risk communication with the public will provide feedback to decision-makers regarding the public's awareness levels and compliance with instructions—including knowledge about how to behave safely during an earthquake and how to proceed with the process of building reinforcements. The four dimensions will serve as the basis for the comparison between Israel and Switzerland's earthquake mitigation and preparedness policies.

2.1 Seismic hazard and risk assessments

The seismic hazard and risk assessment serves as a basis for understanding which regions are (the most) affected by earthquakes [11] and for planning mitigation and preparedness actions accordingly. Earthquake risk comprises four factors: earthquake hazard, soil conditions, vulnerability, and exposure [12]. Various products (e.g., earthquake scenarios, rapid impact assessments, and risk maps) are based on the risk assessment and should be co-designed with the end-users to fulfill their specific needs [13]. The European Seismic Risk Model (released publicly in April 2022) shows that the highest risk and consequently the most severe impacts are expected in urban areas situated in regions with a high risk level [11]. Regions with only moderate seismic hazard levels can also become high-risk areas due to high vulnerability or high exposure (e.g., mountain areas for landslides, cities by the sea for tsunamis). Thus, mitigation actions should be expanded to these regions as well.

In addition to the assessment of the seismic risk, secondary hazards triggered by earthquakes should also be assessed, as these can be as dangerous as ground shaking. The most relevant secondary hazards, which differ according to region, are tsunamis, landslides, liquefaction, fire, and dam breaks [14]. The same authors showed that in the most damaging earthquakes, secondary effects caused around 40% of the economic losses and fatalities, with some events causing up to 98%. One challenge related to secondary hazards is that people are not affected equally, as local vulnerability and social factors will differ. Thus, information about possible secondary hazards should be disseminated to people living in exposed areas (e.g., vulnerable to landslides, tsunamis, etc.) together with information regarding potential earthquakes. As public surveys in New Zealand and Switzerland have shown, people do wish to receive this kind of information [15, 16].

2.2 Mitigation of buildings and infrastructure collapse risk

Earthquake-resistant building constructions offer the best protection against the consequences of an earthquake [17]. The primary goal of earthquake construction standards and codes is to prevent the collapse of buildings and hence avoid injuries and fatalities. In Europe, the Eurocode 8 has been defined according to the European Seismic Hazard Model [18]. Some countries, however, have designed their own specific earthquake-related building codes. Nevertheless, past research has found that designing and applying building codes and regulations involve political considerations which mainly focus on various stakeholder interests [19] as well as the challenge of harnessing professionals, entrepreneurs, and the community to reallocate the resources accordingly [20].

Spence [21] suggests three types of regulation mitigation policies: i) regulations for new buildings; ii) regulations for existing buildings; and (3) regulations focusing on insurance as a main mitigation and rehabilitation policy. According to [21], all three types are effective when implemented appropriately. Several constraints could adversely affect their effectiveness, however, among them: i) the need to strengthen the building codes; ii) the availability of local and regional knowhow and data to reliably assess the seismic hazards and related risks; iii) the professional capabilities and qualifications of those in the construction industry; iv) appropriate incentives for private home owners to invest in the renovation process; and v) the need to increase public awareness of the risk and to encourage public collaboration with the protection efforts. The issue of the appropriateness of the implementation of these policies is critical. Research has indicated that while earthquake regulations tend to focus on the minimum threshold needed to save the lives of those caught inside a building during a shake, less is being done to minimize economic losses something that could cause serious problems in the rehabilitation phase [22]. Close collaboration between national and local governments is also important, especially in the area of legislation and definition of standards, such as a mandatory disclosure of the risk of suffering an earthquake, as was found in an analysis after the Christchurch, New Zealand, earthquake in 2010 [22].

2.3 Earthquake early warning

Earthquake early warning (EEW) is a mechanism that makes the public aware of an upcoming earthquake, and potentially allows them to respond. There is currently no practical method of predicting the occurrence of an earthquake. It is possible, however, to issue warnings to the public that an earthquake has occurred; moreover, relatively strong ground shaking will be felt within seconds or tens of seconds, depending on the distance to the epicenter. If people are trained and know what action to take, these few seconds will allow them to take protective actions. An EEW also triggers automatic emergency systems and forces, such as the slowing-down of trains [23] and preventing vehicles from utilizing particularly high earthquake risk infrastructure such as bridges [24]. EEWs serve as a buffer between the onset of awareness to experiencing the risk in "real life". As an earthquake can occur suddenly, the first moments are critical in terms of bringing the feeling of the shaking into people's consciousness, connecting the feeling to trained or known behavioral reactions, and finally getting people to act accordingly. In other words, EEWs aim to shorten the reaction process, allow people to realize what is happening, and recall how to behave. It is thus critical for the public, and especially vulnerable populations such as children, the elderly, and the disabled to be aware of an existing EEW system and to be trained for adequate behavioral response. According to [25], warning systems are based on four phases:

(1) Risk knowledge and data: refers to the understanding and assessment of the risk;
(2) Monitoring: refers to constant data collection to monitor the risk and detect any change in advance;
(3) Response capability: refers to building the capacities to react to the warning, by recognizing the alarm and being able to follow the behavioral instructions;
(4) Warnings: combines data detected in the monitoring phase with the technological system so that the response capability can be activated when the warnings operate.

Sukhwani et al. [26], however, suggest three gaps that might reduce the effectiveness of early warning systems in this process, namely lack of knowledge, technology, and institutional factors. The knowledge gap refers to inadequate dissemination of knowledge to the public regarding the hazards and potential mitigation and preparedness action, including how to react when hearing the alarm. The technology gap refers to the potential failures of warning systems when a warning is issued without a real need or, more importantly, when the system does not operate as it should have. In both cases the consequences are critical. While the second can obviously lead to loss of life, the first could lead to loss of trust in the system and less compliance in future events. The institutional gap refers to the situation where an emergency agencies may be unable to disseminate the relevant knowledge on risk mitigation, communicate the potential earthquake risk and safety instructions, or even be unable to provide early warnings. Nevertheless, citizens would prefer to receive an earthquake early warning, even if it is not accurate [27].

2.4 Hazard and risk communication with the public

Communication with the public is key to ensuring that individuals and families are able to prepare, respond, and recover from an event. Past events, such as the floods in Germany in 2021, showed that a fully operating warning system is important in mitigating the consequences of a disaster [28]. Especially in times of uncertainty, lack of authoritative information could also lead the public to believe fake news and misinformation, which in turn can trigger fear and

anxiety [29, 30]). Thus, continuous communication by authorities with the public is crucial to ensure that people receive accurate and timely information, can take informed decisions, and are willing to take protective actions [31].
These days, different products are used to communicate seismic hazard and risk to society. In quiet times, long-term hazard and risk maps, in particular, are a usual means of increasing public awareness of earthquakes. Marti et al. [32] stress the importance of the map design so that the public can interpret them correctly and increase their own awareness. Directly after an event, rapid earthquake messages are often provided by national agencies and also at the European and international level, with mobile applications providing EEW or near-real time messages to the public [33, 34 35]. Earthquake messaging after an event can also be disseminated via multi-hazard apps [36]. Especially in countries with low to moderate seismic hazard levels or low risk perceptions, such apps may be a good means of communicating to a wide range of people.

Trust in the institutions providing the information is also key [36]. Trust in official information providers, for example, influences people's belief in the correctness of the messages [37, 38] and their intention to take protective actions. Moreover, for typhoons, Kurata et al. [39] suggest that people's perceived behavioral control and attitudes significantly affect their intention to comply with the officially advised response to flood disaster risk.

The most important piece of information for affected citizens is to know is what action to take. This is a challenge because, although the behavioral guiding principle is the same for all citizens (i.e. drop down or flee out), the instructions should be compatible with the capabilities of every societal group and for vulnerable populations in particular (such as the elderly, disabled). In Israel, for example, the instructions were changed from "drop down" to "flee outside," first for schools and kindergartens, and later for the entire population [40]. Furthermore, in the United States (USA), the appropriateness of protective actions in an EEW context has been assessed through an evaluation of more than a dozen actions based on reports of the Federal Emergency Management Agency (FEMA) and GeoHazards International (GHI) [41]; evidence-based guidelines were derived from these reports for the EEW context [42], considering factors such as constructions, socio-demographics, and personal abilities (such as physical challenges).

4. Results

4.1 Comparison between earthquake mitigation and preparedness policies in Israel and Switzerland

4.1.1 Seismic hazard and risk assessments

The Swiss Seismological Service (SED) at the Swiss Federal Institute of Technology (ETH) in Zürich operates a monitoring network with more than 200 seismometers. About 1,000 to 1,500 natural earthquakes are registered in Switzerland and its immediate neighboring countries per year (Fig. 1a), of which about 10 to 20 are felt by the public ($M_w \geq 2.5$). Most of the earthquakes occurring in Switzerland are caused by collisions between the European and the African lithospheric plates, but they are possible everywhere. Further, especially in the mountain areas, secondary hazards such as landslides and avalanches are also a threat. Cities near lakes are at risk of lake-tsunamis [43]. Regarding the seismic risk, the first Swiss earthquake risk model was released in March 2023. Urban areas have high risk levels, with the greatest earthquake risk being in the cities of Basle, Geneva, Zurich, Lucerne, and Bern. Although there are different earthquake hazards in different regions, all five cities have, by virtue of their size, a large number of people and assets that would be affected by an earthquake, and many buildings, some particularly vulnerable and often located on soft ground that amplifies seismic waves. Moreover, over a 100-year period, earthquakes in Switzerland can be expected to cause economic damage of CHF (Swiss francs) 11 to 44 billion to buildings and their contents alone [12]. (Fig. 1e). This is due to the high density of residents, properties, and vulnerable buildings [11].

In Israel, the Seismology Division of the Geological Survey of Israel records and analyzes seismic events and publishes a seismological bulletin on a yearly basis. Data from 2019 contains source parameters of 1,141 local and regional earthquakes, including 698 events with magnitude ≥2.0 (Fig. 1b). Six events were reported as felt by the public. Statistically, a damaging earthquake is expected to occur every 100 years. The last was a Mw 6.2 earthquake in the northern Dead Sea area in 1927. Coastal regions could also be affected by tsunamis, potentially triggered by earthquakes [44]. Israel does not formally utilize seismological risk maps, however, but rather bases its risk assessments on mapping the secondary or "by-product" risk, such as expected ground acceleration, amplification, liquefaction, landslides, and tsunami [45] (Fig. 1d). In terms of risk assessment for Israel, the "preparedness framework" was set by the Israeli National Committee for earthquake preparedness following a government resolution of 2012. The preparedness framework determines the minimum preparedness level for the country, by defining the damage that could be caused by possible future earthquakes. It does not determine the severity of the damage in an actual earthquake. The estimations are based on a statistical analysis of the calculated damaged from over 17,000 possible earthquakes in Israel, of different magnitude and location. According to the "preparedness framework," the government is preparing for 28,000 destroyed or heavily damaged buildings; 290,000 medium to lightly damaged buildings; 7,000 people dead; 8,600 badly wounded; 37,000 lightly wounded; 9,500 trapped under the rubble; 170,000 people left without homes.

In Switzerland, the earthquakes felt yearly are only slightly higher than in Israel. Another similarity is that the last damaging earthquake occurred some time ago (in Israel in 1927 and in Switzerland in 1946); thus people's memories of these events and their risk awareness tend to be low, with the majority of the population not having experienced a severe earthquake within their lifetime. Furthermore, except for Jerusalem in Israel and Basle in Switzerland, the largest cities in both countries are not within the highest hazard regions; due to the large population and building density, however, the large urban metropolises are vulnerable and thus have a high seismic risk. Both countries, too, are prone to landslides in mountain areas. In terms of differences, in Israel the long coastal area increases the risk of a tsunami, and in Switzerland avalanches are a relevant secondary hazard.

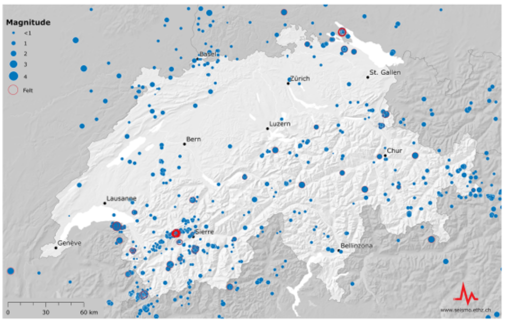

Fig. 1a: Earthquakes in 2019 in CH. All recorded earthquakes in Switzerland in 2019. Earthquakes (blue dots) with a red circle are those that were felt by the public. [Source: seismo.ethz.ch]

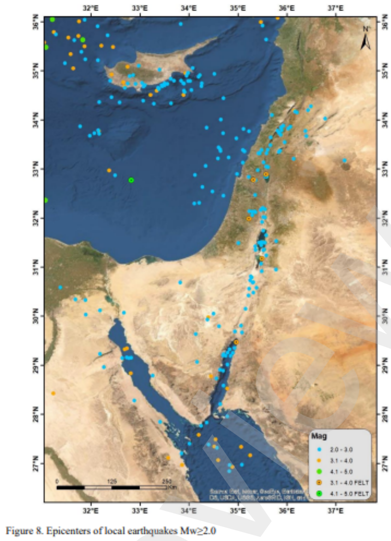

Fig. 1b: Earthquakes in 2019 in IL. [Source: https://eq.gsi.gov.il/docs/bulletin/2019_BP.pdf]

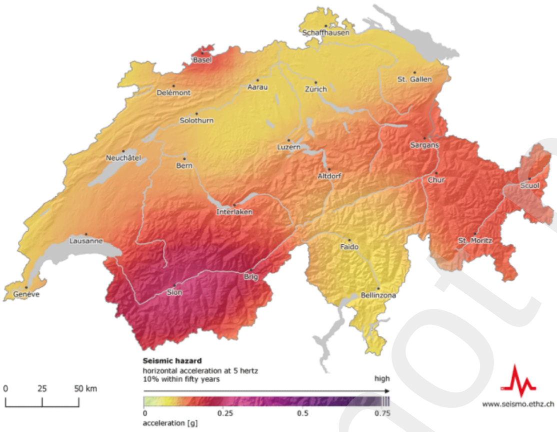

Fig. 1c: Seismic hazard map of CH. [Source: seismo.ethz.ch]

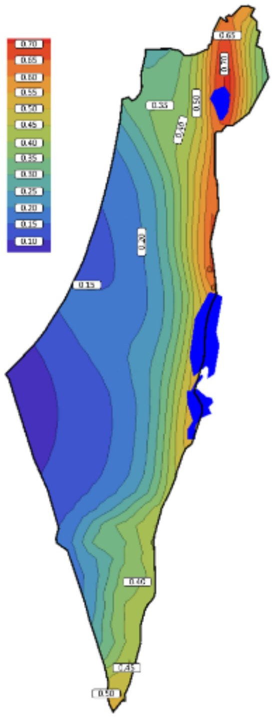

Fig. 1d: Expected ground acceleration map of IL
[Source: https://www.sii.org.il/media/1963/ss-10-in-50-years.jpg]

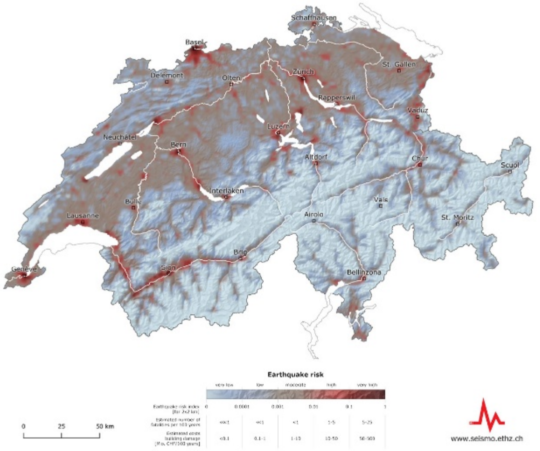

Fig. 1e: Earthquake seismic risk index map for Switzerland [http://seismo.ethz.ch/export/sites/sedsite/earthquakes/.galleries/img_maps/RZ_ERM_Riskmap_EN_1200px_WEB.jpg_2063069299.jpg; 17.3.2023]

Fig 1f: Active and potentially active faults in Israel [Geological Survey of Israel: https://egozi.gsi.gov.il/WebApps/Hazards/ActiveFaults/]

4.1.2 Mitigation of building and infrastructure collapse risk

Ultimately, the most effective way of preventing loss of life and property damage during an earthquake is to increase the resistance of buildings. Building codes, which follow national risk assessments, are basic to this effort. While both countries have construction standards and building codes, there are differences in the actual implementation of the legal frameworks and building codes.

In Israel, the code came into force in 1975 and has been updated several times over the years. The building code is binding by law, and it is presumed that all buildings constructed since 1975 are built according to it. (The engineer signs a legal document stating that the building complies with all standards, but there are not checks or audits). The National Outline Plan for Strengthening Buildings Against Earthquakes (TAMA 38) was approved in 2005 to suggest how buildings constructed before the earthquake building code was established, might be reinforced, and provides a legal framework for doing this. The outline plan provides economic incentives to reinforce residential buildings built before 1 January 1980 to encourage implementation of the plan. This plan is implemented mostly in areas with high real estate values. Between 2005 and 2021, 4,498 building permits were issued for the reinforcement of residential buildings. This amounts to about 100,000 apartments + 47,000 new apartments added [46](The Governmental Authority for Urban Renewal, 2021). As it is assumed that about 80,000 residential buildings were built prior to the building code, this process might take a long time. The downside of the plan is that most of the building-strengthening projects were carried out in non-high-risk but high-land-value zones, leaving the high-risk zones, where the value of properties is lower, unprotected due to the lack of economic viability of building reinforcements. It did, however, provide a fair solution for high-risk buildings in high-price areas. In peripheral areas, governmental intervention is needed to initiate the building reinforcement project. Public funding for these projects has yet to be allocated.

In Switzerland, earthquake-resistant building designs (following *SIA building code 26)* of the Swiss Society of Engineers and Architects [SIA]) offer the best protection against the consequences of an earthquake. These building designs aim to i) protect people from collapsing structures; ii) limit damage to structures; iii) maintain the functionality of important structures in the event of an incident; and iv) limit damage caused by earthquakes (e.g., fire, loss of production). The first national building codes came into force in 1989 and were updated and made stricter in 2003. There is no available data about the exact number of earthquake-resistant buildings in Switzerland. Masonry buildings, however, which are considered to be particularly vulnerable, make up a large part of the Swiss building stock [12]. On a federal level, all national buildings and infrastructure construction, including national roads, are under the auspices of the Swiss Confederation in neighboring countries. Those not earthquake-resistant will be renovated by 2029. Buildings and infrastructure coming under the auspices of the authority of the canton and the (smaller, local) commune, or under private ownership are governed by cantonal legislation, with further legislative decrees being issued at the commune level. Only seven cantons (i.e., Valais, Basel-City, Aargau, Bern, Jura, Lucerne, and Nidwalden) have passed legislation explicitly requiring compliance with the SIA standards, while some cantons have imposed earthquake-specific conditions as part of their building permit procedure (SED, 2022).

Regarding insurance, buildings are insured against fire and natural hazards by a state-owned monopoly insurer (18 Swiss cantons) or private building insurers (8 Swiss cantons). Earthquake risk cannot, however, be insured currently within this obligatory building insurance. The only solution for contractual coverage of earthquake damage in Switzerland are voluntary earthquake insurance policies offered by private companies. The federal government and the cantons recognize that current coverage is inadequate. Although past efforts to introduce a mandatory insurance scheme have failed, there are ongoing efforts to offer more suitable earthquake insurance policies.

Private property in Israel can be insured by private insurance companies. About 65% of the apartments are insured against earthquakes. This is mainly because mortgage banks demand that those taking out a loan also buy insurance to cover the mortgage. Most Israeli insurance companies are insured by international sub-insurers. There is a standard insurance policy, regulated by the government, but buying the policy is not compulsory [47].

A comparison between the two countries' mitigation policies reveals that both countries have earthquake-resistant building codes. While, in Israel, applying the building code (since 1980) is mandatory at the national level, in Switzerland each canton has the prerogative to implement and enforce it. Both countries also deal with the issue of strengthening public and private properties. In both countries, public buildings, such as hospitals, schools, and infrastructure facilities, are being retrofitted by the government (this process is ongoing), whereas private and local-level building have to be strengthened by their owners. While in Israel a national plan encouraging the strengthening of private buildings has been implemented only in places where there is a financial incentive to do so, in Switzerland the new Swiss earthquake risk model should encourage cantons to increase public awareness of the importance of earthquake-resistant building constructions (e.g., retrofitting campaigns) and insurance.

4.1. 3 Warning systems

In Israel, the Geological Survey of Israel monitors ground shaking 24/7. A government decision (Decision No. 4738 dated 7.6.12) stated that an earthquake early warning will be sent only to schools. A specialist team, appointed by the Israel Steering Committee for Earthquake Preparedness, examined this policy and determined that the early warning must also be available to the public through the Home Front Command warnings app and via loud-speaker sirens found in every town in Israel. In the event of earthquakes of magnitude 6 or higher, a message will be sent to the public throughout the entire country by all means available by the national warning system—mobile phones apps, sirens, radio, television, and internet websites. This "Truaa" system will detect the occurrence of an earthquake and automatically determine its epicenter and magnitude. From this data and fast calculations, alerts will be sent to all places where a ground vibration is expected to occur with a strength higher than the threshold vibration which is 5 cm per second squared. The initial estimates of the "Truaa" system may be an underestimation, and as the seconds tick by, information accumulates and the automatic estimates of the location of the source and the magnitude improve. Therefore, a warning in the "Truaa" system will be issued in a rolling manner according to the changes in the improving assessments. Starting with earthquakes with a magnitude of 4.5, a warning from the "Truaa" system will be sent only to areas near the epicenter, where the vibrations are expected to be felt. As the magnitude increases, the warning radius will increase. These warning criteria will be re-examined over time and updated if necessary. An alert to the education system will be issued through sirens and mobile-phone apps (available in several languages) combined with local earthquake alert systems, which can provide a few seconds' warning in places near the epicenter, where the "Truaa" system is unable to perform. (Israel is a very small and narrow country, the distance between the Dead Sea fault on the eastern border and the sea on the west being only a few tens of kilometers.)

In Switzerland, ground shaking is constantly monitored by the Swiss Seismological Service (SED). Within approximately 90 seconds after detection of an earthquake, details about the time, location, magnitude, and possible effects are published on the SED website and Twitter channel in the three national languages—German, Italian, and French—and also in English. Notifications are also given via the Swiss national weather app (MeteoSwiss). From magnitude 3 on, an email is also sent to a list of journalists/news portals informing them of the event. During the earthquake detection process in Switzerland, the SED automatically informs the National Emergency Operations Centre (NEOC), which is part of the Federal Office for Civil

Protection (FOCP). Their task is to inform the relevant cantonal and federal authorities, the operators of telecommunications, energy, and traffic networks, and the international organizations and situation centers of neighboring states, and also to make operational the emergency services needed. Every message is assessed by a standby team ("Pikett") that takes preliminary measures and calls the first echelons. Regarding earthquake early warning (EEW), Switzerland does have a potential early warning system [48] and the public wishes to receive EEW alerts [36], however, is still not operational.

Although both countries invest in warning systems, there are differences between their warning policies and dissemination methods. In Israel, the early warning system detects earthquakes before the significant shake occurs and provides a warning through sirens and mobile apps to the affected area. This is in accordance with the national behavioral instruction to flee outside when an earthquake is felt, and it should allow the public some time to hear the alert and quickly flee from the building or enter the in-house shelter. The importance of such an alert is that it enables the individual to be aware that an earthquake could occur immediately. If individuals are trained beforehand in terms of knowing the alert and the instructions, such a warning will lead to automatic and immediate protective behavior. Right after the warning has been issued, pre-defined instructions will also be disseminated to the public.

In Switzerland, the system currently does not provide a pre-event alert: rather, the alert accompanies the shake. Even so, the warning is still significant in providing citizens with the spur to take protective actions and it is appreciated by them. Thanks to the dissemination of the notification via multiple channels, a wide audience is reached, who, in turn can inform the people in their surroundings. The clearly defined warning procedures ensure an efficient communication in the case of a (severe) event.

Both countries' warning policies reflect the risk assessment each country has. Given the high density of Israeli cities and towns, including, for example, public places such as schools, the need for an early warning system is crucial. For example, according to data from the Organization for Economic Co-operation and Development (OECD), the average number of students per classroom in Israel is 28 in primary education and 32 in secondary, while in Switzerland it is 20 in primary education and 19 in lower secondary education.[2] Given that school attendance is compulsory in Israel, and that many school buildings in the country were built before the building codes were implemented, the pupils must be protected by an early warning system.

As both countries are located in earthquake-prone areas, investing in warning systems reflects the level of risk that the country would tolerate, taking into consideration the costs, existing infrastructure, and available scientific expertise. In Switzerland, the SED mentions that considerations regarding the utility of EEW include the "blind zone," namely the area in close proximity to the earthquake epicenter where warning cannot be given, especially in the cases of less severe earthquakes. In Israel this problem has been mitigated by the local alerting

[2] OECD (2014), "How many students are in each classroom?", in Education at a Glance 2014: Highlights, OECD Publishing, Paris.

systems in schools distributed all over the country, but especially those along the Dead Sea fault.

4.2. Hazard and risk communication with the public

4.2.1 Behavioral recommendations

One of the most important aims of disaster risk management is to provide people with behavioral recommendations for protective actions to take before, during, and after an event. Defining these recommendations depends on contextual factors such as the vulnerability of buildings or the resources people have. Appendix 3 presents an overview of the recommendations in Switzerland and Israel.

Regarding the protective actions people can take **before** an earthquake, Israeli authorities provide a detailed description of how to prepare for an earthquake, especially how to arrange living areas and homes. Switzerland, in comparison, uses the same descriptions and adds further recommendations on earthquake insurance.

Regarding recommended actions **during** the shaking, both countries provide recommendations for different locations, namely inside or outside a building or when being transported by vehicle. Israel further provides recommendations for when staying at the beach, which makes sense, as the country has a sea connection and coastal regions could be faced with a tsunami. In Israel, however, the first recommended action is to get out of the building, whereas in Switzerland it is to protect oneself on the spot. Further, Israel states that the elevator should not be used after the quake and provides advice for people with disabilities and people in hospital.

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In terms of the recommendations for **after** the shaking, both countries indicate that people should expect aftershocks, leave the building, close water and gas pipes, and listen to the radio for further instructions. Switzerland, in addition, provides recommendations for outside the damage zone. Israel gives advice on how to help people trapped under rubble and how to behave when you yourself are trapped.

4.2.2 Dynamic hazard and risk communication

Both Israel and Switzerland have two types of earthquake information dissemination: i) information that is permanently available on the internet, including information on the seismic hazard and risk, and ii) information that is communicated shortly before (in Israel) and after an earthquake has occurred (in Switzerland and Israel) (e.g., notifications, emergency information).

In Israel, emergency information is routinely provided mainly through the Home Front Command website.[3] Given the security emergencies Israel faces on occasion, this "emergency portal" provides information regarding all potential hazards and emergency situations. While this information is mainly behavioral and instructive, however, more scientific and in-depth

[3] https://www.oref.org.il/12410-en/Pakar.aspx?tab=12846&parentCategory=12628

information can be found on the Israel Geological Survey website[4] including the "did you feel it" app, and information on recent earthquakes in the area. This information is mainly used by professionals (geologists, engineers etc.).

The notifications sent to the general public during and after an earthquake depend on the magnitude of the event. In terms of drills and public risk awareness, Israel organizes a national earthquake awareness day every three years or so, with public campaigns, activities at schools, drills, and other activities. Schools have earthquake drills at least once every year.

In Switzerland, permanent available information is provided by the SED[5] about earthquakes in general (e.g., causes, measurements), behavioral recommendations, significant past earthquakes, the (inter)national seismic hazard and risk, latest research findings from (inter)national projects, materials for educational institutions, explanations on how the warning system works, products and services for professional users, and materials (e.g., reports, brochures). This information is mainly available in static format, but there are also interactive tools accessible to explore the seismic hazard in Switzerland.

During an earthquake in Switzerland, and right after it, information dissemination is dynamic, and the public receives relevant information via the website and Twitter, and news articles after an event (*Aktuellbeiträge*). With respect to the notification thresholds, in any earthquake, the SED will publish a notification on its website and Twitter account. In the event of an earthquake of magnitude 3, an announcement will be provided by the SED to its mobile phone app, a "Shakemap" will be published on the portal, and the information will be disseminated to the general public, cantons, and relevant authorities and institutions. These thresholds were chosen as—starting from magnitude 2.5—the earthquakes can potentially be felt, and the public wishes to receive information about the situation [36]. In Switzerland, but only in some cantons such as the canton of Valais, one of the regions with the highest seismic hazard in the country, earthquake drills take place at primary and secondary schools. There is, however, a nationwide seismo@school project, the aim of which is to sensitize pupils to earthquakes and demonstrate what they can do to minimize their own risk.

In Israel, there are several educational programs targeted at advancing pupils' understanding of earthquakes and their preparedness for them. The Homefront Command instructs 5th graders in designated lessons at schools—what to do in case of an earthquake and how to prepare at home. A unique program for 8th graders also uses innovative VR videos and games to explain the phenomenon of earthquakes and give them the experience of what an earthquake feels like and how to take action in the event of one. Lastly, 10th graders learn simple search and rescue techniques.

Both countries provide well detailed behavioral instructions for the three phases—before, during, and after the earthquake. Most of the instructions are quite similar (especially in the "before" phase). Furthermore, official information for the public is published on well-established websites. In Israel, however, the information is not concentrated on one website as

[4] https://eq.gsi.gov.il/
[5] http://www.seismo.ethz.ch/

in Switzerland, but rather can be found from various sources. In both countries, information is available to the public right after the earthquake on multiple channels. In Israel, a designated mobile phone app provides personalized information regarding the warning depending on where you are when the earthquake occurs.

4.3 Societal perspective comparison

4.3.1 Perceived probability of a damaging earthquake

Table 1 presents a comparison between Israel and Switzerland in terms of perceived earthquake risk. In both countries, citizens perceive earthquake risk to be higher for the entire country compared to where they live. This indicates that people tend to believe that they are personally not affected. This follows the optimism cognitive bias ("it won't happen to me") which leads to the tendency to ignore actual risk. People in Israel, however, perceive the risk as higher for both themselves and their country than do Swiss citizens. In addition, the distribution is bigger in Switzerland indicating a wider range of risk perceptions starting from lower values but also reaching higher values. This finding is significant when the results at the canton level are examined. We found that people living in seismic hazard–prone regions (cantons of Basel-City, Basel-Country, and Valais) have a significantly higher risk perception both for the place they live in ($t(594)=-4.019$, $p < .001$) and for the entire country ($t(594)=-4.084$, $p < .001$) than the people living in other cantons. In Israel, in contrast, the hazard levels of the regions where people live do not differ greatly from the perceptions of people in other parts of the country.

Table 1: Public earthquake risk perception for where they live and the entire country. The scales ranged from 1=lowest value to 5=highest value and the mean (M) and standard deviation (SD) are indicated.

	Switzerland		**Israel**	
Place of residence	A damaging earthquake will occur in my community in my lifetime.	2.56 (1.13)	What is the likelihood that a strong earthquake will affect your area in the next ten years?	2.98 (0.92)
Country	A damaging earthquake in Switzerland is probable.	2.79 (1.10)	What is the likelihood that a strong earthquake will occur in Israel in the next ten years?	3.27 (0.93)

Sources: CH: (Dallo et al., 2022)[36] / IL: National survey for the Israeli National Committee for Earthquake Preparedness

4.3.2 Preparedness measures

As shown in table 2, the two countries have in common the finding that about two thirds of inhabitants have informed themselves about how to respond to an earthquake, and about 15% have practiced responses (with the family). Regarding the other preparedness actions, respondents from Israel have higher implementation levels. Namely, more people have prepared essential items for an emergency and a family emergency plan, have earthquake insurance, and have taken measures to increase their preparedness. The high percentage of people in Israel with earthquake insurance is mainly due to the obligation to take out insurance when taking a mortgage on a house or apartment (66% of citizens in Israel own their apartment or house, 28% rent, and another 6% live in public-owned apartments[6]). In addition, many Israelis prepare themselves for other emergencies; these measures are applicable to earthquake preparedness. Such preparedness includes having an in-house shelter against missile attacks (these shelters strengthen the building to sustain shaking and provide shelter in case of an earthquake) and are familiar with siren notifications, given security events that have occurred in the past. On the other hand, given the federalist, local risk management in Switzerland, the analysis should be carefully examined at the canton- level as well. With McNemar tests, we identified that people living in seismic hazard-prone regions (cantons of Basel-City, Basel-Country, and Valais) are significantly more likely to have looked for information on how to respond to strong shaking or how to prepare for an emergency ($p< .001$).

Table 2: Preparedness actions taken by people in Switzerland and Israel. The percentages of participants who ticked the corresponding action are indicated..

Switzerland		**Israel**	
I have informed myself on how to respond.	66.6	I know the recommended behavior instructed during an earthquake.	63.0
I have informed myself on how to prepare for an emergency such as earthquakes.	40.3	To a (high) extent I prepared for the possibility of an earthquake in my place of residence.	14.6
I have practiced responding to an earthquake drill (on my one or as part of a drill).	15.4	I practiced with my family the behavior instructions during an earthquake.	20.8
I have sufficient home insurance cover that will allow me to rebuild should my home be severely damaged.	13.7	I have purchased home insurance.	40.0
I have prepared a family emergency plan.	7.4	I have prepared a family emergency plan.	19.3

[6]https://www.cbs.gov.il/he/mediarelease/pages/2020/%D7%94%D7%93%D7%99%D7%95%D7%A8-%D7%91%D7%99%D7%A9%D7%A8%D7%90%D7%9C-%D7%9E%D7%9E%D7%A6%D7%90%D7%99%D7%9D-%D7%9E%D7%A1%D7%A7%D7%A8-%D7%94%D7%95%D7%A6%D7%90%D7%95%D7%AA-%D7%9E%D7%A9%D7%A7-%D7%94%D7%91%D7%99%D7%AA-2018.aspx

I have taken measures to increase my residence's earthquake resistance (e.g., secured furniture).	5.4	I have taken measures to increase my residence's earthquake resistance (e.g., secured furniture).	26.9

Sources: CH: (Dallo et al., 2022)[36] / IL: National survey for the Israeli National Committee for Earthquake Preparedness

4.3.3 Knowing the behavioral instructions during an event

In Israel, the government recommends what people should do during shaking, in the following order: i) go outside; ii) enter a protected room/stairwell; iii) get under a heavy table. As shown in Table 4, these were also the top three actions people indicated they would take, with 63% saying that they would evacuate. Thus, it seems that people's awareness of what to do is high.

In Switzerland, in comparison, the main recommended action is to protect oneself on the spot, which about 20% would do (Table 3). This is quite a low percentage, taking into account that 66.6% indicated earlier in the survey that they know what actions to take during (strong) shaking. These actions do not seem to have been internalized. The majority of the participants indicated that they would rather warn or protect others (23.2%), which is in line with other studies [49, 50]. The rest would move to a place they believe to be safe, run outside, look for further information, or mentally prepare. Regarding the differences between high- vs. low-to-moderate hazard regions, we identified no significant differences in the intended responses of respondents to strong shaking.

Comparing the two countries, it is evident that people in Israel have a higher awareness of what actions to take and a higher intention to actually take those actions. Further, in Israel no participant answered that they would do nothing, whereas in Switzerland 5.5% would do nothing. These results must, however, be interpreted with caution, as in Israel the participants had no option to "warn or protect others," we do not know whether this option would have been selected the most or not.

Table 3: Intended behavioral actions people would take during strong shaking in Switzerland and Israel. The actions are sorted in descending order according to the number of mentions. Further, we highlighted in color, which actions correspond to each other in the two countries. The percentage of the participants who would take the action is indicated.

Switzerland [single answer]		**Israel [multiple answers]**	
Warn or protect others.	23.2	Run outside.	52.0
Protect myself on the spot (e.g. take cover under a table).	21.1	Protect myself on the spot (e.g. take cover under a table).	24.9

Move nearby to where I think it is safe.	16.4	Go to a secured room/ shelter.	3.4
Run outside.	13.6	Go to the stairwell.	1.0
Look for further information about the earthquake.	7.7	Move nearby to where I think it is safe.	10.2
Mentally prepare myself for the shaking.	6.7	Look for further information about the earthquake.	1.1
Do nothing	5.5	Lie on the ground.	3.2
Stop, and stay still, awaiting the shaking on the spot.	2.5	Do nothing.	0.0
Report the earthquake.	1.7		

Sources: CH: (Dallo et al., 2022)[36] / IL: National survey for the Israeli National Committee for Earthquake Preparedness

5. **Discussion**

Both Switzerland and Israel are earthquake-prone countries and have experienced destructive earthquakes in the past. Both countries have a national earthquake preparedness policy, which is based on a scientific hazard and risk assessment (for Switzerland, the first detailed earthquake risk model was released in March 2023), constant monitoring, enforcing building codes, well-established warning systems (operational EEW exists only in Israel as of now), and solid risk communication mechanisms. These preparedness and mitigation efforts aim to increase societal resilience to destructive earthquakes by strengthening critical infrastructure and public services, as well as by increasing citizens' awareness and intention to take protective actions.

The two countries do, however, differ in terms of the policy implementation approach. The main difference lies in the centralization of the decision-making authorities. In Israel, the mitigation and preparedness policy is centralized and is being applied nationally, while in Switzerland, it is decentralized, and certain policies are implemented only by high-risk cantons. This has led to differences in citizen awareness, risk perceptions, and preparedness in across Switzerland. In Israel and in the Swiss cantons that enforce mitigation actions (i.e., building codes), more citizens knew the instructions, perceived the risk as higher, and in general were more aware of earthquake risk than those who were not exposed to risk communication campaigns (e.g., drills at school).

Both countries also invest in public communication, but have a different approach to it. In Israel the focus is on the recommended behavior, with dissemination of short and specific behavioral instructions on various websites (the Geological Survey, the IDF's Home Front Command, and governmental websites). This information can be found on various sources, but not on a designated, widely known, and established one. The Home Front Command's website will provide ongoing updates during the event, and people in Israel are aware of this website, as it serves for emergency information in other contexts. In Switzerland, the earthquake information is mainly concentrated on one source—the SED website—but it is also provided on the natural hazard portals of Switzerland (multi-hazard platforms combining information about all natural hazards in Switzerland) and the most used national weather app and website (MeteoSwiss). The well-established network with national and local media also ensures the wide dissemination of relevant information on the media channels (e.g., release of new products such as the risk model, event-related information after a quake). It is further planned to disseminate event-related earthquake information via the national emergency app AlertSwiss, where various professional and societal stakeholders are able to issue notifications (e.g., police, civil protection).

Given that both countries have not experienced a strong earthquake in recent decades, a major issue is how to engage public in preparedness actions and risk awareness. This highlights the need for efficient communication between the authorities and the population to educate people about what actions they need to take to cope with earthquakes. Although information on behavioral recommendations before, during, and after an event is available and communicated to the public on various occasions, people need to internalize those behaviors so that they become automatic. Only then can people react immediately they feel shaking or receive an EEW alarm. The challenge is to facilitate the transfer from "just knowing" and being aware of what one should do during an earthquake, to behaviors being "automatic" or tacit knowledge. As our analysis shows, both countries invest in such communication with the public at the national level, but less is being done at the local levels in terms of local campaigns, local drills, and direct information dissemination with the specific needs of, for example, the elderly or disabled being taken into account.

These similarities and differences highlight the need for a model that considers the most effective implementation channels for decision-makers to examine earthquake policies. On the basis of the analysis we identified two main dimensions that are critical to the effective implementation of earthquake mitigation and preparedness policy:

(a) Formulation of the policy level. Is the policy centralized or decentralized in its planning, design, and decision making?
(b) Implementation level. Should the policy be implemented at the national or local level?

We classified the four earthquake preparedness components we examined in this research, according to a matrix representing these two dimensions—centralized / decentralized and national / local. The result is the following matrix (Figure 1). The results of our analysis show that Israel and Switzerland are similar in their centralized risk assessment, which is constantly being performed by scientists and professionals at national seismological and geological institutions. These assessments are national-level, as data is collected from nationwide (and even international) seismological stations, and are integrated and analyzed for the entire country and for high-risk zones in particular. Constant monitoring and data analysis at the national level are important for the scientific relevance and accuracy of the assessments.

<table>
<tr><td></td><td colspan="2">Centralized</td><td></td></tr>
<tr><td rowspan="2">National implementation</td><td>Risk assessment (both)

Hazard and risk communication (both)

Mitigation (IL)</td><td>Warning (both)</td><td rowspan="2">Local implementation</td></tr>
<tr><td>Mitigation (CH)</td><td></td></tr>
<tr><td></td><td colspan="2">Decentralized</td><td></td></tr>
</table>

Figure 1: Model of collaborative earthquake mitigation and preparedness policy

Our analysis also showed mitigation efforts to be generally national and centralized in Israel, (in terms of mandatory building codes), while when specific strengthening plans were applied, it was decentralized, as in Switzerland. In Switzerland, building codes for the entire country have existed since 1989 (then updated and strengthened, especially in 2003), but their implementation is then regulated at the cantonal level (i.e., certain cantons have explicitly stipulated compliance with earthquake-resistant construction standards in their building regulations and monitor them). It is thus recommended that building codes be defined on a national level, taking into account local contexts, and then applied either at the national or local level. By doing this, the government could concentrate investment of public funds in important public assets such as hospitals, schools, and infrastructure (as has occurred in Israel), while allowing local actors, such as local authorities, to manage carry out structural reinforcements in accordance with local needs and capabilities. A collaborative approach, for example, with local authorities, prioritizing, planning, and executing reinforcement projects within their own jurisdiction and receiving governmental support, could be more efficient and effective than a "top-down" approach.

Third, hazard and risk communication is effective when applied locally (i.e., when it fits the needs of a certain area and social groups), while also being decentralized in terms of the means of disseminating it. Currently, both Israel and Switzerland have centralized hazard and/or risk communication approaches that focus mainly on the content and the channels of communication. While in Israel the hazard and risk communication is implemented nationally, (e.g., in national campaigns and preparedness days), in Switzerland it is applied more locally at the canton level (e.g., drills at schools in the canton of Valais). We suggest that a collaborative approach fits here as well: hazard and risk communication with the public should be centralized in terms of the contents and sources, but also decentralized in the sense that each local government and/or local authority uses its appropriate channels to communicate with the local communities, which allows local risk characteristics to be taken into account. As we have shown in the case of Switzerland, cantons with a higher seismic hazard put more effort into communication with their residents, as reflected in residents' higher risk awareness and knowledge of what to do during strong shaking.

Lastly, the approach to issuing warnings was found to be the same for Israel as for Switzerland. Both countries issue warnings for the affected area. In Israel the EEW is local and installed in schools under the education budget. Given the complexity (in terms of interoperability and connection to other national systems) and the high costs of setting up and maintaining a warning system, it represents the centralized/local quarter, although for Israel, its implementation is local, under the responsibility of the local authority. With a collaborative approach, however, local entities could connect to the warning system or use it to increase its influence on local residents and visitors, for example, to broadcast the warning to all relevant areas and/or provide a notification on local mobile apps. In Switzerland, only a non-operational pilot EEW system is available at the moment.

The matrix has several advantages for disaster risk reduction policies in general and earthquake mitigation and preparedness policies in particular:

1. It highlights the importance of the collaborative approach between central and local governments and the population. As shown, both countries have similar approaches to their hazard and risk communication and building codes. It is, however, evident that there are gaps in the preparedness domain in the decentralized/local area. As stated, localized preparedness and mitigation actions are invaluable, and it is only through collaborative efforts on the part of national and local forces that preparedness and mitigation efforts can be efficient and socially and economically effective;
2. The model allows for a more nuanced understanding of the basic factors that make up a country's earthquake mitigation and preparedness policy. Policymakers could use this matrix to examine improvements in their policies if found solely national or totally centralized.
3. All four preparedness and mitigation components have the same weight in policy terms: however, the model allows for an understanding of how they are implemented. For example, in large countries such as the USA, the model can be used to challenge current policies and advise on a more refined, place-based, and collaborative application of the policy.

6. Conclusions and recommendations

Earthquake preparedness and mitigation policies are complicated processes. They involve building reinforcement, high-tech and cutting-edge scientific knowledge, and technologies, and they rely on collaborative public behavior—all under extreme conditions of uncertainty, legal issues, and budgetary and political constraints. A collaborative approach is thus needed that integrates national and local actors so that the capabilities and efficiency of all systems is increased, including the central government–local authority axis, and, for example, the private sector and civil society organizations. Such decentralization would allow local actors to apply national decisions and policy more effectively, while prioritizing the interests of local populations and businesses, as well as environmental interests. This not only ensures better societal preparedness for future earthquakes, but also ensures an optimal fit to the local needs, capabilities, and planning. As risk assessments, warning systems, and mitigation domains should always be directed and guided from national officials to the local authorities, the collaboration of local governments is critical in both hazard and risk communication and in the management of public awareness and knowledge.

On the basis of our analysis and model we make the following recommendations:

First, the local authorities—states, cantons, and municipalities should be deeply involved in earthquake policymaking and implementation. The local authority level can be an active mediator with the public in terms of conveying national regulations and budgetary constraints involved in policymaking. **Second,** there is a significant challenge to earthquakes preparedness in terms of the gap between citizens' risk awareness and their actual preparedness. This could be addressed by collaborative approach combining decentralized decision-making with localized implementation. This could improve communication with the public, encouraging them to join, for instance, drills and local preparedness campaigns. **Third,** information dissemination is critical for saving lives before, during, and after an earthquake. Our analysis shows that while there were differences in the number of information dissemination sources in the two countries (one official source in Switzerland, and multiple official sources in Israel), the important, and shared, factor is the reliability of the information. A unified, consistent, and reliable information is key to gaining public trust and collaboration. Using a single trustworthy message that is available on various channels and that reach as many people as possible (e.g., media, civil protection platforms) is important. A multi-hazard platform may facilitate access to information for all relevant hazards in a country/region. To this end, routine well-established networks between the information provider and the dissemination entities are indispensable.

7. Appendix

Appendix 1

	Switzerland	Israel
Latest three damaging and strongest earthquake	25.01.1946: Mw 5.8 earthquake in Sierre (VS) 25.07.1855: Mw 6.2 earthquake in Stalden-Visp (VS) 10.09.1774: Mw 5.7 earthquake in Altdorf (UR) The strongest:	22.11.1995. 7.1Mw in the Red Sea. This was the strongest earthquake ever recorded in the area. The epicenter was 100 km south to the cities of Eilat (Israel) and Aqaba (Jordan). Given that the epicenter was far from populated areas, the earthquake did not cause significant damage and loss of life. Few deaths and slight damages occurred in small villages along the Sinai seashore and Saudi Arabia.

	18.10.1356: Mw 6.6 earthquake in Basel (BS)	July 1927. 6.2Mw epicenter in northern Dead Sea. Affected Cities: Jerusalem, Jericho, Lod, and Nablus. January 1837 in northern Israel. Large damage and loss of life in the town of Zefat.

Appendix 2

Comparison of country-level indicators for Israel and Switzerland

	Switzerland	**Israel**
Political system	Federal semi-direct democracy under a multi-party assembly-independent directorial republic, with seven federal councils	Unitary parliamentary republic
Inhabitants	~ 8.5 million	~ 9.5 million
Area	41,000 km2	21,000 km2
Capital city	Bern	Jerusalem [economic center: Tel Aviv]
Wealth inequality in 2022 (Gini coefficient)	33.1%	39.0%
Educational levels in 2022	Below upper secondary: 10.7% Upper secondary: 44.0% Tertiary: 45.3%	Below upper secondary: 12.0% Upper secondary: 37.9% Tertiary: 50.1%
Net national income per capita (US$) in 2021	60,182 US$	32,427 US$
GDP per capita (US$) in 2021	88,244.1 US$	39,913.1 US$
GDP per capita growth (annual %) in 2021	3.0%	6.5%

Racially diversity in 2022	Ethnic Fractionalization: 53.1% Linguistic Fractionalization: 54.4% Religious Fractionalization: 60.8%	Ethnic Fractionalization: 34.4% Linguistic Fractionalization: 55.3% Religious Fractionalization: 34.7%
National languages	German (62.8%), French (22.9%), Italian (8.2%) and Romansh (0.5%)	Hebrew and Arabic
Religions	Roman Catholic (34.4%), no religious affiliation (29.4%), Protestant Reformed Church (22.5%), Muslim and Islamic communities (5.4%) & others (7.2%)	Jewish (74.2%), Muslim (17.8%), Christian (2.0%) & Druze (1.6%)

Sources: CH: *https://www.bfs.admin.ch/bfs/en/home/statistics/population/languages-religions/religions.html*;
IL: Central Bureau of Statistics
GDP and net national income data: *https://data.worldbank.org/indicator/*
Wealth inequality: *https://worldpopulationreview.com/country-rankings/*
Educational levels: *https://worldpopulationreview.com/country-rankings/most-educated-countries*
Fractionalization: *https://worldpopulationreview.com/country-rankings/most-racially-diverse-countries*

Appendix 3

Behavioral recommendations before, during and after an earthquake in Switzerland and Israel

	Switzerland	**Israel**
Before	**1) New, redeveloped, and converted buildings** - Consider taking out earthquake insurance to reduce your personal (financial) risk. **2) Sources of danger inside buildings** - Make sure the objects that could fall down or topple over due to the shaking, and cause injuries, are secured. This includes, for example, ceiling linings, shelves and their contents, televisions and stereos, and light fittings. **3) Be prepared (for earthquake and other emergencies)** - Think about what to do during an earthquake. - Put together a first aid box. - Keep a supply of emergency	**Preparing the home** Many deaths during earthquakes are caused due to shelves and heavy objects collapsing, broken glass, fires, and gas leaks. It is thus advisable to perform the following actions today: - Locate the safest place we can reach during an earthquake - for example, an open area in a detached house or ground floor apartment, protected room, or stairwell in a high-rise building. - Make sure it is free for passage and that there are no objects on the way that may fall or interfere with movement. - Heavy objects should be placed in low places. - Make sure there are no heavy shelves

	provisions. - Copy important documents such as your passport or driving license and have them within reach in case of an incident. - Have a torch, battery-powered radio, and cash (ATMs may no longer function) within reach in case of power cuts. - Know where the main valves and switches for gas, water, and electricity are and how to turn them off.	or objects hanging over the household beds. - Cabinets, air conditioners, bookshelves, TVs, shelves and other objects that may fall during an earthquake should be strengthened and secured. - The connections of solar water heaters and heating, gas cylinders, air conditioners and compressors must be strengthened. - Hazardous and flammable materials should be stored in a locked place and away from any heat source. **Preparing emergency equipment** - To be prepared for any scenario, we must prepare emergency equipment in advance that will be enough for us for a few days, store it in a bag and put it in an accessible place. **Preparing emergency methods of communication** - When preparing the home and the equipment required for an emergency, it is of great importance to make a telephone list of the emergency organizations, family members, and neighbors in advance. **Preparing the family** For the entire family to be prepared for an earthquake, it is important to have a family conversation on the subject, make sure everyone is familiar with the guidelines, and practice the guidelines
During	**1) Inside a building** - Take cover (e.g., under a sturdy table) - Beware of falling objects and keep away from windows and glass walls, which may shatter. - Only leave the building when the surrounding area is safe (when there are no more falling objects such as roof tiles, etc.). **2) Outside** - Stay outside, do not seek shelter in a	**1) When inside a building:** Quickly move to a safe place in the following order of priority: **1. Go outside to an open area** - if you can get out of the building immediately (within a few seconds), go out into an open area (especially true if you are in a detached house/ground floor apartment). **2.** If it is not possible to get out immediately (within a few seconds) **enter a protected room or a**

building.

- Keep away from buildings, bridges, electricity pylons, large trees, and other things that could collapse or fall.
- Keep away from the shores of bodies of water.

3) **In a vehicle**
- Stop the vehicle and do not leave it during the quake.
- Do not stop on bridges, in underpasses, or tunnels.
- Keep away from buildings at the side of the road (danger of collapse).

stairwell - and sit there until the shaking ends (especially if you are staying in a multi-story building).

3. Get under a heavy table or in an inner corner of the room - if you are unable to get out immediately or move quickly to the protected room/stairwell - take shelter under a heavy table or in an inner corner of the room.

Additional instructions:

• Stay away from external walls, windows and shelves.

If you are in a wheelchair - lock it and protect your head.

• Do not use the elevator during and after the earthquake - you may be stuck in it.

2) **When outside:**
- Stay in an open area as far from buildings as possible. Open space is the safest place!
- Beware of falling objects such as wall cladding stones, air conditioner compressors, broken glass, and broken electrical wires.

3) **When in a car**:
- If the shaking occurs while you are driving - stop immediately and wait inside the vehicle until the vibration stops - the car protects you.
- Avoid stopping under a bridge, on an interchange, near buildings or under a steep slope in case they collapse. Get away by car or by foot.

4) **When at the beach:**
- If you are at the beach during an earthquake, leave the beach immediately and get as far away from it as possible, in case a sea surge ("tsunami") comes and flood the beach.
- A strong and sudden retreat of the sea is a sign of an approaching "tsunami" wave.

		- Note: The education system's guidelines for behavior in kindergartens and schools during an earthquake are provided separately.
After	**1) Inside the damage zone** - Expect aftershocks. - Help others without putting yourself in danger. - Check building for damage. Leave building in the case of severe damage. (The building may be at risk of collapsing and will not withstand further quakes.)_ - Exercise caution when leaving the building. (Pieces of masonry, roof beams, titles, and the like may still fall off) - Check the building and surrounding area for potential fires. (When possible, extinguish small fires and/or alert the fire service.) - Check water and gas pipes and electric wiring for damage. (Turn off supply if damage is suspected.) - Seek information from television, radio, or the internet. - Follow the instructions of emergency service personnel. - Only use telephone in an emergency. (Phone lines should be kept free for genuine emergencies.) - No individual travel by car. (Roads should be kept free for emergency services.) - Power cuts are likely. **2) Outside the damage zone** - Be ready for aftershocks. - Seek information from television, radio, or internet. - Avoid entering the damage zone. - Only make telephone call in an emergency (the network will be overloaded and should only be used in genuine emergencies). - Power cuts are likely.	**1) How to act immediately after the earthquake:** - Do not light a fire or turn on an electrical switch of any kind (including using a cell phone) in case an explosion occurs due to a gas leak. - Leave the building and stay in an open area, away from buildings. - Before leaving the building, disconnect the cooking gas supply tap and the main electrical circuit breaker for the apartment. It is also recommended to close the main gas tap of the entire building. The renewal of the gas/electricity supply to the building will only be done by a qualified technician after the gas system and the taps of all the consumers in the building are found to be in good order and closed. - Do not enter damaged buildings without permission from a structural engineer. (except for rescue purposes). - Listen to the radio (for example, the radio in the car) for information and instructions. **2) Helping trapped people under rubble:** - If there are people trapped under rubble in your vicinity, exercise discretion and use household means to lift heavy objects such as a car jack or an iron bar. Administer first aid if possible. - If you are trapped under the rubble, try to extricate yourself. Cover your airways with dust protection clothing and avoid

	exhausting yourself by shouting. Tap on pipes or walls to allow rescuers to locate you. Do not light a fire! **3) Aftershocks:** - Be prepared for additional tremors (aftershocks) - these tremors appear minutes, days, or months after the tremor and may collapse buildings weakened by the first tremor.

Sources: CH: seismo.ethz.ch / IL: https://www.oref.org.il/12846-19066-en/Pakar.aspx

Appendix 4

The Israeli survey included 920 adult citizens (aged 18+), and was representative in terms of all religious groups and levels of religiosity. Data were collected via an internet panel of the Geocartography company (https://www.geokg.com/en/) during April 2022. Among the respondents, 43% were men and 57% women, with a mean age of 37 years (SD=13 years). In terms of religious affiliation 66% defined themselves as Jewish, 24% as Muslims, 5% as Christians, and 5% as Druze, which is similar to the proportion of these religions in Israeli society. 54% were married, 8% were cohabitating (living with a partner without marriage), 7% were divorced, and 6% widowed and 26% were single. 27% had graduated from high school, 21% had a secondary education (higher than high school), 51% had academic education, and less than 1% refused to answer. Income levels were: 41% had a monthly income of 2,200 EUR or less, 15% between 2,220–3,000 EUR, 29% between 3,000–4,500 EUR, 7% between 4,500–5,500 EUR and 8% had a monthly income of more than 5,500 EUR.

The Swiss survey included 596 adult citizens (aged 18+), and was representative in terms of age and gender. Data were collected in March 2021 via an ISO-accredited polling company Bilendi & Respondi (https://www.bilendi.de/). Among the respondents, 50.7% were men and 49.3% women, with mean age of 44 years (SD=14.8). Further, 26% spoke French and 74% German. Most participants worked full-time (49.8%) or part-time (16.3%). Moreover, most participants had as their highest educational degree either a university degree (23.8%), a completed vocational school (15.1%), a federal diploma (14.4%), a completed apprenticeship (13.1%), or a completed Matura (12.6%). Compared to the Swiss average, the sample was slightly overeducated. Most participants indicated that the total monthly gross income of all persons living in their household was 5001–7000 CHF/month (23.0%), under 5000 CHF/month (21.6%), or 7001–9000 CHF/month. Regarding the household composition, 76% had no person under 18 years, 43.8% had two persons between 18 and 65 years, and 68.9% had no person over 65 years. Last, 67.8% lived in a rented apartment/house and 31.2% owned an apartment/house.

Declaration of Competing Interests

The authors acknowledge that there are no conflicts of interest recorded.

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Author contributions

We use the CRediT Contributor Roles Taxonomy to categorise author contributions. Conceptualization: CR, ID, YK. Resources: CR, ID. Methodology (country comparison): CR, ID, YK. Writing - original draft: CR, ID. Writing – review & editing: YK, MM, IA, NK.

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The same but different: Cross-country comparison of national earthquake policies and societal perspectives of seismic risk in Israel and Switzerland

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Abstract

National earthquake policies aim to mitigate earthquake risk by minimizing the potential damage to lives, property, and infrastructure and by preparing the population to carry out recommended behaviors when an earthquake is felt or a warning heard. In this research, we compare two earthquake-prone countries, Israel and Switzerland, to examine how citizens react to the national earthquake policies in terms of their perceived risk of earthquakes and their preparedness. We examine four national-level earthquake policy components—risk assessment, mitigation regulation, early warnings system, and risk communication with the public—to analyze the differences between citizens' responses in the two countries to the implementation of these policy components. We find that centralized national-level policy in Israel, which includes regulated building codes, a nationwide early warning system, and national awareness campaigns, does lead to higher levels of reported awareness and preparedness. Similarly, in high-risk cantons in Switzerland, which apply these policies (except for the warning system), citizens were also more prepared than in low-risk cantons. We suggest that earthquake policies should include collaboration with local authorities and the population through a more decentralized and localized approach, which includes drills, training, and information dissemination.

Keywords: Earthquake preparedness; seismic hazard and risk; cross-country comparison; earthquake mitigation policies; risk communication