3 A TECHNOLOGY TO MITIGATE RISK

The Third International Conference on Earthquake Early Warning in 2014 was a packed event, with attendees from around the world. It opened with a talk about the urgent work that drew conference participants together (see figure 3.1). The first speaker, UC Berkeley seismologist Richard Allen, had long been a strong advocate of earthquake early warning systems. He saw great potential for these technologies, even in places that sat closer to faults than Mexico City. No longer would earthquakes take people by surprise. Seconds of warning before earthquakes struck would open up new opportunities to protect vulnerable people. Whatever promises earthquake early warning offered, Allen reminded all of us that these systems would only work if they were implemented. Allen had, at that point, yet to secure the support necessary to launch a truly public earthquake early warning system in California, despite the state's well-known seismicity and thriving tech industry. He was working hard to do so, though, and his work to rally interested parties and energize collaborators used Mexico City as a touchstone. He explained:

> Mexico City has a warning system, built after ten thousand people were killed in 1985. The question is, therefore, what would it take to build a public earthquake early warning system in the United States?[1]

Over three days in Berkeley, we heard about a variety of sensor instruments, data processing algorithms, and uses associated with earthquake early warning systems around the world. All earthquake early warning system design is about the relationship between earthquakes and human well-being. Roughly one hundred of us had gathered in a wood-paneled auditorium in Berkeley to

FIGURE 3.1
Richard Allen introduces a distinguished panel of Californian politicians, policy makers, and seismic policy advocates (from left to right, those seated are Jerry Hill, Gavin Newsom, Alex Padilla, Mark Ghilarducci, Ed Lee, and Lucy Jones). *Source*: *Berkeley News*, photographer Peg Skorpinski (2014).

learn about cutting-edge earthquake early warning technology. The 2014 conference brought primarily scientists and engineers but also emergency managers, policy makers, and inquisitive anthropologists together from universities, businesses, NGOs, and government offices across East Asia, western Europe, and North America.[2] Teams of experts gave talks, one after another. At regular intervals the talks broke for coffee and snacks, and to give us time to peruse a small set of posters and draw each other aside for focused conversations in the hallway or in the California sunshine. There was professional diversity here, but a few trends too: discussion tended to be grounded in the geophysics and engineering of these systems; it seemed built on commitment to addressing seismicity as a danger to human well-being; and it showcased a shared confidence that earthquake early warning made sense as part of such efforts.

Most of the people attending the conference had come to talk about what they saw as technical aspects of these systems: high-tech sensors, data analysis, and communication techniques to change the way people experienced earthquakes. Allen's introduction reflected the way that, for all that these technoscientists outlined different subject matter, many thought that earthquake early warning would save lives, property, or money. The people at the conference, drawn together by this common interest, generally seemed optimistic about early warning's utility. Most, however, did not discuss this utility in any substantial detail. Their presentations often mirrored Allen's by describing various early warning technologies as the benefits were obvious and positive impacts inevitable, just a matter of some issues that still needed to be worked out. These potential benefits may not have been fully articulated, but they seemed to be persuasive to many—I only had to look at the who's who of earthquake risk mitigation and California politics on the stage[3] or listen to the ways people spoke about their projects to find evidence of how much promise the people in this community thought that earthquake early warning had.

For all that ShakeAlert was of primary concern to conference hosts and local attendees, there was a good reason that Allen referred to Mexico and its SASMEX in his opening remarks. Mexico's public system had been the first of its kind; in comparison, most of the technologies being described at the conference were in their infancy.[4] SASMEX belongs in any introduction to early warning and its opportunities.

I was attending the conference to learn about approaches to early warning outside of Mexico so as to better understand the Mexican earthquake risk mitigation project within this international context. Two men from CIRES, the NGO responsible for developing and maintaining SASMEX, were there too, though their priorities were less about understanding their own projects and more about showcasing them. Juan Manuel Espinosa Aranda had directed CIRES since it was formed in 1989 and seemed to know nearly everyone at the event. Armando Cuéllar was meeting many for the first time. He was a thoughtful man in his thirties with a PhD in geophysics nearly completed and was responsible for representing CIRES as the head of the organization's Public Outreach Department. The Mexican earthquake early warning system that they came to speak about seemed well known within this community.

In his comments at the 2014 meeting, Allen moved on quickly from the solemn reminder of the disastrous Mexico City earthquake and the development of SASMEX. For Allen, as for many of the others listening, this was a way of framing technical innovations and drive toward implementation.[5] Sitting beside Cuéllar and Espinosa Aranda, who I knew to be working around the clock to refine SASMEX and advocate for it, this way of characterizing earthquake early warning's development seemed detached from reality. It sounded easy. By 2014, with several years of research under my belt, "easy" was not a word I would ever use to describe SASMEX's development and implementation. In this chapter, I address how technoscientists in this community describe earthquake early warning systems' benefits—and foreground its promises while neglecting the challenging aspects of real-world implementation.

To do so, I draw on my experiences as a participant observer at conferences like this one as well as reflections on popular media, scholarship, and archival documents. I consider prevalent ideas about risk mitigation that circulate in international communities and Mexico, and I argue that the way that this international community understands the promises of earthquake early warning needs to be understood in the context of contemporary ideas about how hazardous environments threaten human life and well-being. Further, these ideas easily support techno-optimistic trust in earthquake early warning to change relationships between environments and society, without careful attention to issues of specific use. In this chapter, I introduce the ideas about seismic hazards and people at risk that inform earthquake early warning design. I historicize the development of these technologies. Finally, I describe these global trends in risk mitigation in the particular forms that they take in Mexico. In this way, I show how earthquake early warning technologies make sense to so many as a tool to mitigate risk in hazardous environments, and I situate SASMEX in the context of these logics.

HAZARDOUS EARTHQUAKES AND VULNERABLE PEOPLE

For most, if not all, of the technoscientists I sat with in Berkeley (and many at other conferences before and since), the term "earthquake" is a way to describe how the ground shakes. Earthquakes are generally caused[6] by constant and subtle shifts in our planet's crust.[7] This may happen for a number of reasons—the earth is, after all, a thermodynamic system of pressure and motion. Tectonic plates are always moving in different directions, over, under, and against each other, but immense friction also keeps them from slipping while stress builds up at faults within plates and at their interfaces. Eventually, the stress is great enough that rock slips against rock, releasing seismic energy, which travels through the earth at roughly the speed of sound according to physical effects of density, rigidity, resonance, and refraction. Earthquakes move through various materials differently, with a variety of measurable effects evident in the waters, soils, and built environments that respond to and propagate quakes.[8]

By the late nineteenth century, a number of mechanical tools had been developed for understanding earthquakes, most of which were associated with research programs in Europe, East Asia, and, to a lesser extent, the United States.[9] When contemporary earthquake early warning systems register quake motion and describe it in terms of the magnitude of energy that a quake releases or in relation to wave frequency or ground acceleration, they are relying on tools and using language that technoscientists around the world share.[10] However, the way we describe earthquakes remains contingent on other issues—including why we understand earthquakes to be worth describing in the first place.[11]

For those gathered at the Berkeley conference in 2014, earthquakes were not just geophysically fascinating subjects for investigation. They were also hazards. This distinction is both crucial and deceptively simple. For those involved with emergency management and disaster prevention, it is not only necessary to grapple with the physical characteristics of the unpredictable and ongoing movement of the earth's crust but also to consider their implications, that is, the destruction that such motions cause. When earthquakes are not just seismic phenomena but also hazards, describing them means more than talking about faults, waves, or soils; the ways that they threaten people also become key aspects of their definition. How exactly the risk that earthquakes pose should be described is a crucial topic of attention—and debate—for those who build and operate earthquake early warning systems.

In physical terms, an earthquake with a larger magnitude tends to be more dangerous than a smaller one. It shakes things harder. If it originates near a population center, observers are likely to experience more intense shaking, in the language of seismology, assessed by the effects it has on the built environment. But when a quake starts deep underground or far from human habitation, that energy may dissipate and prevent it from becoming a significant threat to people. Certain soils may be more or less sensitive to seismic motion, too. Emergency managers and disaster prevention specialists regard magnitude, distance, and soil qualities as insufficient for describing how earthquakes put people at risk. Other issues are far more important than those.[12]

The United Nations Office of Disaster Risk Reduction and the Centre for Research on the Epidemiology of Disasters address the issue on a national scale, in relation to both physical and social conditions. These agencies calculate that almost 500,000 people were killed by earthquakes between 1996 and 2015,[13] and nearly 126 million affected in other ways—injured, left homeless, or in need of emergency assistance of some kind. People in low- and high-income nations alike experienced similar levels of shaking, but the consequences of the magnitude 7 earthquake that struck Haiti in 2010 were devastating compared to the 7.1 quake that shook Aotearoa, New Zealand that same year. The Haitian earthquake had a hypocenter thirteen kilometers underground, just twenty-five kilometers west of the capital city of Port-au-Prince. New Zealand's was similarly close to a city—just ten kilometers underground and forty kilometers from Christchurch. But while the Haitian government's official tally shows that 316,000 people lost their lives in Haiti—over half of those killed by earthquakes between 1996 and 2015 died then and there[14]—no one died in New Zealand at all.[15] According to the reporting agencies, this terrible difference can be attributed to the comparative wealth of people living in these places, the condition of the built environment, and the involvement and effectiveness of government.[16] These inequities extend far beyond the immediate impact of an earthquake event and into recovery and redevelopment.[17]

When people who study earthquakes call them "hazards," they are alluding to this relationship between environment and society. They mean that an earthquake might cause harm to people but that this harm is not inevitable from a purely geophysical perspective. An earthquake may cause harm, or not, depending on factors that have nothing to do with its physical characteristics. Making sharp distinctions between a hazard and a disaster has been conceptually important for many involved in earthquake early warning, and for people who work in emergency management and disaster prevention more generally. Popular culture and colloquial conversation in Anglophone and Hispanohablante worlds alike are full of casual references to earthquakes as "disasters" by definition—natural disasters, to be precise. To name earthquakes "disasters," however, is to confuse one component of a complex set of events and conditions with the cumulative effects of all of them put together. Not all earth motions have to be disastrous. Social scientists have been documenting patterns in disaster effects for many years, and the idea that it takes more than an earthquake to make a disaster is well established in policy.[18] As historian Scott Knowles has written, we live in "an era of disaster 'adaptation,'" and this has consequences for how we make plans to minimize disasters' effects. Institutions like university programs and emergency management centers have encouraged these trends.[19] It has become commonplace to assert that disasters are "not natural"[20] and can, consequentially, be prevented.[21] The notion that the dangers of seismic disasters might be avoided if only the designers of built environments made different choices is powerful today.[22]

This mode of thinking is sometimes quantified to integrate it into technical systems and mathematical reasoning. "Risk is a product of hazard and vulnerability" becomes "risk is hazard multiplied by vulnerability" or "risk = hazard x vulnerability."[23] This relationship among risk, hazard, and vulnerability is one way to describe and compare the dangers that one earthquake might pose to different communities. The formula also serves as a purely rhetorical device to discuss how social conditions and human action might influence the likelihood of a nasty outcome.[24] When "risk = hazard x vulnerability," attention to social conditions becomes key to diminishing the effect of hazards. This is not the same as a call for greater justice to equalize distribution of suffering, but it may direct our attention in ways that are foundational for such claims.

Many people referenced this relationship between risk, hazard, and vulnerability throughout my ethnographic fieldwork. It came up in interviews, lectures, and archival documents. Sometimes these experts used it to conduct a practical evaluation of quantified hazards, risks, and vulnerabilities—and in those cases, it did tend to bear the mathematical signs of "x" and "=" as marks of their straightforward, mutual dependence. At other times, the formulation simply referred to a collection of issues, each separately defined, that have effects on each other. Often, it served as an argument for considering ongoing social conditions along with other factors when discussing the propensity for disaster.[25] Operationalized or not, the equation has marked real disaster prevention and risk management efforts. Since earthquakes cannot be stopped, something about social life would have to be changed to reduce risk.

The equation circulated in UN documents and disaster policy discourse, notably in a UN Disaster Relief Coordinator meeting of multidisciplinary experts in 1979, describing an effort to standardize language around disaster.[26] "Risk" was defined in this report in terms of expected degree of loss, and "hazards" as probability of an event within a given time.[27] The report authors proposed that, in the context of the equation, vulnerability could be assessed in scale from 0, no effect, to 1, "total loss."[28] At that point, minimizing human vulnerability could be conceptualized as a simple matter making changes in the built environment.[29]

Addressing vulnerability to hazards, however, has come to mean more than changing the built environment. Today it might incorporate addressing complexes of ongoing social practices, capacities, relations, and resources that facilitate exposure or interfere with resilience. In the latter half of the twentieth century, experts began to consider this "expected loss" a matter of how people lived, not just where they lived.[30] In recent years, the United Nations program has increasingly asserted the importance of issues related to poverty and institutional capacity.[31] While some challenge the idea that "disasters" begin with hazardous events when radical inequality and poverty already characterize so many lives,[32] others find it easier to acknowledge that social issues have important effects but focus their attention on physical ones.[33] These insights are borne out in diverse research, and guide efforts to describe and model the physical and social factors of disaster impact and long term recovery.[34] All these currents exist in the context of broader debates about environmental justice and whether to emphasize a community's existing capacities, including opportunities to build resilience, or to instead highlight a community's deficits, limitations, and needs.[35]

These ways of understanding hazardous environments and people at risk have had significant consequences for risk mitigation system design. Earthquake early warning systems are primarily designed in light of physical vulnerability, but the systems concern social vulnerabilities, too. Systemic poverty, after all, has consequences for how buildings are constructed and how people rebuild their lives after experiencing a disaster. Even if the Mexico City built environment never became safer, however, and its significant problems with poverty remained unalleviated, the earthquake early warning system could help in the moment of an earthquake.[36]

DEVELOPING ESSENTIAL INVESTMENTS

The UN Office for Disaster Risk Reduction has called early warning systems "essential investments that protect and save lives, property and livelihoods, [and] contribute to the sustainability of development." Warnings are derived from technologically mediated ways of understanding, analyzing, and communicating information about issues like air quality, bombings, tsunamis, extreme weather, floods, fires, and mudslides.[37] In general, these systems work best in places where dangerous events are likely but are not precisely predictable.[38]

In the most basic sense, warnings are meant to make it possible for people to learn about dangerous events as they begin and act based on this knowledge. While any warning is challenging to generate, earthquake early warnings are particularly troublesome.[39] Earthquakes are quick, and unlike floods, they have no reliable precursors.[40] An earthquake can only be detected after it starts. The development of a useful warning under these conditions is no easy task. Earthquake early warning nonetheless captures the imagination. The idea of making new kinds of knowledge about earthquakes available fascinated people long before Mexican engineers started building a system that could do it.

Contemporary proponents of earthquake early warning systems cite a shared ancestor in the nineteenth century, long before the approaches to risk, hazard, and vulnerability outlined above became explicit rationalities for disaster risk reduction.[41] This nineteenth-century plan is the earliest on record for automatically registering, analyzing, and communicating information about the earth's motion.[42] It appeared in the *San Francisco Chronicle*'s Daily Evening Bulletin on November 3, 1868. There, in the middle of a dense page of news, commentaries, and advertisements (just above an announcement about the arrival of a steamer from San Luis Obispo and just below a long and involved account of a Republican political event), a medical doctor named John Cooper described what he called an "Earthquake Indicator" which offered "the means, perhaps, of saving thousands of lives."

This earthquake early warning plan, like those in use today, makes sense in the context of certain conditions and ideas about both the unsteady earth and the people that it might put at risk. As a Californian, Cooper had probably experienced his share of ground motion. He had also been reading up on earthquakes, a matter of popular fascination at the time.[43] For him, an earthquake was "a fearful convulsion" and "a wave motion of the surface of the earth." He based his understandings on the writings of J. B. Trask, a physician who also served as the first unofficial state geologist of California.[44] If, Cooper wrote, an earthquake started far enough away from San Francisco, his system could notify residents before it reached the city. Cooper was proposing a new configuration of what historian Megan Finn has called "disaster informatics"—an information infrastructure that might have ongoing consequences for the experience of earthquake emergencies.[45]

It was clear to Cooper that such a system would need to be automatic and responsive to earthquakes that might happen at any hour of the day or night. It should not rely entirely on human discretion, either. Telegraph operators might be unreliable; they might not be ready to ring the bell when needed, or they might ring it too often. Instead, he proposed a system based on electricity that included a networked "mechanical contrivance" arranged between ten and one hundred miles outside of San Francisco. If a wave crossing the surface of the earth "rose high enough" to set off the mechanism, it could start an alarm bell ringing near the center of the city.

That was Cooper's system as proposed. A successful execution of his plan would require more than just a "mechanical contrivance," however. Crucial to Cooper's scheme was the idea that people—at least, any hearing person in range of the bell, who understood what the sound meant—would know when an earthquake was imminent. They could produce and share knowledge about not just what was happening across substantial distance but what was occurring in the earth itself.[46]

Cooper's ideas about an automated system were part of a broader trend in earth science: a turn toward mechanical sensing. While human senses were, and are, necessary for detecting and parsing the effects of earth motion, mechanical tools were becoming increasingly popular.[47] Such sensory technologies have formatted new ways of knowing the complex geophysical systems that comprise the earth we experience. STS scholar Paul Edwards has described this knowledge as a matter of integrating diverse data collection strategies, analytic techniques, and models to make data global. But this globalism is, itself, infrastructural. Efforts to sense and model earth systems are not just a matter of knowledge production, but they also frame new ideas about what might be possible. The ways we want to understand the earth—indeed, how we expect to know planetary systems and motions and use this knowledge—inform the increasing popularity of environmental monitoring projects.[48]

Early warning systems should be considered just one kind of environmental monitoring project. These projects take many forms that consider and seek to transform the way people live with earth systems today.[49] They do not quite provide the kind of integrated models that Edwards wrote about. Each earthquake early warning system is discrete, incorporating its own sensors and site-specific analytic processes and mathematical models. All share a few basic features. They incorporate automated processes. Some make an earthquake distinguishable from background ground motion, such as that created by a passing vehicle.[50] Others make it possible to estimate an earthquake's magnitude just as it begins to shake.[51] They are networked to communications systems and trigger a variety of different actions depending on both social and technical possibilities. Earthquake early warnings slow trains, send elevators to the ground floor of tall buildings, and raise bridges. They trigger sirens and secondary alerting systems, like smartphone apps.

The first earthquake early warning systems were implemented nearly one hundred years after Cooper suggested the idea. Mexico and Japan were the first nations to develop earthquake early warning technologies, but these tools have also been implemented in many places in western Europe, as well as Romania and China, though not always for public use so much as industrial automatic functions.[52] Systems are currently under development in Chile and Nepal, and, of course, the west coast of the United States.

For all that this tool has become more practical, few sites for earthquake early warning have the affordances that Mexico does; with its rich, populous, and powerful city located at a distance from quakes that would allow warnings to be particularly useful, it has provided an ideal context for earthquake early warning adoption. Critics note that warning systems have very little time to alert for shallow earthquakes that originate close to population centers. If quakes are strong enough to be concerning, their P-waves may provide the most effective early warnings.[53]

These debates make it evident that there are significant differences of opinion regarding the nature of a productive warning within the community of technoscientists who design and debate earthquake early warning systems. Far from a singular kind of technoscientific undertaking, then, early warning systems represent an opportunity to change how people experience earthquakes, potentially in a variety of ways. In Mexico, this technology provided a chance to improve physical safety in a new way that could work in concert with other ideas, programs, and priorities.

PART OF A SEISMIC CULTURE

Talks, posters, and even conversations between sessions of the 2014 conference were often related to sensor technologies or algorithms. However, the presence of fire and emergency service workers in the audience meant that I could never quite forget that earthquake early warning was not just a matter for technoscientists or that speedy data processing would not necessarily mean a successful warning. Pulling off effective warnings required technoscientists to collaborate with others and integrate their systems with institutions and relationships in context. Local coordination is crucial to how and whether earthquake early warning functions. It is never only a matter of integrating computer programs, connecting wires, or even making processes coherent across organizations. It is also a matter of the conceptual integration of priorities and projects in their contexts.

CIRES is officially tasked with developing and maintaining SASMEX's instruments. They look to emergency managers in Mexico's National Civil Protection System to integrate their systems with other technical and social infrastructures. Civil Protection agencies are charged to "protect as well as preserve the individual and society."[54] This work makes Civil Protection part of what researchers call a security apparatus, that is, the collection of semi-coordinated systems and practices that inform how people and institutions orient toward danger and safety.[55]

Civil Protection coordinates emergency action, post-disaster recovery, and attempts to prevent disasters in the first place. Although all thirty-one Mexican states and Mexico City have Civil Protection offices integrated into their governance structures,[56] the agency has been institutionalized differently everywhere. It occupies a variety of positions in governmental hierarchies throughout the nation.[57] While Civil Protection state offices have legal responsibility for resource coordination, these municipal governments have primary responsibility for emergency response.

In Oaxaca and Guerrero, Civil Protection officials gave me the same glossy, stapled booklets I often received in interactions with Civil Protection officials—documents developed centrally to explain one hazard or another, and how it might be prevented from becoming a real risk, selected particularly for those issues most pertinent in each state. Oaxaca officials also shared an internally produced document about Oaxacan earthquakes. I visited the SASMEX servers in the back of the Civil Protection offices, enclosed by dark glass panels beside a screen displaying the status of the loudspeakers that broadcast earthquake sirens through the city, and I saw earthquake early warning as just one effort among many. I also witnessed the real stuff of emergency rescue on display: motorcycles receiving maintenance and an organized mix of departmental and various staffers' personal tools on shelves and along walls, ready for emergency evacuation or first-aid in the face of common hazards like earthquakes, mudslides, and floods (the threat of hurricanes and tsunamis was not particularly high that far inland, though they were more of an issue on the state's coast).

While officials told me that Guerrero had one of the more respected Civil Protection institutions in Mexico, this power was not immediately visible in its offices. The ceiling of Guerrero's office of Civil Protection in Chilpancingo drizzled an inconsistent spatter of dirty water that had, when the building's drains were clogged in a storm, simply collected on the roof and was slowly filtering down upon us. Like Oaxaca, Guerrero is among the most seismically active and poorest states in the nation.[58] It was the site of the first field stations in the Mexican earthquake early warning system, and after Mexico City and Oaxaca, it was the next to start disseminating earthquake early warnings. It also suffers storms, mudslides, tsunamis, floods, and dangers from incendiary materials like the gas canisters people use for cooking.

The Civil Protection offices were busy with people working to improve the structural components of buildings, enforce building regulations, support governments' abilities to maintain crucial services in the event of a crisis, and change individual priorities and social behavior. There, my questions about earthquakes and earthquake risk mitigation were put in context of broader projects of risk mitigation focused explicitly on social life. "We cannot predict quakes," one thoughtful official in Oaxaca calmly explained, "but our job is to build a culture."[59] He and his colleagues were tasked with more than earthquake risk mitigation. They explained "culture" as a key concept they used in their work to make Mexicans safer.

There are many ways to define "culture." As anthropologist Michael M. J. Fischer explains, the concept has experienced "historically layered growth of specifications and differentiations . . . that . . . allow new realities to be seen and engaged as its own parameters are changed."[60] For anthropologists like myself, "culture" often suggests the habits of life and mind that people receive, rework, and reproduce, as well as the structures and forces that frame how they do so. The term is not anthropology's alone to work with, however, and it has other meanings outside of our research.[61] In the offices of Civil Protection, "culture" means something very specific. Some of their materials defined it as "the set of knowledges, beliefs, abilities, attitudes, and values related to earthquakes which, in a given place and moment, every community has as a product of its historical experience."[62] Civil Protection's founding documents described "culture" as an optimal site where an intervention can happen to both reinforce aptitudes that already exist and teach new abilities, while elevating "aspiration and creativity."[63] By 2012, Civil Protection authorities had been tasked not only with recognizing and fostering communities' existing capabilities or strengths but also with developing new and useful elements of culture by educating people and encouraging them to change how they live.[64]

Many Civil Protection officials and commenters in the popular media thought they had a long way to go to reach such goals. They described a public uninformed about and unprepared for hazards and as "uncultured." In conversations and systematic searches of news archives, I learned that many people thought Mexicans had no seismic culture (or risk culture, self-protection culture, or prevention culture) at all.[65] In fact, rather than describing culture as certain sets of knowledge, beliefs, and attitudes that might not include as much engagement with risk mitigation strategies, these accounts suggested that Mexico simply did not have culture relevant to risk mitigation at all. I asked Civil Protection officials about it when I met with them. In a community with an adequate "culture," I learned, ordinary people understand their roles and responsibilities, and incorporate strategies for risk mitigation into their lives. People with adequate cultural awareness would know how earthquakes occur and where they are likely to be felt, and would respond appropriately to that knowledge. Taking part in drills, knowing and implementing general strategies to make buildings safer, and developing emergency plans and the ability to stay calm in an emergency were all key activities that Civil Protection officials associated with developing a culture of preparedness. All the work they did to cultivate such a culture, however, never seemed to have satisfactory results. By and large, Civil Protection officials told me, most Mexicans were not aware of or committed to seismic safety—or, indeed, any form of risk mitigation—in this way. Amid discussion of an absent seismic culture, there is, of course, an occasional reference to such a culture that may once have existed in a pre-Hispanic Mexico. Inevitably, these references to a mythologized and unified historical past rarely include much detail.[66] I have asked experts in disaster prevention if positive examples exist in Mexico. While perhaps they do, I have yet to learn of any.

Many times, culture is depicted in deficit, with outreach envisioned as a one-way communication process in which experts simply distribute information and try to instill correct priorities and elicit certain behaviors. Science education and communication researchers have critiqued deficit models like this. People are not passive recipients of knowledge, and treating them as such without substantially engaging the variety of ways in which people might encounter the world not only privileges elite experts' perspectives over those of others whose lived experience—and indeed, lives—may be at stake, but it is also an ineffective strategy for communication and cultural change.[67]

There are further implications, though. Addressing culture as a deficit means placing responsibility for acting to mitigate unsafe conditions on ordinary people. When these conditions are the product of broader physical and social issues, such as poverty and marginalization, then individuals have limited opportunities to make significant changes.[68] As critics of such strategies point out, "scapegoating" people for how they are exposed to danger means treating those who suffer harm as passive, indebted, or simply bad victims for pursuing their own goals and livelihoods.[69] By this logic, vulnerability to earthquakes becomes the result of failures of the Mexican people, not the state, which creates and enforces safety regulations. Mexican disaster scholar Jesús Manuel Macías has critiqued Civil Protection institutions on precisely this issue, writing that they "transfer responsibility for the protection of life and property from a state authority to the population at risk."[70] Some Civil Protection officials, however, including those I met in the dripping and dirty office in Guerrero, spoke passionately about what they wanted to do for people and about their careful efforts to engage communities in appropriate risk mitigation practices.

What a tangle. In a Starbucks on busy Insurgentes Street in Mexico City, I laid all these issues out before Alejandro Martínez, an engineer and Civil Protection official who had been involved in seismic risk mitigation work for many years. He was generous with his insights and easy to talk to, so I described my confusion. What was I supposed to make of how some people approached risk mitigation as if ordinary people were always failing at keeping themselves safe? How could I understand approaches to reducing vulnerability through culture that some saw as engaging with community needs and practices and others used to scapegoat the very people most at risk? After traveling to Oaxaca and Chilpancingo, sitting down for meeting after meeting, and collecting and evaluating articles from local newspapers, I knew this was a key issue. These ideas about Mexicans and their culture formed the backdrop for the development and growth of SASMEX.

Martínez was sympathetic. He explained the use of the "culture" concept that he observed as a sort of heuristic, a way of drawing attention to issues that could be addressed in the context of incredibly limited resources and funding. "*Our* culture," he told me, using the term now to describe the beliefs and practices of those who worked within Civil Protection, "is to identify problems and work for the future."[71] It is true that Mexico suffers from corruption and a limited ability to enforce building codes, and that many Mexicans do not have the resources to build and maintain safe spaces. An earthquake early warning can be used to address this conundrum.

An earthquake early warning system makes sense as one of many efforts to reduce vulnerability and is particularly revealing as an effort to put responsibility for personal risk mitigation on ordinary people in the absence of other resources. Mexico is a poor nation in comparison to others represented at the International Conference on Earthquake Early Warning, and others have different logics and institutions of risk management into which such a technology fits. Taken on its own, an earthquake early warning system may put the onus on ordinary people for preserving their own safety when there is a limited amount that they can do if the agencies and organizations around them are not also working to reduce their vulnerability and support resilience by hardening infrastructure, enforcing regulations, or providing financial support to struggling people.

THE TECHNOLOGY EXISTS

At the third International Conference on Earthquake Early Warning, the then California state senator and earthquake early warning advocate Alex Padilla commented, "I don't want to be here after the next big one wondering why we didn't implement a system when the technology existed."[72] Certainly, tools for earthquake early warning exist, but the implication that they can simply be implemented in one place as they have been in another is misleading. Although technology advocates do not always take the time to unpack exactly why they believe a given tool makes sense, technology development relies on certain ideas that are both shared internationally and, as I have shown, are specific to a nation or community.

Padilla's comments were like many discussions of this technology at the conference in that they described earthquake early warning systems as largely technical. In the worst articulation of this popular logic, people developing effective networked sensors and algorithms for early warning need not concern themselves with considerations of user perspectives and needs. Certainly, the diverse technical innovations that make earthquake early warning possible are worth celebrating and mobilizing to inspire new implementations. Treating risk mitigation technology in this way, however, while also explicitly considering reduction of human vulnerability as its core purpose, creates a difficult, almost paradoxical, situation. Here, people are the central beneficiaries of these technologies.

Earthquake early warning technologies makes sense to so many as tools to change how people at risk live in hazardous environments. Paying attention to how people may be vulnerable to hazards is essential to modern perspectives on risk mitigation around the world. Just as vulnerability can mean both physical exposure and poverty, however, addressing it can mean very different things: for example, giving ordinary people or governments responsibility for risk mitigation, or engaging with communities' particular practices and needs, or denigrating them as deficient by definition. These concepts inform technology development and adoption. Nonetheless, those technoscientists concerned with making changes in how people experience earthquakes may share only the loosest understanding of what a risk mitigation technology can do.

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