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Engineering on Shaky Ground: Lessons From Mexico

A close examination of Mexico's public earthquake warning system demonstrates that if these technologies are to be effective, they must be integrated into institutional and social infrastructure.

The Third International Conference on Earthquake Early Warning in 2014 drew roughly 100 attendees from around the world, enough to pack a small lecture hall. The first speaker, University of California, Berkeley seismologist Richard Allen, saw great potential for better systems. No longer would earthquakes take people by surprise. Seconds of warning before earthquakes struck would create new opportunities to protect vulnerable people—sirens would wake them and help them evacuate, and automated signals would slow factory lines, elevators, and commuter trains.

At the time of the conference, United States-based scientists were working hard to secure the support necessary to launch a public earthquake early warning system for California, Oregon, and Washington (a project I have studied and written about elsewhere). Allen's introductory talk used California's southern neighbor as a touchstone. He explained: "Mexico City has a warning system, built after 10,000 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?"

The warning system Allen referred to is the Sistema de Alerta Sísmica Mexicano (SASMEX). It relies on a network of accelerometers strung along the central western coast of Mexico to automatically register quakes as they start and then send out warnings. Mexico City can sometimes get more than a minute of notice before shaking that starts on the Pacific coast of Mexico reaches them, and SASMEX can also offer at least 10 or 20 seconds of warning to places elsewhere in Mexico.

When SASMEX went online in 1991, it was the first system of its kind in the world, and at that point it used just 12 stations. Since then, the state-funded system, maintained and championed by a small community of Mexican engineers, has expanded to include 98 seismic field stations that send alerts to six cities. Proponents suggest that this system, and others like it around the world, can help ordinary people and automated systems prepare for oncoming earthquakes, saving lives and limiting economic losses.

Early warning technologies were the focus of the 2014 conference, which primarily brought together scientists and engineers but also emergency managers, policymakers, and me, an inquisitive anthropologist. Attendees hailed from universities, businesses, NGOs, and government offices across East Asia, Western Europe, and North America. The audience represented professional diversity as well as an abundance of training in geophysics and engineering, and a concomitantly shared confidence that earthquake early warning made sense in the effort to save lives, property, and money.

Conference presentations often centered on technological developments, and they discussed early warning technologies as if the social benefits were obvious and the positive impacts inevitable—as if it was just a matter of some issues that still needed to be worked out.

To me, those characterizations of earthquake early warning development seemed detached from reality. As described in many papers and posters at that conference, getting from alert to response sounded easy. Having studied it for years, "easy" was not a word I would use to describe SASMEX's development and implementation. But technologists in this community often elaborate on the benefits of earthquake early warning systems and foreground their promises while neglecting mention of the challenges involved in practical use.

Seismicity

These challenges were on full display three years later, when a terrible earthquake shook central Mexico on September 19, 2017. SASMEX worked, I was told, but not as well as it might have. Though exact numbers of those impacted are always hard to determine in a disaster, more than 200 people were killed in Mexico City alone and almost 150 elsewhere. It was the kind of complicated "success" that can happen when a technology designed to support public safety is released into the wider world.

The complications with the warning system in September 2017 arose from intersecting issues: unpredictable earthquakes, Mexican social practice, and unevenly maintained technologies. For example, the system was designed to prevent a repetition of the 1985 disaster by anticipating the range of earthquake possibilities inherent in the region's geology and geography. The engineers at the Center for Seismic Instrumentation and Registry (or CIRES, from its Spanish-language initials) planned the earthquake early warning system based on the likelihood that another large earthquake would originate from the west coast of Mexico, not 150 miles inland like the quake in September 2017. It is not clear that a substantial warning could have been generated even if stations had been positioned differently, but as it was, the system offered comparatively little advance notice before the ground began to shake.

The magnitude 7.1 quake originated outside the central Mexican city of Puebla, less than 100 miles away from Mexico City. Only a few of SASMEX's networked stations were positioned nearby, so the earthquake early warning system could only generate an alert 12 seconds before serious shaking began in Mexico City at 1:15 p.m. By that time, some of the fastest-moving seismic waves—the comparatively weak compression waves, or P-waves—had already hit the city.

Also relevant was an unfortunate coincidence of timing and how the disastrous quake of 1985 had been used as a lesson. On the morning of September 19, 2017—32 years to the day after the 1985 earthquake—the nationwide earthquake drill was conducted, an activity coordinated each year in remembrance of the quake. An estimated 7.5 million people responded to an earthquake alert at 11:00 a.m., practicing their response as if a magnitude 8.0 quake were rushing inland from Mexico's west coast.

The actual earthquake that followed barely two hours later was not part of the plan. Coming so soon after the drill, people who did hear the alert for the real quake reported confusion and doubt. This uncertainty did not encourage them to take advantage of what little time they had to drop, cover, and hold on before the shaking escalated.

Finally, next-step systems responded to SASMEX alerts in ways that created additional challenges: some sirens blared the warning out for all to hear, while others remained silent. Their upkeep, tasked to disparate agencies with varying priorities, was simply inconsistent.

This decentralized way of managing earthquake risk mitigation runs counter to its presentation as a single intervention. CIRES is officially tasked with developing and maintaining SASMEX's instruments; its engineers take care of the technologies that generate alerts, and municipal governments handle emergency responses. Mexico's National Civil Protection System, with emergency managers in Mexico City and all state governments, is supposed to integrate earthquake detection with relevant infrastructure such as sirens and response teams. But, like so many engineering projects worldwide, Mexico has approached early warning as a technical system with social implications, rather than as a system integrated into social life with environmental conditions.

When technologists presented their sensor technologies and algorithms at the 2014 conference, they focused on the speed of calculations to generate an alert, not the strength of connections needed to produce a response from various communities that might make use of an alert. Among the attendees were a few fire and emergency service workers—to me, their presence was a reminder that even the speediest, smartest data processing does not necessarily guarantee a successful warning. That would require collaboration: technoscientists forging relationships and integrating their alert systems with social institutions.

Part of a seismic culture

Similar earthquakes can have very different impacts. Consider the consequences of the magnitude 7.0 earthquake that struck Haiti in 2010 compared to the 7.1 quake that shook New Zealand that same year. The Haitian earthquake had a hypocenter 13 kilometers underground, just 25 kilometers west of the capital city of Port-au-Prince. New

Zealand's quake was also close to a city—just 10 kilometers underground and 40 kilometers from Christchurch. But while the Haitian government's official tally shows that 316,000 people lost their lives—representing over half of all earthquake deaths globally between 1996 and 2015—not a single person died in the New Zealand quake. 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. These inequities extend far beyond the immediate impact of an earthquake event and into recovery and redevelopment.

Emergency managers in Mexico's National Civil Protection System are charged to integrate earthquake alerts with other technical and social infrastructures, and although they can see what a difference adequate resources make, civil protection offices often have fewer resources than they need. Officials told me that the Mexican state of Guerrero had one of the more respected civil protection institutions, but this was not immediately obvious. For instance, as we met in Guerrero's office of civil protection in Chilpancingo, dirty rainwater that had pooled on the roof from the building's clogged storm drains drizzled an inconsistent spatter onto us from the ceiling. Guerrero is one of the most seismically active and poorest states in the nation. In fact, Guerrero was the site of the first field stations in the Mexican earthquake early warning system, and, after Mexico City and Oaxaca, it was the third to start disseminating earthquake early warnings. Yet Guerrero must also deal with storms, mudslides, tsunamis, floods, and dangers from incendiary materials like gas canisters for cooking, which is a lot for its people and civil protection services to manage at any given time.

In Oaxaca and Guerrero, which are a thousand miles apart, civil protection officials gave me the same glossy, stapled booklets explaining hazards and how to minimize risks. 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. But the real stuff of emergency rescue was also all around: 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.

All the civil protection offices I visited were busy with people working to do things like respond to immediate emergencies, conduct activities that support 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 the 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." He and his colleagues explained "culture" as a key concept they used in their work to make Mexicans safer.

Many civil protection officials and commenters in the popular media felt there was a long way to go to reach such goals. They described a public uninformed about and unprepared for hazards as "uncultured." In a community with an adequate "culture," officials told me, 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 to implement 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 a culture of preparedness. 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. And all the work they did to cultivate such a culture, they felt, never seemed to have satisfactory results.

It's not uncommon for people professionally concerned with earthquake risk mitigation to describe culture as deficient, with outreach envisioned as a one-way communication process in which experts simply distribute information to try to instill correct priorities and elicit certain behaviors. Science education and communication researchers have critiqued so-called deficit models like this and found that treating people as passive recipients of knowledge, rather than engaging with how they encounter the world, is not only a misunderstanding of how people learn new information—it's ineffective for communication.

There are further implications, though. By this logic of culture as a deficit, vulnerability to earthquakes becomes

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the result of failures of the Mexican people, not the state. 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."

It is true that the Mexican government, charged with creating and enforcing safety regulations, suffers from corruption and a limited ability to enforce building codes, and that many Mexicans lack access to the resources needed to build and maintain safe spaces. Many 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 their careful efforts to engage communities in appropriate risk mitigation practices. They want to do more than "transfer responsibility," though they do not have many resources to work with.

An engineer and civil protection official who had been involved in seismic risk mitigation work for many years explained that the use of the "culture" concept he observed was a sort of heuristic way of drawing attention to issues that could be addressed in the context of incredibly limited resources and funding. "*Our* culture," he told me, referring to the beliefs and practices of those who work within civil protection, "is to identify problems and work for the future."

An earthquake early warning system makes sense as one of many efforts to reduce vulnerability—but is particularly revealing when it's operationalized as an effort to put responsibility for personal risk mitigation on ordinary people in the absence of other resources. Taken on its own, an earthquake early warning system may put the onus on ordinary people for preserving their own safety. But there is little they can do if the agencies and organizations around them are not also working to reduce vulnerability and support resilience by hardening infrastructure, enforcing regulations, or providing financial support to struggling people.

The technology exists, but…

It seems to me that well-meaning technologists limit their effectiveness by defining their responsibilities as purely technical, without overlaps with policymakers, emergency managers, and other potential collaborators. But even excellent performance within a narrow task will not yield broad success when it comes to early warning. Instantaneous, accurate detection is not enough to warn people out of harm's way. And educational campaigns and a responsive culture cannot generate the safety that comes from well-constructed buildings.

With the proliferation of seismic monitors, technologists can now render the earth as a place that's constantly moving, crisscrossed by faults and tectonic plate interfaces. They can study the deep composition of the planet and detect secret bomb tests. Data generated by seismometers and accelerometers have allowed twentieth- and twenty-first-century researchers to collect masses of information about earth motion and put it to use in ways that would have been unimaginable in previous environmental monitoring regimes. The proliferation of technologies designed for risk mitigation seems inevitable.

But experts need to do better if they want to understand—and maybe even succeed at developing—environmental monitoring and risk mitigation technologies that have more of an impact. While I remain guardedly optimistic about the potential of earthquake early warning, fulfilling its promises is no small undertaking.

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Technocentric approaches are an impediment. When technologists take on alerting on their own, when interagency and interdisciplinary collaborations are not built, when potential user communities are not meaningfully involved in alert decisionmaking (or even consistently taught about alert utility), when the infrastructures that support early warning dissemination are not well integrated, and when funding for earthquake early warning is unreliable at best, it should be no surprise when earthquake early warning falters.

On the other hand, if experts in communication and social research are brought in from the very beginning, if education and community involvement are made high priorities, if efforts at warning are controlled and coordinated, and if funding is reliable—well, earthquake early warning might help protect people and property precisely in the ways that advocates hope.

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