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Social sustainability dimensions in the seismic risk reduction of public schools: a case study of Lima, Peru

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The provision of education is a vital feature of a socially sustainable system. However, students in highly seismic areas are under permanent hazard, a critical situation for student populations with high vulnerability factors such as insecure infrastructure, low teacher salaries, and poor living conditions due to social exclusion and inequity. In this article, we use community-based elements, such as institutional arrangements and a collaborative and interdisciplinary approach, to develop a comprehensive multi-scale risk model for socially sustainable seismic risk reduction in schools. We analyze the case of schools in the city of Lima, Peru, integrating aims, objectives, and methodologies based on risk-reduction strategy from previous disciplinary studies. Identifying schools that, on one hand, can be most useful during emergency-relief work and, on the other hand, educational facilities that could cause the most harm to students are priorities for a risk-reduction strategy. We identify social sustainability factors in schools, such as security and well-being of the student population, accessibility, incomes, basic service provision, and community organization. Specifying the spatial and territorial relationships within public school surroundings is essential to guaranteeing the effectiveness and efficiency of risk-mitigation strategies.

Keywords: Social sustainability, seismic risk, mitigation, community-based disaster risk management

Introduction

The effective provision of education is a main feature of a socially sustainable system (Harris et al. 2001). However, educational arrangements—including students, teachers, administrators, authorities, curriculum, equipment, and infrastructure—in highly seismic areas are under permanent hazard. This situation is critical for student populations that attend public schools with high vulnerability factors, such as insecure infrastructure, low teacher salaries, and poor living conditions due to social exclusion and inequity (including populations living in conditions of poverty and extreme poverty). The combination of hazard, vulnerability, exposure, and low resilience results in a high-risk situation.

Risk reduction challenges decision makers because of the sheer number at factors and the lack of economic capacity to attend to them simultaneously (Freeman et al. 2003; Cardona, 2010).

Academics and international agencies have been working for the past several decades to develop risk-reduction strategies for educational systems. These efforts have ranged from programs to reduce structural vulnerability to initiatives focused on nonstructural elements like retrofitting building infrastructure, improving earthquake preparedness, and contingency planning. Although these endeavors involve different knowledge areas, no opportunities have been created for interdisciplinary and
participatory work to create an integrated vision of the problem.

More specifically, retrofitting measures in schools proposed from an engineering point of view tend to rely on a “top-down” management (TDM) approach that prioritizes the most urgent tasks from a multifactor standpoint based on physical and structural risk analysis and student numbers (Grant et al. 2007; Pina et al. 2012; Grimaz et al. 2010; Tesfamariam et al. 2012). Strategies focused on preparedness, especially through the training of teachers, principals, and administrative staff, and informing parents and students, have shown little increase in school-team and parent awareness about the importance of taking precautionary actions such as participating in emergency simulations and drills (IASC, 2007; Rivera et al. 2016). By contrast, strategies aimed at children have been more successful because messages disseminated by youngsters have a high level of acceptance among parents (Izadkhah, 2005).

In this article, we use community-based elements, such as institutional arrangements (UNDP, 2015) and collaborative and interdisciplinary approaches, to understand the risk factors and to develop comprehensive, socially sustainable risk reduction strategic plans for educational systems. We aim to demonstrate that 1) design of seismic risk-reduction strategies should include an emphasis on social sustainability and 2) a participatory and interdisciplinary approach should integrate aims, objectives, and methodologies used by previous TDM studies in a knowledge-creation process.

Community-based Disaster Risk Management

Community-based disaster risk management (CBDRM) is a complementary approach to TDM (Birkman, 2007). The concept of CBDRM is based on a multi-sectoral and interdisciplinary strategy, experience, local knowledge-sharing, and community empowerment and ownership by the target beneficiaries.

Programs based on CBDRM have been used extensively worldwide (Maskrey, 2011), mainly to improve emergency-response capabilities, urban planning, and disaster prevention (Chen et al. 2006; Vilela & Fernández de Córdova, 2013) as well as to facilitate post-disaster reconstruction processes (Rivera, 2010; Velásquez et al. 2016). For instance, participatory multi-sectoral partnership and community engagement has also been deployed by a grassroots parents group in Berkeley, California (USA) as part of a process to retrofit a local school (Chakos, 2004). Although these initiatives are useful examples entailing the empowerment of target beneficiaries, they lack an interdisciplinary vision that can encompass all risk-management activities in greater detail.

The community-diagnosis method is a tool of CBDRM that enables a knowledge-creation process that combines local knowledge and technical know-how for implementing participatory disaster preparedness (Matsuda & Okada, 2006). It consists of two phases: a diagnostic survey and a prescriptive meeting, the latter providing space for face-to-face interaction to share survey results and to combine the local knowledge of various participants. The prescriptive meeting also plays the role of providing a community with a solution for risk reduction.

Social Sustainability Dimensions

Social sustainability is based on two dimensions: social equity and the sustainability of a community itself (Bramley & Power, 2009). An equitable society is one with no “exclusionary” or discriminatory practices hindering individuals from participating economically, socially, or politically. Within an urban context, social equity is related to access to services, facilities and opportunities, public transportation, and adequate infrastructure. Community sustainability involves social interaction among community members, including the opportunity to participate in public life, the existence of formal and informal organizations, as well as the presence of interpersonal trust, security, and positive sense of identification.

In this article, we examine an ongoing project for developing a strategic plan for seismic risk reduction of the student public school population in Lima, Peru using the community diagnosis method. Both TDM and CBDRM benefits are integrated in a participatory manner, with a focus on an interdisciplinary and multi-sectoral approach to yield a risk-reduction proposal that
takes into account the dimensions of social sustainability.

**Case Study: Student Population in Lima**

Lima, Peru, is located in the seismically intensive “Ring of Fire” of the Pacific Ocean and has been subjected to many earthquakes over the years (Tavares & Buffon, 1998). Since the 1950s, Lima has grown largely on an informal basis to an estimated population of nine million people and today lacks adequate public infrastructure and urban facilities including schools, hospitals, health clinics, and cultural centers.

The city’s current residential and commercial patterns are scattered and uncoordinated, leading to socio-spatial segregation (Fernández de Córdova, 2012). Informal settlements located in the expansion areas occupy lands exposed to hazards and poor performance during seismic events. This configuration fails to incorporate notions of compactness and inclusion that are inherent in most urban models of a sustainable city and reduces the resilience of student residents. The large number of public schools located in these problematic expansion areas increases the risk to this portion of the population. School buildings also suffer from poor construction practices arising from a lack of regulated procedures and quality supervision (Blondet et al. 2004), increasing the likelihood of injuries to students during a post-disaster evacuation. This situation degrades resilience and will likely delay the recommencement of school activities following an emergency. With no regular budget for investment in facilities, parents frequently build schools themselves after pooling their own financial resources. Most of the schools in Lima were built in a staged construction process and additional capacity has been added when there has been money from either families or the government (Santa-Cruz et al. 2013).

In school buildings, the presence of unsupervised alcoves, dead ends, and narrow corridors are prevalent due to a lack of planning. In addition, some evacuation routes include staircases with low parapets and are likely to become overcrowded. Safety areas are located near elevated water tanks, but do not meet structural safety standards, presenting increased risk for evacuees.

According to previous studies, if a seismic event were to occur (similar to the one that affected Pisco, located 250 kilometers south of Lima, in 2007), 92% of public schools would become inoperative and 89% of students would be adversely affected (Santa-Cruz, 2013). This situation is mainly due to the fact that schools have been built in accordance with obsolete earthquake-resistant criteria and poor quality-control processes. For typical modules built before 1997 (Figure 1), a shear failure in columns (called a short-column failure) is likely to occur, causing the structures to collapse if the event scores higher than VII on the Modified Mercalli Intensity (MMI) scale. More than 50% of the school buildings in Lima require total replacement to bring them into conformance with the Peruvian building code (MINEDU, 2015).

Furniture and placement of doors and windows in public school classrooms often do not comply with the current Peruvian safety legislation. This situation is mainly a consequence of the staged self-build process. The lack of technical inspections, along with insufficient training of people involved in construction and those responsible for use of the space and furniture, hinder correct definition and maintenance of safety areas and emergency exits.

School children in Lima have been targets of previous campaigns to raise risk awareness and build capacity for emergency preparedness. Elementary and high-school students have achieved a basic level of risk awareness after community training and monitoring activities.
involving teachers, parents, and the students themselves (Roca, 2011). However, government entities, academic staff, teachers, and healthcare workers lack the proper training required to provide information or humanitarian aid to students adversely affected by seismic events (Rivera et al. 2014). The experience in Pisco demonstrated that poor communication skills could increase injuries and psychological problems for students.

In summary, Lima’s student population is exposed to earthquake risks in many aspects of daily life and at different scales: classroom, school building, neighborhood, and the city (Table 1). These hazards are to physical, psychological, and social health, including quality of life, well-being, education, and development. An interdisciplinary approach is needed to help communities organize themselves to face seismic events and to encourage coordinated activities to foster integrated risk management.

Community Diagnosis for Seismic Risk Reduction in Lima’s School Population

In September 2014, Pontificia Universidad Católica del Perú (PUCP) organized a participatory workshop using the community-diagnosis method to develop a comprehensive risk-reduction and strategic plan for Lima’s educational system. The objective was to adopt an interdisciplinary vision in seismic risk management and to incorporate CBDRM elements in the diagnosis and formulation of the plan.

### Table 1 Seismic risk analysis scales and examples of main issues

| (a) City | (b) Urban areas |
|----------|----------------|
| Social-spatial segregation due to diffused patterns | Poor community preparedness and inadequate construction and land-use practices |

| City | Urban areas |
|------|-------------|
| Expansión urbana: 1964, 1981, 1990, 2007, 2013 |

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### Community Diagnosis for Seismic Risk Reduction in Lima’s School Population

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A diverse group of primary stakeholders from academia and the government participated in the workshop. Participants included authorities and decision makers, with officers from the National Program of Educational Infrastructure (known by its Spanish acronym PRONIED); Office of Investment Planning; Office of Strategic Planning; Office of Strategic Planning and Measurement of Educational Quality, Office of Community and Environmental Education; and researchers from the World Bank and the PUCP Departments of Architecture, Engineering, and Psychology. Lima school principals were represented by officers from the Regional Directorate of Metropolitan Lima (DRELM). The participation of the stakeholders was possible due to the relationship that all parties had built while participating in research and social responsibility projects previously implemented by the PUCP Engineering Department.

#### Diagnostic Survey

The participants presented the main aspects of seismic risk facing Lima’s student population based on three recent studies of public schools in Peru: 1) Short-term strategy for immediate upgrade of the educational infrastructure in the city (MINEDU, 2014), 2) Probabilistic seismic risk assessment of local schools and hospitals (Santa-Cruz, 2013), and 3) Program Vulnerability Reduction and Emergency Disaster—PREVAED 0068 (DRELM, 2014). All of these studies estimated risk indexes using hazard and structural fragility factors. While the first two reports recommended carrying out structural measures (retrofitting or replacement) to most high-risk schools, the third proposed a strategy focused on school preparedness (Table 2).
The last part of the diagnostic survey was aimed at preparing a comprehensive and participatory diagnosis of seismic risk to students based on discussion of previous risk-analysis studies (Vilela & Fernandez de Córdova, 2013). To facilitate discussion, participants were divided into groups (Figure 2) and received maps and tables with information on the location and characteristics of the school buildings, land uses, routes and roads, socio-economic characteristics, and soil types for three representative districts located in the expansion area of Lima: Comas, San Juan de Lurigancho, and Villa el Salvador (Figure 3). An effort was made to create multidisciplinary working teams to identify the risk problems and their associated factors in a collaborative manner from different approaches and areas of knowledge.

**Table 2** Studies of seismic risk of schools in Lima City

| Recommended actions and prioritizing criteria | Short-term strategy for the immediate attention of the educational infrastructure in Lima 2015 (MINEDU, 2014) | Probabilistic seismic risk assessment of local schools and hospitals Lima (Rivera et al. 2014) | Program Vulnerability Reduction and Emergency Disaster—PREVAED 0068 “Safe Schools in Lima” (DRELM, 2014) | Participatory proposal |
|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|
| Methodology                                   | Implement some of three actions: maintain, retrofit, or replace schools prioritizing the most vulnerable and located in the most densely populated districts | Urgent structural retrofitting or replacement in schools with highest expected annual loss (EAL) | Distribution of basic safety kits to schools with higher risk and award to the most prepared schools | Incremental retrofitting prioritizing schools that could be more useful during emergency and could cause the most harm to students |
| Factors                                       | Establish an index of structural interventions according to ad-hoc algorithm | Determination of EAL for each school using CAPRA© | Evaluation of safety index of the schools | Multi-criteria and GIS analysis, related to weaknesses or capabilities in all risk-generation levels: classroom, school, environment, and city |
| Factors                                       | Technical expertise of the constructor, Year of construction, Predominant structural system of the building, Condition of the structure | Seismic hazard, Type of soil, Predominant structural system of the building | Distance from main street and facilities, Interior free area, Structural inspection results, Basic services coverage | Expected structural performance in future events, Interior free area, Surrounding density, Accessibility, Socioeconomic class, Community organization, Basic services coverage |

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![Figure 2](image-url)
Based on the information analysis and the reflections of the participants on the potential disaster and post-disaster situation, participants identified possible critical situations, as well as their associated factors. Factors were found in relation to weaknesses that would increase the physical, psychological, and social impacts on students, and capabilities that could decrease the adverse effects of a seismic event. Positive factors, that is strengths and capabilities, were written down on green cards with negative factors, weaknesses, and lack of capabilities, on red cards (Figure 4).

![Figure 3](image3.png)

**Figure 3** Representative zones of the expansion area of Lima used in the diagnosis survey

![Figure 4](image4.png)

**Figure 4** Identification of positive and negative factors related to the risk of the student population

**Results of Diagnosis Survey**

Participants first cited factors related to the structural fragility of buildings. Construction prior to 1997 was the main indicator of high structural weakness of some schools. Another factor was the soil’s low load bearing capacity. Buildings located in areas with soft soils were identified as the most at risk, because poor quality soils can amplify seismic ground motion. Students at these schools could suffer harm from fallen objects or partial collapses during an earthquake.

Accessibility in a post-disaster scenario was another factor that the workshop participants identified. For example, the location of main avenues in lower elevation and plain areas of the Comas District was considered positive because such conditions could allow for distribution of humanitarian aid or, if necessary, evacuation of injured victims. However, the district’s upper areas pose serious difficulties due to overcrowding, slope instability, and the lack of well-maintained roads and highways. By contrast, the large number of schools in the vicinity was considered to be a positive factor because the existence of these buildings could increase the possibility that local habitants would be able to continue classes and have a focal point if some schools in the area became inoperative. Participants highlighted the need for information about the total number and built-up area of school buildings, deemed to be relevant information because vacant areas would be useful for setting up prefabricated classrooms in a post-disaster reconstruction scenario. A finding that produced major concern was the high number of public school buildings without property title, a result of the informal settlement and construction process. This is a risk factor since it could delay the provision of financial aid in post-disaster reconstruction process.

The working groups also discussed social sustainability with respect to socioeconomic, class-based, and community resilience. In the three study areas, most of the population is low to medium income which was considered to be a negative factor because insufficient financial resources are associated with a slow recovery process. Problems of alcoholism, violence, and crime in parts of these districts were also identified as social gaps for community cohesion.

Workshop participants indicated that a good relationship between the school and the community would be a significant factor in the
whole reconstruction process. They suggested that the government should provide training to teachers to help them respond to a crisis without allowing feelings of distress and sadness to intervene with respect to the children and other community members. Finally, participants stressed the importance of the school building as a community-meeting point, especially in areas characterized by low socioeconomic status.

The working groups also took land-use information into account. The arrangement of a residential area was considered a positive factor for responding to emergencies, together with the presence of wide green areas in strategic locations for post-disaster humanitarian logistics. Likewise, isolation from industrial areas was also considered to be helpful because such districts are usually associated with secondary risks caused by seismic events, like explosions and fires. However, the workshop participants questioned the official land-planning and land-use data because they were not reliable given the widespread informal construction process in Lima. A summary of identified factors and related problems appears in Table 3.

**Prescriptive Meeting**

The participants arrived at the first part of the workshop with various forms of tacit knowledge and this diversity of perspectives led them to discuss a range of risk-reduction procedures for schools. Specific topics included structural retrofitting, planning evacuation routes and safety areas, preparedness, community responses, and psychological support teams. In the second part of this session, groups worked together to comprehensively define the aims, objectives, and methodologies of strategic planning for seismic risk mitigation.

With respect to risk reduction, the structural retrofitting measures that participants presented included adding complementary frames, energy-dissipation devices, and enlarging columns. First, the complementary frame technique, used in previous interventions in other Peruvian cities, consists of supplementing the original structure

| Table 3 Problems, factors, and measures identified in the participation process from two sessions |
|---------------------------------|---------------------------------|---------------------------------|
| Factors                        | Problem                          | Measures                        |
| Soil type                      | Potential physical damages caused due to fallen heavy objects or partial collapses. | Complementary frame technique   |
| Structural fragility           | Disruption of classes            | Enlargement of columns          |
| Population density             |                                  | Installation of energy-dissipation devices |
| Distribution of the buildings and free areas inside the school | Potential physical damages caused by falls, crashes, and overcrowding of students during the evacuation | Specific regulation for rehabilitation of existing constructions and use of new materials |
| Implementation of emergency exits and safety areas |                                  | Upgrading corridors and ramps that do not meet the required standards |
| Accessibility and closeness to main routes | Deficiency and delays in humanitarian response and difficulties in evacuation procedures during the emergency response and rehabilitation stages | Awareness-raising activities for students to correctly follow instructions during evacuation procedures |
| Basic services                 |                                  | Adopting urban models of sustainable cities with compactness and inclusive solutions |
| Socio-economic level related to social segregation and little compactness |                                  | Improvement of water supply, electricity, and telephone communication systems |
| Level of preparedness and commitment of neighboring communities | Psychological impact due to poor crisis management by local authorities and humanitarian aid | Civic and social empowerment to face the disaster |
| Regulation of the Ministry of Economy and Finances for Public Investment Projects | Difficulty to obtain funds for retrofitting projects | Training teachers, health workers, parents, church leaders, and NGO representatives through "community interventions" |
|                                 |                                  | Legal clearing of property      |
with a reinforced concrete frame. This technique is suitable for low-rise structures and eliminates the short-column problem in typical modules built before 1997. Second, the technique of incorporating energy-dissipation devices, like dampers and base isolators, was considered too costly by the experts. Finally, the enlarging-columns alternative was questioned because it has a very disruptive construction process.

To decide the optimum retrofitting alternative, it is necessary to analyze all of the options using multi-criteria decision-making methods (Caterino et al. 2004; 2009) or life-cycle economic assessments aimed at maximizing benefits or minimizing costs and losses (Santa Cruz & Heredia, 2009). The implementation of all of these structural interventions typically requires rapid assessment and analysis methods for strengthening existing structures and new technologies and materials (e.g., carbon fiber, electro-welded meshes, geo-meshes and fabrics). Unfortunately, Peru has no precise regulations pertaining to structural intervention in existing structures so local engineers have no guidance on which to rely when applying new techniques.

Another proposed measure was to improve school-evacuation routes by building ramps, removing obstacles and stairs from safety areas, constructing additional staircases, and strengthening walls, elevated tanks, and parapets. For the immediate school surroundings, workshop participants suggested enhancing road infrastructure and removing informal facilities and open dumps. In addition, they stated that awareness-raising campaigns should continue as well as preparedness activities (like the scheduled simulations carried out by the Ministry of Education), and regular emergency-management workshops for teachers and students. To address a potential post-disaster crisis, the workshop participants proposed changes to the urban model, including compactness, inclusivity and social cohesion, and improvements to the water supply, electricity and telecommunication systems.

In terms of community organization, workshop participants proposed mobilizing social and human resources to respond to potential crises through community interventions that promote solidarity among neighbors and their organized participation in rehabilitation and emergency-relief processes. Due to their roles and positive influence on the population, stakeholders like teachers, healthcare workers, church representatives, and employees of nongovernment organizations (NGOs) would also be involved in such interventions. In addition, they noted the importance of training potential members of the psychological support team to identify harmful emergency-relief practices, such as healthcare workers prescribing unnecessary drugs or “antidepressants” to students.

Workshop participants also proposed a third point of intervention, namely to formalize ownership of school buildings in accordance with the law. This measure requires the help of architects, engineers, and lawyers to gather relevant data, necessitating the involvement of pertinent professional associations.

Participants agreed that all of these measures should include regular follow-up assessments. In particular, contact with disaster victims was recognized as important for identifying intervention results and verifying whether goals were accomplished. Table 3 includes a summary of the proposed measures.

We now turn our attention to specific recommendations raised at the workshop for achieving seismic risk-reduction objectives. According to the guidelines established by the Ministry of Education and the objectives of the National Risk and Disaster Management Plan 2014–2021 (PLANAGERD), the school is the intervention target (e.g., infrastructure, equipment and furniture, teacher training and teaching management). The first action calls for acknowledging the high risk levels in most school buildings, as well as the limited resources and time for their retrofitting and improvement. We posed the following questions: What should the strategic goals be? What methodology or criteria should be followed to attain them? How can viability of the proposals be ensured?

Workshop participants agreed that the strategy should be to implement priority interventions in: 1) schools likely to be most useful during emergency-relief work and 2) schools with the greatest risk of injury to students. The first objective was to list buildings with
higher capability and preparedness in terms of high accessibility, quality services, well-distributed free areas, and effective community organization. The second objective was to prioritize the least adequate buildings by accounting for structural weakness, poorly planned evacuation exits and safety areas, and segregation by socioeconomic class.

To achieve the objectives, the participants reviewed the risk factors identified in the diagnostic survey which could be useful to establish an index or ranking to measure the need for interventions. It was deemed that a list of priority schools could be prepared later. For instance, the project team started a qualitative assessment of risk factors in schools located in one of Lima’s represented districts. The year of construction was used as an indicator of structural weakness of school buildings and socioeconomic class as a measure of resiliency (i.e., conditions of extreme poverty were deemed to be less resilient). They next established a ranking and prepared a list of the priority schools. However, this strategy was found to be inappropriate because in some cases highly ranked school buildings were relatively close to each other or lacked access. The project team therefore realized that algorithms and multi-criteria tools for risk-management decision-making processes in school buildings had to be correlated with the relationship between schools and urban systems to be reliable.

Workshop participants identified that the infrastructure of some school buildings could be so severely damaged that safety could no longer be guaranteed, risking injuries to the student population, as happened in Pisco’s 2007 seismic event. Thus, the group understood that multifactorial prioritization needed restrictions, since particularly vulnerable school buildings need an emergency intervention owing to their high fragility, as is the case of adobe-wall buildings and typical modules built before 1997 (Muñoz et al. 2004).

With regard to healthcare, emergency intervention would require an immediate measure to stabilize patients, although that might not mean that they could be discharged. In the case of school buildings, an emergency intervention would have limited objectives to stabilize the structure. In relation to these constrained scopes, the workshop participants agreed that it would not be feasible to approve a structural project with lower design performance than required in the construction standards.

An option for implementing these emergency measures would be to include incremental retrofitting which entails adapting the school to regulatory requirements in partial interventions or stages (Krimgold et al. 2002). Under these arrangements, an improvement would be made in the structural performance in every stage until the performance reached the requirements of existing construction codes. Some progress has occurred regarding regulations in Peru and designers have since 2016 begun to apply this concept to existing structures.

Regarding this proposal’s feasibility, the team members were skeptical about the efficacy of the requirements set by the Ministry of Economy and Finances for the approval of Public Investment Projects (PIP), as these are too complicated and slow to address the problems of school buildings in need of urgent intervention. The time that it takes for the preliminary design and the comprehensive approach required by the Ministry are not consistent with the timescale associated with emergency interventions.

It merits observing, though, that there is previous experience with rapid approval processes in hospitals in Peru. A 2014 decree stipulated that special measures should ensure their operation even during seismic disasters. Through similar measures, the national government has been able to speed up interventions in school buildings identified as “representative.” The workshop concluded that this topic required political attention and commitment from legal and regulatory authorities.

Conclusion

Community diagnosis is a tool that is appropriate for developing strategic plans for socially sustainable seismic risk reduction in schools. In the case described here, the prescriptive meeting provided a comprehensive and participatory framework for risk reduction-strategy planning and introduced social
sustainability dimensions into the scoping process. This approach integrates TDM and CBDRM benefits and can create knowledge from previous risk studies that have been developed separately from the perspectives of different disciplines. Therefore, a new comprehensive multi-scale risk perspective has been created. Aims, objectives, and methodologies of the risk-reduction strategy are redefined by integrating previous studies. We have found that social sustainability factors such as social equity and the sustainability of a community itself must be taken into account to achieve these new goals.

To address the situation of high risk and limited resources, we suggest a prioritizing methodology, one that is based on indicators or rankings that take into account factors related to weaknesses or capabilities at all stages of risk occurrence: classroom, school, neighborhood, and city. It is also necessary to analyze physical, psychological, and social factors that may have an impact on the student population.

During the course of the workshop, participants prioritized two sets of schools: those that could be more useful during emergency-relief work and those where students faced the greatest risk. The most highly ranked facilities were identified through social sustainability factors such as security and well-being of the student population, accessibility, income, presence of basic services, and community organization. Identifying spatial and territorial relationships in public school surroundings is essential to guaranteeing the effectiveness and efficiency of risk-mitigation strategies.

The regulation and approval processes for public projects provide critical windows of opportunity for proposing interventions, mainly for urgent cases. Specific urban and construction standards are required for more effective titling of property, better connectivity among public spaces, and incremental retrofitting of school buildings. Such measures could mitigate risk to the school population by reducing weaknesses and increasing resilience and capability. Likewise, political commitment is needed to exempt emergency projects from the demanding approval process that other public investment projects are required to undergo.

This project was an opportunity for interdisciplinary discussion that led to consensus on risk management in a participatory manner involving different areas of knowledge. It also allowed members of the PUCP academic community from different departments to attain a more complete vision of the cross-cutting topic pertaining to the safety of vulnerable students and raised the need to continue holding similar meetings.

The next steps are: 1) to determine a methodology to analyze the feasibility of the retrofitting measures to reduce structural fragility and interventions to increase the resilience and capacity of the education systems from a multi-criteria point of view and 2) to develop a methodology for risk reduction of public schools based on the prioritization criteria presented in this article.

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References

Birkman, J. 2007. Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies. New Dehli: The Energy and Resources Institute.
Blondet, M., Dueñas, M., Loaiza, C., & Flores, R. 2004. Seismic Vulnerability of Informal Construction Dwellings in Lima, Peru: Preliminary Diagnosis, Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, August 1–6, Paper No. 2122. http://www.iitk.ac.in/nicee/wcee/article/13_2122.pdf.
Bramley G. & Power, S. 2009. Urban form and social sustainability: the role of density and housing type. Environment and Planning B 36(1):30–48.
Caterino N., Iervolinit, I., Manfredi G., & Cosenza, E. 2009. Comparative analysis of multi-criteria decision-making methods for seismic structural retrofitting. *Computer-Aided Civil and Infrastructure Engineering* 24(6):432–445.

Cardona, O. 2010 Indicators of Disaster Risk and Risk Management: Program for Latin America and the Caribbean—Summary Report Technical Notes No. IDB–TN–169. Inter-American Development Bank. Environment, Rural Development and Disaster Risk Management Division.

Chakos A. 2004. Learning about seismic safety of schools from community experience in Berkeley, California, pp. 45–51. *School Safety and Security. Keeping Schools Safe in Earthquakes*. Paris: Organisation for Economic Co-operation and Development.

Chen, L., Liu Y., & Chan, K. 2006. Integrated community-based disaster management program in Taiwan: a case study of Chang-An Village. *Natural Hazards* 37(1):209–223.

Bostenaru, D. 2004. Multi-criteria decision model for retrofitting existing buildings. *Natural Hazards and Earth System Science* 4(4):485–499.

Dirección Regional de Educación de Lima Metropolitana (DRELM). 2014. Plan de Gestión de Riesgo de Desastres de la Dirección Regional de Educación de Lima Metropolitana (Disaster Risk Management Plan of the Regional Bureau of Education of Metropolitan Lima). http://www.academia.edu/7935463/PLAN_DEGESTI%C3%93N_DE_RIESGOS_DE_DESAS TRES.DE_LA_DIRECCII%C3%93N_REGIONAL.DE_EDUCACI%C3%93N_DE_LIMA_MEO TROPOLITANA_.PGRD_DRELM_2014-2021 (in Spanish).

Fernández de Córdoba, G. 2012 *Socio-spatial Diversity as a Strategy for Metropolitan Lima’s Urban Sustainment*, 2007. Proceedings of the 28th International Passive and Low Energy Architecture PLEA Conference on Sustainable Architecture + Urban Design, Lima, November 7–9. http://www.plea2012.pe/proceedings.php.

Freeman, P., Martin, L., Linnerooth-Bayer, J., Warner, K., & Pflug, G. 2003. Gestión de Riesgo de Desastres Naturales: Sistemas Nacionales para la Gestión Integral del Riesgo de Desastres: Estrategias Financieras para la Reconstrucción en Caso de Desastres Naturales (Disaster Risk Management: National Systems for the Comprehensive Management of Disaster Risk and Financial Strategies for Natural Disaster Reconstruction). http://www.bvsde. paho.org/bvsacd/cd47/riesgo.pdf (in Spanish).

Grant, D., Bommer, J., Pinho, R., Calvi, M., Goretti, A., & Meroni, F. 2007. A prioritization scheme for seismic intervention in school buildings in Italy. *Earthquake Spectra* 23(2):291–314.

Grimaz S., Slejko, D., Cuccci, F., Barazza, F., Garcia, J., Leita, P., Malisan P., Rebez, A., Santulti, M., & Zini, L. 2010. An Holistic Approach in the Definition of Priority Interventions List for Seismic Risk Reduction of Strategic Buildings at a Territorial Level. Proceedings 14th European Conference of Earthquake Engineering, Ohrid, Macedonia, August 30–September 3, pp. 4733–4740.

Harris J., Wise T., Gallagher K., & Goodwin, N., Eds. 2001. *A Survey of Sustainable Development: Social and Economic Dimensions*. Washington, DC: Island Press.

Inter-Agency Standing Committee (IASC). 2007. Guía del IASC sobre Salud Mental y Apoyo Psicosocial en Emergencias Humanitarias y Catástrofes (IASC Guidelines on Mental Health in Psychosocial Support in Emergency Settings). Geneva. https://interagencystandingcommittee.org/node/2903 (in Spanish).

Izadhkay, Y. & Hosseini, M. 2005. Towards resilient communities in developing countries through education of children for disaster preparedness, *International Journal of Emergency Management* 2(3):138–148.

Krimgold, F., Hattis, D., & Green, M. 2002. Report FEMA–395 Incremental Seismic Rehabilitation of School Buildings (K–12). Virginia Polytechnic Institute and State University. Washington, DC: Federal Emergency Management Agency.

Matsuda, Y. & Okada, N.2006. Community diagnosis for sustainable disaster preparedness. *Journal of Natural Disaster Science* 28(1):25–33.

Ministerio de Educación (MINEDU). 2015. Presentación de Estrategia (Strategy Presentation). http://www.minedu.gob.pe/minedu/archivos/p/presentacion-estrategia-app-oxi-minedu.pdf (in Spanish).

Ministerio de Educación (MINEDU). 2014. Resolución Ministerial 562–2014 (Ministerial Resolution 562–2014). http://www.pronied. gob.pe/wp-content/uploads/RM-562-2014-MINEDU.pdf (in Spanish).

Maskrey, A.2011. Revisiting community-based disaster risk management. *Environmental Hazards* 10(1):42–52.

Muñoz, A., Blondet, M., Quintana, U., & León, H. 2004. Earthquake-Resistant Performance of Peruvian School Buildings. Proceedings of 13th World Conference on Earthquake Engineering.
Pina, F., Taylor, G., Ventura, C., & Finn, L. 2010. Seismic Risk Assessment Tool for Seismic Mitigation of Schools in British Columbia. 9th United States National and 10th Canadian Conference on Earthquake Engineering, Toronto, Canada, July 25–29.

Rivera, M. 2010. Apoyo Psicosocial y Salud Mental Comunitaria en el Proceso de Reconstrucción Post-terremoto en Chinchá: Murales para Ver y Soñar (Psychosocial Support and Community Mental Health in the Process of Post-earthquake Reconstruction in Chinchá: Murals to See and Dream). Lima: American Red Cross (in Spanish).

Rivera, M., Velázquez, T., & Morote R. 2014. Participación y fortalecimiento comunitario en un contexto posterremoto en Chinchá, Perú (Participation and community empowerment in a post-disaster situation in Chinchá, Peru). Revista Psicoperspectivas 13(2):144–155 (in Spanish).

Rivera, M., Velázquez, T., & Morote, R. 2016. A post disaster capacity building model in Peru. Intervention Journal 1(1):4–17.

Roca, L. 2011. Percepciones de Soporte Social en Mujeres Organizadas en Comedores de Emergencia por el Terremoto del 2007 (Perceptions of Social Support Among Organized Women in Emergency Community Kitchen’s During the Earthquake of 2007), Unpublished Master’s Thesis. Department of Psychology, Pontificia Universidad Católica del Perú, Lima (in Spanish).

Santa-Cruz, S. 2013. Evaluación Probabilística del Riesgo Sísmico de Escuelas y Hospitales de la Ciudad de Lima: Componente 2 (Probabilistic Seismic Risk Evaluation of Schools and Hospitals in the City of Lima: Part 2), Pontificia Universidad Católica del Perú (in Spanish).

Santa-Cruz, S., Ottazzi, G., Carpio, J., Demichelili, M., Zyber, R., & Dextre, J. 2013. Daños En Locales Escolares Públicos Debido Al Sismo Del 25 De Setiembre Yauca-Acari 2013 (Local Public School Damage Due to the Earthquake of September 25 in Yauca-Acari 2013), Department of Civil Engineering, Pontificia Universidad Católica del Perú (in Spanish).

Tavera, H. & Buforn, E. 1998. Sismicidad y Sismotectónica de Perú: Física de la Tierra, Norteamérica (Seismicity and Seismotectonics of Peru: Physics of the Earth, North America). http://revistas.ucm.es/index.php/FITE/article/view/FITE9898110187A/12151.

Tesfamariam, S. & Wang, Y. 2012. Risk-based seismic retrofit prioritization of reinforced concrete civic infrastructure: case study for State of Oregon schools and emergency facilities. Natural Hazards Review 13(3):188–195.

Velázquez, T., Rivera-Holguín, M., & Morote, R. (2016, in press). Disasters and post-disasters: lessons and challenges of and for community psychology. In: Handbook of Community Psychology, Vol. 2, M. Bond, C. Keys, & I. Serrano-García (Eds.). pp. 1–16. Washington, DC: American Psychological Association.

Vilela, M. & Fernández de Córdova, G. 2013. Metodología Participativa para la Investigación-acción en el Ordenamiento Territorial, Lima, Perú (Participatory Methodology for Action Research in Land Use Planning, Lima, Peru), Department of Architecture, Pontificia Universidad Católica del Perú (in Spanish).

United Nations Development Program (UNDP). 2015. Institutional Arrangements. http://www.undp.org/content/undp/en/home/ourwork/capacitybuilding/drivers_of_change/institut_arrangemt.html.