Petal, M. et. al., School Seismic Safety and Risk Mitigation, in Khazai, B., et. al. Eds. Encyclopedia of Earthquake Engineering: Section: Policies and Approaches in Earthquake Res...

Encyclopedia of Earthquake Engineering
DOI 10.1007/978-3-642-36197-5_396-1

School Seismic Safety and Risk Mitigation

Marla Petal[a]*, Ben Wisner[b], Ilan Kelman[c], David Alexander[d], Omar-Dario Cardona[e], Djillali Benouar[f], Sanjaya Bhatia[g], Jitendra Kumar Bothara[h,i], Amod Mani Dixit[h], Rebekah Green[j], Ram Chandra Kandel[k], Tracy Monk[l], Bishnu Pandey[m], Janise Rodgers[n], Zeynep Türkmen Sanduvaç[o] and Rajib Shaw[p]
[a]Risk RED (Risk Reduction Education for Disasters), Los Angeles, USA
[b]Oberlin, OH, USA
[c]Institute for Risk and Disaster Reduction and Institute for Global Health, University College London, London, England
[d]University College London, London, England
[e]Universidad Nacional de Colombia, Manizales, Colombia
[f]University of Bab Ezzouar, Algiers, Algeria
[g]UNISDR Recovery Platform, Kobe, Japan
[h]NSET, Kathmandu, Nepal
[i]Miyamoto Impact, Christchurch, New Zealand
[j]University of Western Washington, Bellingham, USA
[k]Toronto, Canada
[l]Families for School Seismic Safety, Vancouver, Canada
[m]University of British Columbia, Vancouver, Canada
[n]GeoHazards International, Menlo Park, USA
[o]Risk RED, Istanbul, Turkey
[p]University of Kyoto, Kyoto, Japan

Synonyms

Comprehensive school safety; Critical infrastructure; Safe school construction; Safe school facilities; School construction

Introduction

Access to education is a basic human right. It is enshrined in Convention on the Rights of the Child (1990), the World Declaration on Education for All (in 1990), and the World Education Forum (WEF 2000). It is one of the Millennium Development Goals for the decade starting in 2005 and continues to be part of the "post-2015" development agenda. Education is strongly associated with poverty reduction, and there are strong global and national drives to implement it. The Global Partnership for Education has 29 national partners, supporting the implementation of universal, free, quality basic education in 57 partner developing countries. In GPE's 2012–2015 Strategic Plan, the first of its four strategic goals is "All children have access to a safe, adequately equipped space to receive an education with a skilled teacher." However, none of its monitoring indicators mention safety. Since 2004, the GPE has contributed to build, rehabilitate, and equip close to 53,000 classrooms (GPE 2014). However, up until at least 2013, there was no systematic due diligence with respect to disaster-resilient construction. In the rush to fulfill the right to education, are children being put at risk?

This entry assesses seismic threats to schools and reviews incidents of children and teachers killed by structural failure of school buildings as well as structural damage to schools and near misses. It reviews progress, good practices, and lessons learned based on these threats. The entry goes on to overview school

*Email: mpetal@imagins.com

vulnerability, global experiences in seismic-resistant school construction, and retrofit. A summary of progress in school seismic safety along with a recommended systematic all-hazards approach to comprehensive school safety set the stage to make the case for continued advocacy for school seismic safety.

The Threat

According to estimates made by the Center for International Earth Science Information Network at Columbia University in 2006, there are more than 100 million school-aged children exposed to significant seismic risk throughout the world (New York Times 2008). In 2004, 10 of the 16 contributors to this article initiated recording of case studies on progress and struggles for school seismic safety which are updated in the entry "► School Seismic Safety: Case Studies." They set out the magnitude of concern and main arguments for advocacy in an unpublished article. At the time, the authors posited the gruesome estimate of "4,800 school children killed by earthquake-related school collapse or severe damage over the next decade. . . It might be reasonable and prudent to plan to avoid a loss of student life in earthquakes of somewhere between 2,000 and 5,000 in a 10 year period." At the time it was written, this estimate seemed to the authors to be somewhat alarmist.

The following year, shortly after the unprecedented destruction caused by the Indian Ocean earthquake and tsunami, 168 countries agreed to the 2005–2015 Hyogo Framework for action. Over the course of this 10 year period, this dire predication has been exceeded fourfold as the result of only two major earthquakes during school hours: the 8 October 2005 Kashmir earthquake which killed more than 18,000 students, in addition to staff, in schools, and the 12 May 2008 Sichuan earthquake which killed more than 5,300 students, in addition to staff, in their schools (UNISDR 2008).

In the powerful earthquake and massive tsunami on 11 March 2011 in northern Japan, schools themselves were by and large structurally sound and resisted earthquake damage, but tsunami-retaining walls were breached as the tsunami was larger than expected and land subsidence had not been factored in. Disaster drills and practice of "tendenko" (automatic tsunami evacuation), by many school children, saved many lives. Some schools provided vertical evacuation, and many survived at evacuation and shelter centers. But instances of confusion occurred and many school pupils and teachers also died. Today, the students now displaced by the resulting nuclear disaster recognize this neglected threat as the most catastrophic of all. The international community is virtually silent on this threat.

In common with other infrastructure, school buildings are subject to damage and collapse in earthquakes. Many of these have resulted in children killed while being educated (Table 1).

Pictorial evidence of historic earthquake damage to schools is available in the NISEE, Earthquake Engineering Online Archive.

There have also been many cases when an earthquake destroyed school buildings when they were not in session, and thus deaths and injuries were narrowly avoided (Table 2). However the severe impact on continuity of education and the potential magnitude of loss of life in these events further highlight the importance of ensuring the seismic safety of schools.

Making the Case for School Seismic Safety

Many public buildings and different sorts of critical infrastructure are threatened by earthquakes. The case can be made for giving priority to schools from three perspectives: Duty bearers have moral and legal obligations to fulfill children's rights to both safety and survival and educational continuity. In more affluent countries, the cost benefits of investments in public safety, the importance of safeguarding

Encyclopedia of Earthquake Engineering
DOI 10.1007/978-3-642-36197-5_396-1

Table 1 Children killed by structural failure of school buildings

Date/local time (Source)	Location/magnitude[a]	Consequences/schools	Consequences/children
12 Jan 2010 16:53 (CNN 2014)	Port-au-Prince, Haiti M 7.0	MoE estimates 4,992 schools affected (23 % of the nation's schools)	Deaths and injuries unknown. Many children with disabling injuries. Some schools were holding their third shifts. Est. 1.3 m children and youth affected
12 May 2008 14:28 (COGGS 2008)	Wenchuan, China M.7.9	175 schools (7,000 classrooms) in Sichuan and Shaanxi provinces were destroyed	>5,300 school children died in dozens of schools In the Beichuan Middle school, 1,300 of 2,999 students and teachers died
6 Mar 2007 11:00 (COGGS 2008)	Western Sumatra M 6.4	The wall of a primary school collapsed. Fire followed. Up to 329 schools affected by several earthquakes (2005–2010)	4 primary school children died
8 Oct 2005 St. 08:50 (UNISDR 2008)	Kashmir, Pakistan, and India M 7.6	More than 10,000 schools collapsed 80 % of Mahesehra's 2,749 66 % of Batagram's 678, and 37 % of Abbottabad's 1,829 public schools were destroyed or seriously damaged	>18,000 school children died >50,000 school children were seriously injured
1 May 2003 03:20 (Rodgers 2012)	Bingöl, Turkey M 6.4	4 school buildings collapsed. Only the dormitory was occupied	84 students killed and 114 survived in the dormitory
24 February 2003 10:03 (COGGS 2008)	Bachu, Xinjiang, China M 6.4	900 classrooms collapsed	Students were outside in physical education at the time of the earthquake. At least 20 students killed in one middle school collapse
31 October 2002 11:40 (COGGS 2008)	San Giuliano di Puglia, Molise, Italy M 5.9	San Giuliano infant school collapsed	26 children and 3 adults killed. 35 children rescued alive from the building but some reports suggest that one child died later
26 January 2001 Friday 08:16 Republic day holiday (COGGS 2008)	Gujarat, India M 7.6	1,884 school buildings collapsed. 5,950 classrooms destroyed. 36,584 unfit for instruction	971 school children and 31 teachers were killed in school activities. 1,051 students and 95 teachers seriously injured 32 children died at Swaminarayan School
13 February 08:22 and 13 January 2001 (COGGS 2008)	El Salvador M 6.6	85 schools damaged beyond repair. In aftershock 22 preschoolers and their teacher were killed	50 % of fatalities were children
9 July 1997 15:24 (COGGS 2008)	Cariaco, Venezuela M 7.0	Two out of five school buildings collapsed. Four reinforced concrete buildings had serious structural defects	46 students killed
10 May 1997 12:57 (COGGS 2008)	Ardekul, Iran M 7.3	Elementary school collapsed	110 young girls were killed
1992 (COGGS 2008)	Erzincan, Turkey M 6.9	6-story medical school collapsed	62 students were killed.
7 December 1988 11:41 (COGGS 2008)	Spitak, Armenia M 6.8	380 children and youth institutions destroyed. 105 of 131 in Spitak and Leninakin destroyed	Likely thousands of school children killed. At least 400 children died in the collapse of a Dzhrashen elementary school

(continued)

Encyclopedia of Earthquake Engineering
DOI 10.1007/978-3-642-36197-5_396-1

Table 1 (continued)

Date/local time (Source)	Location/magnitude[a]	Consequences/schools	Consequences/children
27 July 1976 03:42 (COGGS 2008)	Tangshan, China M 7.8	Most school buildings destroyed	2,000 students killed in the dormitory of the College Mining Institute
13 April 1949 11:58 (COGGS 2008)	Olympia, Washington, USA M 7.1	10 schools destroyed, 30 damage. Spring break	2 children in school were killed
31 October 1935 (COGGS 2008)	Helena, Montana, USA M 6.2	Newly built secondary school wing collapsed	2 students killed. Classes not in session, could have been much worse
10 March 1933 Long Beach (COGGS 2008)	Long Beach, California, USA M 6.4	70 schools destroyed. 120 with major damage. Classes held in tents for 2 years. First legislation for safe school construction	2 children died in gymnasium collapse. Spring break, classes not in session, could have been much worse

[a]Magnitudes from USGS or Wikipedia

Table 2 School structural damage from earthquakes

Date (Source)	Location/magnitude[a]	Structural and educational impacts
2 July 2013 14.37 (Pandey 2013)	Aceh, Indonesia M 6.2	966 schools affected
4 April 2010 15:40 (Rodgers 2012)	California, USA, and Baja, Mexico M 7.2	Significant structural damage to several schools in Mexico. Significant nonstructural damage to several schools in the USA. Cost of repair almost 20 % of annual budget for one school district School was on spring break. Nonstructural damage would have caused injuries and blocked egress. In California hazardous asbestos from collapsed walkways and mercury from light fixtures closed schools for extended periods
30 September 2009 17:16 (Rodgers 2012)	Padang, West Sumatra, Indonesia M 7.6	2,164 severely damaged, 1,447 moderately damaged, 1,137 lightly damaged School was recently dismissed for the day. Temporary school buildings of timber frame and corrugated steel
2 September 2009 14:55 (Pandey 2013)	West Java, Indonesia M 7.0	716 schools affected
21 September 2009 14:53 (Rodgers 2012)	Mongar, Bhutan M.6.1	91 schools affected: 6 destroyed, 17 required major repair, 44 required partial repair, 24 required minor repair (cost 12.9 m USD) plus damage to boarding schools, water, and sanitation School was dismissed early for holiday. Temporary learning facilities inadequate for weather
6 April 2009 03:32 (Rodgers 2012)	L'Aquila, Italy M 6.3	78 schools had extended closures and 12 partial closures
12 September 2007 18:10 (Pandey 2013)	Bengkulu, Indonesia M 8.5	240 schools affected (2005–2010)

(*continued*)

DOI 10.1007/978-3-642-36197-5_396-1

Table 2 (continued)

Date (Source)	Location/magnitude[a]	Structural and educational impacts
15 August 2007 23:40 (Rodgers 2012)	Pisco, Peru M 8.0	116 schools were severely damaged. 478 classrooms were needed to restore school activities
27 May 2006 05:53 (Rodgers 2012)	Yogyakarta, Indonesia M 6.3	Yogyakarta: 2155 educational facilities damaged or destroyed; Central Java: 752 damaged or destroyed. Damage and losses estimated at 1.7 trillion Indonesian Rupiah
26 December 2004 early am (UNISDR 2008)	Indonesia, Sri Lanka, Maldives, Thailand M 9.1–9.3	School earthquake and tsunami damage combined: Indonesia – 750 destroyed 2,135 damaged. Sri Lanka – 51 destroyed, 100 damaged. Maldives – 44 destroyed or damaged. Thailand – 30 destroyed
26 December 2003 5:26 (COGGS 2008)	Bam, Iran M 6.6	67 of 131 schools collapsed. The remaining 64 were heavily damaged and unusable 33,000 students were affected
22 September 2003 12:45 (UNISDR 2008)	Puerto Plata, Dominican Republic M 6.4	50 public schools damaged, 140 classrooms impacted 18,000 students were without classrooms
21 May 2003 19:48 (COGGS 2008; OECD 2004)	Boumerdes, Algeria M 6.8	130 schools damaged beyond repair. 753 schools extensively damaged or destroyed The earthquake occurred out of normal school hours, so children were not at school. Cost of school rehabilitation $79 million+
24 February 2003 (COGGS 2008)	Xinjiang, China	Dozens of schools collapsed The earthquake struck 27 minutes before thousands of children would have been in classrooms
25 April 2002 22:41 (Rodgers 2012)	Tbilisi, Georgia M 4.5	Approximately $8 million US in school damage. No collapses; 1 school with very heavy damage; 35 with substantial damage; 68 with moderate damage; 98 with negligible or slight damage
21 September 1999 1:47 (COGGS 2008)	Chi-Chi, Taiwan M 7.7	51 schools collapsed. 786 schools nationwide were damaged. 22 % of schools and 71 % of post-secondary institutes damaged The earthquake happened in the middle of the night, so no one was in the building. Cost of repair and reconstruction $1.3 billion
June 23 2001 15:33 (COGGS 2008)	Arequipa, Peru	98 school buildings seriously damaged School not in session on Saturday
17 August 1999 3:02 (COGGS 2008)	Kocaeli, Turkey M 7.6	43 schools were damaged beyond repair. 381 minor to moderate damage In Istanbul 60 km away 35 schools were unsafe and demolished School was not in session but was suspended for 4 months. In Istanbul 131 schools were closed temporarily, for inspection
25 January 1999 13:19 (OECD 2004)	Pereira and Armenia, Colombia M 6.2	74 % of schools in Pereira and Armenia were damaged School was not in session
20 August 1998 (UNISDR 2008)	Udayapur, Eastern Nepal M 6.6	1,200 schools heavily damaged or destroyed. 6,000 affected
17 July 1998 00:19	Papua, New Guinea M 7.0	Schools destroyed
9 July 1998 5:19 (COGSS 2008)	Faial, Azores, Portugal M 6.2	Schools damaged School was not in session
20 May 1998	Afghanistan/Tajikistan M 6.6	Unknown
12 November 1996 15:33 (COGSS 2008)	Nazca, Peru	93 school buildings seriously damaged

(*continued*)

DOI 10.1007/978-3-642-36197-5_396-1

Table 2 (continued)

Date (Source)	Location/magnitude[a]	Structural and educational impacts
1996 (OECD 2004)	Temouchent, Algeria M 5.6	6 schools destroyed, 17 moderate damage, 36 light damage
17 January 1995 5:46 (COGSS 2008)	Hanshin-Awaji, Japan M 6.9	54 buildings school damaged beyond repair. Extensive earthquake and fire damage to 4,500 educational buildings. ¥94 billion. School was not in session
1994 (OECD 2004)	Beni Chourgrane, Aleeria M 5.6	4 schools destroyed, 16 moderate damage, 30 light damage
17 January 1994 04:31 (FEMA 2011)	Northridge, California, USA M 6.7	24 of 127 affected schools suffered significant structural damage. Suspended lighting and ceiling systems were damaged in 1,500 buildings 2, 204 schools were used as shelters. Had this occurred during the school day, significant injuries and lack of safe egress for thousands would have resulted. The Los Angeles Unified School District, amongst others, embarked on projects for nonstructural mitigation, now the responsibility of school maintenance personnel
25 March 1993 (COGSS 2008)	Scott Mills, Oregon, USA	Part of masonry school building collapsed Spring break, school was not in session
17 October 1989 17:04 (EERI 1990)	Loma Prieta, California, USA M 6.9	7 schools in three districts and one headquarters sustained severe damage. 1,544 were schools surveyed. Total value of damage $81 million USD
10 October 1989 (OECD 2004)	El Asnam, Algeria M 7.3	70–85 schools suffered extensive damage or collapsed The earthquake occurred out of normal school hours, so children were not at school
20 August 1988 4:39 (COGSS 2008)	Bihar, India, and Udaypur Nepal M 6.6	950 school buildings were damaged in Bihar 6,000 schools destroyed in Nepal School was not in session
8 November 1988 (UNISDR 2008)	Yunan, China	1,300 schools destroyed in earthquake
19 September 1985 :17 (COGSS 2008)	Mexico City, Mexico M 8.0	137 school buildings collapsed, 1,687 school buildings were damaged Schools were not yet open
2 May 1983 23:42 (COGSS 2008)	Coalinga, California, USA	Extensive nonstructural damage noted
10 October 1980 13:25 (OECD 2004)	El Asnam, Algeria M 7.3	70 schools totally destroyed, 25 moderately damaged School was not in session
9 February 1971 06:01 (State of California 2009)	Sylmar, California, USA M 6.6	Only 4 of 1,544 buildings surveyed suffered severe damage. Nearly all damage was nonstructural School was not in session
31 May 1970 4:23 (COGSS 2008)	Chimbote, Peru M 7.9	6,730 classrooms collapsed and hundreds seriously damaged
27 March 1964 (COGSS 2008)	Alaska, USA	Primary school destroyed by an earthquake-induced landslide. Half of Anchorage's schools were significantly damaged The earthquake struck on a holiday, Good Friday, so schools were closed
1963 (COGSS 2008)	Skopje, Macedonia	44 schools (57 % of urban stock) were damaged 50,000 students affected. Sunday, school not in session
21 July 1952 4:52 (COGSS 2008)	Kern County, California, USA M 7.3	20 schools damaged or destroyed (most built before 1933). Significant nonstructural damage also noted

(continued)

Table 2 (continued)

Date (Source)	Location/magnitude[a]	Structural and educational impacts
4 March 1952 (USGS 2003)	Sapporo, Japan	400 schools collapsed in Sapporo
10 March 1933 (COGSS 2008)	Long Beach, California, USA	70 schools collapsed The earthquake hit early in the evening after children had left for the day which saved their lives. Five students were killed in a gymnasium
3 February 1931 (Dowrick and Rhoades 2004)	North Island, New Zealand	Several schools were severely damaged The earthquake happened at mid-morning during school playtime when the children were outdoors enjoying the summer weather. Some students were killed, but the death toll could have been several hundreds
17 June 1929 10:17	Murchison, New Zealand	College tower and dormitory roofs collapsed School was not in session
18 April 1906 05:12	San Francisco, California USA	28 schools burned in fire. 41 schools damaged or destroyed Classes were not in session

[a]Magnitudes from USGS
Bibliographic references on many structural impacts on schools are available on the internet (Rodgers 2012)

development investments, and preventing educational disruption are undisputed. And, the uses of school buildings as multipurpose community centers and disaster shelters, even when children are not harmed, have cascading social and economic consequences beyond the replacement cost of school buildings themselves. In most cases public discussion and debate on these issues tend to mix these ethical and pragmatic arguments.

Human Rights Argument

The human rights argument suggests that no society should tolerate a choice between the safety of children's lives and their education. The right to life and the right to education are both recognized human rights, and both should be met. This argument takes on additional salience in view of the current international effort to increase school enrollment and attendance by girls, disabled children, and children of the very poor and marginalized groups in society.

Around the world, at least 100 million children of school age do not attend school representing about 14 % of the world's children (UNESCO 2004). Providing facilities to educate them requires construction of schools and rapid expansion of building programs. The Education for All campaign originally hoped to enroll 24 million of these children in a decade. Millennium Development Goals (MDGs) specifically aim to "[e]nsure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling."

In 2004 it was estimated that more than 7,500 new schools were needed within the next 3 years solely in Afghanistan, a country with a significant seismic hazard. It would be ironic and tragic if in the course of achieving one MDG, another is undermined.

Another MDG target is to reduce the under-five mortality rate by two thirds, between 1990 and 2015. On the one hand, the international community is seeking to save the lives of under-fives, only to put them at risk a few years later when they go to school.

Educational authorities changed with the construction and maintenance of schools are also the ones tasked with many other functions: They develop curricula, hire teachers, and choose educational resources such as textbooks and computers. School safety issues have to find a place in the capital, maintenance, and operation budgets of school buildings and school operation.

DOI 10.1007/978-3-642-36197-5_396-1

Retrofitting schools for seismic safety can be perceived to compete for funds with the rest of the educational process. The question facing decision makers can actually appear to be: "What is more important: an up-to-date textbook and good laboratory facilities now or a building that can withstand an extreme event which might or might not occur with the next few decades?"

Under most circumstances, young people do not lobby for their own rights to health and safety. Children cannot refuse to go to school because a building is unsafe. By law, they must attend school, though teachers, parents, and others may advocate on their behalf. Faculty and support staff in schools should also be concerned for their occupational safety and theoretically be natural advocates of safe school facilities. Yet there are no examples mentioned to date of teachers unions becoming involved in the issue of school disaster vulnerability.

Cost-Effectiveness Arguments

There are two forms that cost-effectiveness arguments may take. One asserts that the authority responsible for education incurs greater cost in the long run to repair and replace schools damaged by earthquakes than the cost of enforcing building codes and making sure that every new school is a safe school (or even of retrofitting older or poorly built schools). In some cases, replacement of unsafe schools is more cost-effective than repair (e.g., see entry "► School Seismic Safety: Case Studies," for examples from Algeria, Colombia, and Turkey). Notable studies of the benefits and costs of retrofitting schools in the USA, Italy, Mexico, and Peru have been published in the decade between 2004 and 2014.

A more ambitious and difficult case to make concerns the relative cost-effectiveness of investments in school seismic safety when compared to investing that money in other kinds of public health, safety, and welfare. In cases where child and infant mortality is high, longevity is shorter, basic vaccinations are not universal, or safe domestic water and sanitation facilities are inadequate, then the relative ranking of school safety as a cost-effective public health intervention may be low. Competition for public health funds could occur in trying to decide between clean water and vaccinations for everyone versus school seismic safety. In more affluent countries, the cost-effectiveness of saving lives in a future disaster usually has a high place among prioritized goals.

Of course, the physical safety of children, both in schools and out in the world at large, goes well beyond school seismic safety. HIV/AIDS, malnutrition, sexual violence, malaria, labor practices, and forced military service are day-to-day threats to the physical safety of many of the world's children. The small potential for an earthquake over the next century might appear to pale beside other concerns which daily kill many more children.

However, in places where school seismic safety is a prominent issue – such as Tehran, Vancouver, Kathmandu, Bogotá, and Wellington – a significant earthquake has a high probability of happening during the lifetime of schools currently standing and, therefore, for the gradually changing cohort of children during the life of the building. If earthquakes happen with equal probability around the clock, then approximately a 6–23 % chance exists of schoolchildren being in the school during a damaging earthquake. Cost-benefit studies of seismic construction estimate that it would add about 5 % to the cost of building a school in the USA, and in other countries the highest estimates are about 15 %, making the expectation that "every new school be a safe school" a realistic expectation.

DOI 10.1007/978-3-642-36197-5_396-1

When a population at risk is predominantly children, depending on the country, each death represents 40–70 years of lost life and productivity, and each injury represents 40–70 years of potentially expensive medical care, such as for brain or spinal injuries. Fix schools and several generations of children are protected. Health economics and medical ethics agree that the greatest social benefit comes from investment in the health and capacities of children. Aside from saving lives, the cost of education interrupted, and the serious potential for drop out adds another cost factor that seismic safety could help avoid.

Argument from the School's Multiple Functions

The symbolic, cultural, economic, and political significance of schools as a community hub gives them an importance beyond merely being the site for educating children. Schools often play roles as central places for meetings and group activities, including literacy classes, religious services, political activities, and marriage ceremonies, particularly in rural areas where the school might be the only location big enough to hold such an event. Schools may also provide essential nutrition programs and serve as makeshift hospitals or vaccination centers even in normal times.

Where schools are the safest buildings in a community, they often serve as temporary shelter from storms and floods. They may be staging areas for first aid or rescue operation or other disaster response functions and even provide temporary housing, while still fulfilling their role as an education facility.

Thus schools have a value in the social fabric of a community, providing adult education, promoting public health, building and maintaining sustainable livelihoods, and protecting people. The monetary value of those social gains defies estimation but clearly adds value and further justifies investment in safe school construction and maintenance.

We know from many disasters the important role that schools play in anchoring and speeding community recovery. Rapid school re-opening has tangible benefits in terms of children who are safe, supervised, and progressing towards their educational goals. Intangible benefits of schools functioning normally following a disaster include the psychosocial support in the face of loss and change. The importance of operational continuity of schools is linked to community recovery.

To take another example, retrofitting can spread a message far beyond the school. When children see their school being seismically retrofitted, they may have and may be designed to have ripple effects on safer residential construction. However, this is by no means automatic, and just how to maximize school construction or retrofit experience into a wider learning opportunity is a promising line of pursuit. Schools certainly serve as community hubs for propagating the seismic safety messages. School seismic safety can not only protect a community's children but also educate communities to protect themselves.

Progress, Good Practices, and Lessons Learned

Assessing School Safety from Disasters, A Global Baseline Report (UNISDR 2012) found several consistent threats to safe school facilities:

- **Failure to assure every new school is a safe school:** Neither donors, governments, nor NGO associations have unequivocally committed to providing evidence or assurances or submitted to monitoring to assure that every new school is a safe school. Many small-scale donors are particularly unaccountable and are not reached by the same accountability mechanisms and efforts of UN agencies and major international non-governmental agencies.

- **Multi-hazard awareness is often lacking:** In the construction of school facilities, there are many examples of fulfilling resilience to one hazard, while failing to mitigate against others – sometimes resulting in schools being dangerous in spite of good intentions or lying unused.
- **Impact of construction on education and family life not well understood:** School remodeling, retrofit, and replacement all have an impact on existing school programs and families. Planning these projects to minimize adverse impacts continues to be a concern.
- **Opportunity for construction and retrofit as an educational experience is untapped:** School construction and retrofit provide ideal opportunities for students and communities to learn the many principles of disaster-resilient construction to be applied throughout their communities. This opportunity is typically wasted as school sites are hidden from view and the experience is not used as a learning opportunity.
- **Lifeline infrastructure failures threaten school attendance:** Vulnerabilities in roads, bridges, and transportation systems must be prioritized when school attendance is threatened.
- **Failure to prioritize school re-opening jeopardizes community recovery:** Schools play a critical role in disaster recovery and community resilience where adults cannot return to work (UNISDR 2012).

The same study found consensus around the following core commitments required for safe school facilities: (1) Every new school must be a safe school. (2) Legacy schools should be prioritized for replacement and retrofit. (3) Lifeline infrastructure and nonstructural safety should be assessed locally and measures taken to mitigate [dangers]. (4) School furnishings and equipment should be designed and installed to minimize potential harm they might cause to school occupants.

The expert review process that was part of the *Guidelines for Safer School Construction* (INEE 2010) yielded identification of a rich set of enabling factors associated with successful and sustained programs for school structural safety that all school safety advocates need to consider awareness, community ownership, partnership and dialogue, quality assurance, appropriate technology, integrated education, cultivating innovation, encouraging leadership, and continuous assessment and evaluation.

Overview of School Building Vulnerability

Rodgers (2012) reviewed earthquake damage assessment reports through 2009, for 32 earthquakes globally and aggregated findings from 31 school building vulnerability assessments. Table 3 shows the most commonly cited sources of vulnerability from both sources.

The general lack of agreement between vulnerability assessment and damage data likely reflects fragmentary and typically inadequate efforts to collect school damage data following past earthquakes, as well as a tendency for vulnerability assessments to identify common characteristics (such as plan irregularities) that rarely lead to the severe damage noted in post-earthquake damage surveys and reconnaissance reports. More complete earthquake damage data would provide the best indicator of the vulnerability-creating characteristics more likely to cause severe damage, because many vulnerability assessments do not differentiate the severity of damage expected from observed deficiencies.

The sources of and characteristics of structural vulnerability can be summarized in terms of: configuration (large windows with partial height walls below create captive columns or narrow piers, large windows on one side, weak or soft stories, large rooms, buildings one bay wide often with irregular plans),

DOI 10.1007/978-3-642-36197-5_396-1

Table 3 Characteristics found in damage and vulnerability assessments

Characteristics	Cited in 25 % or more		Cited in 15–24 %	
	Damage assessments	Vulnerability assessments	Damage assessments	Vulnerability assessments
Captive columns due to partial height masonry infill walls under windows	✓	✓		
Non-ductile reinforced concrete frame construction	✓	✓		
Generally poor construction quality	✓			✓
Poor-quality engineered materials	✓			
Soft or weak story		✓		
General plan irregularity		✓		
Exterior falling hazards		✓		
Maintenance deferred or lacking		✓		
Inadequate doors, windows, halls/corridors, or stairs		✓		
Vulnerable masonry construction		✓	✓	
Lack of seismic design understanding by engineers			✓	
Interior architectural and contents hazards			✓	✓
Windows reducing solid wall area in masonry construction				✓
Torsion				✓
General vertical irregularities				✓

Rodgers (2012), pp. 4–5

building type (vulnerable forms of vernacular and engineered construction, safer traditional construction forms and practices abandoned, standard building plans with seismic deficiencies, heavy roofs), location (sites susceptible to ground failure, sites that amplify ground motions), construction practices (poor quality, unskilled or low-skilled local labor, reducing quality to save money or time), materials (poor-quality engineered materials, weak local materials), lack of construction inspection, lack of maintenance, subsequent modifications, falling hazards, and inadequate exit pathways (Rodgers 2012).

Underlying drivers create an environment conducive to the vulnerability-creating characteristics cited above. Published literature identifies the following: unregulated community-based construction, scarcity of resources, inadequate building codes or zoning, lack of code enforcement, corruption of enforcement mechanisms, unskilled or unaware building professionals, lack of accountability, lack of awareness, failure to prioritize school safety, and urgent need for large numbers of new schools (Rodgers 2012).

Overview of Global Experiences in Seismic-Resistant School Construction

Some of the major policy and programmatic endeavors to assure seismic resilient construction of schools, worldwide, as of 2013, have involved important steps such as providing risk maps for safe school site selection, construction guidelines, standards, and oversight and commitments to safe school construction in the context of both post-disaster reconstruction and new school construction to meet Millennium Development Goals.

The **provision of risk maps** for safe school site selection requires both national and subnational coordination and often several different agencies reporting on the full spectrum of geophysical and hydrometeorological risks and taking into account nuclear, biological, and chemical hazards. In Peru, a pool of trained consultants based in universities around the country are now available to advise Regional

Education Offices on safe school site selection. They draw from existing risk maps for 115 towns (UNISDR 2008).

In the area of **construction guidance and standards**, California's Field Act in 1933 stands as the starting point of the movement. The Act requited 15 % higher performance standards for new school construction and introduced stringent supervision. Legacy school construction was raised as a policy issue as early as 1938 (Garrison Act) but was not enforced until 1968. The oversight system involves structural plans prepared by engineers and approved by the Division of the State Architect. There is recurring on-site inspection and a final verification process.

The more common approach is the development of technical guidance for planning, design, construction, and local ongoing maintenance. There are numerous variations on this theme. For example, in the Philippines, in 2007, the Department of Education adopted the Principal-Led School Building Program approach where principals or school heads take charge of the implementation of management of the repair and/or construction. Assessment, design, and inspection functions are provided by Department of Education engineers who assist the principal during the procurement process. The Parent, Teacher, and Community Association and other community stakeholders are responsible for auditing procurements (INEE 2010). Interestingly, in Panama, it was the development and implementation of the maintenance guidance tool that paved the way for new school construction standards (UNISDR 2012).

There have been several examples of post-disaster commitment to "building back better," emerging from a general consensus following the 2005 Indian Ocean earthquake and tsunami, on the need use humanitarian assistance and reconstruction financing more responsibly. However, in the area of school seismic safety, these good intentions have only translated vaguely to measurable improvements in safe school construction. In Pakistan, 4 years after a devastating earthquake there, the National Education Policy 2009 section 5.5 addressed Education in Emergencies with several policy actions including requirements for school construction according to international standards (UNISDR 2012). Following the devastating 2010 earthquake in Haiti, many donors stated that the schools that they are supporting seismic, hurricane, and flood-resilient school reconstruction, though there is no program that monitors progress in this regard.

In Indonesia in 2009, the Center for Disaster Mitigation, Institute of Technology Bandung (CDM – ITB), and Save the Children International published a handbook of typical school design and a manual on retrofitting of existing vulnerable school buildings for the Aceh and West Sumatra Earthquake Response programs. The guidelines take into account lessons learned in safe school construction, weaknesses in oversight of local government construction, and the need to incorporate design of dual-purpose multi-hazard shelters. In 2014 they were considered ready for an update.

In the Philippines, following devastating typhoons in 2006, 99 disaster-resilient schools and 26 day-care centers were constructed with the support of the Department of Education engineers, school principals, and community members. The new buildings, with water and sanitation facilities, can also serve as evacuation centers with flexibility to accommodate large numbers of people for emergency shelter (Global Education Cluster 2011).

Following the 1999 Kocaeli earthquake, 820 of 1,651 schools that were 60 km away in Istanbul, were found to have sustained some damage. Thirty-five schools were replaced, 59 schools were strengthened, and 59 were repaired (COGSS 2008).

Clear warrants and commitments from donors IGOs or INGOs when it comes to safe school construction are still clearly much needed.

There have also been too few and/or too quiet **commitments to safe school construction** in the context of the Millennium Development Goals, in spite of the fact that the Global Partnership for Education states as its first strategic goal the provision of a quality basic education in a *safe* environment. The most important and notable has been in Uttar Pradesh, India, where 23.5 million children attend school in this

Encyclopedia of Earthquake Engineering
DOI 10.1007/978-3-642-36197-5_396-1

moderate to severe seismic risk zone; 21,000 new school buildings (30/day) were to be built in a 2-year period. In 2006–2007 the Elementary Education Department proposed to integrate earthquake-resilient design into all new school buildings. One primary school, two upper primary, and three additional classroom designs were prepared with detailed construction manuals. Disaster-resilient measures added 8 % to the construction costs. To cope with massive scale of the project, a cascading approach prepared 4 master trainers for each of 70 districts. These individuals trained 1,100 Junior Engineers and Education Officers. Ten thousand masons were also trained. In Uttar Pradesh every new school is now a safe school (UNISDR 2008).

Overview of Global Experiences in School Seismic Retrofit

In Sichuan, China, Prior to the 2008 Sichuan earthquake, school principal Ye Zhiping pestered local authorities until they consented to retrofit the buildings of Sangzao Middle School to improve their safety. He also initiated regular evacuation drills. The result of his efforts was that during the devastating earthquake, this school provided life safety for all of its students and staff.

The United Nations Center for Regional Development in Kobe began promoting school earthquake safety initiatives in 1999, in the process of resilience-building following the Hanshin-Awaji earthquake. A multi-country school seismic retrofit initiative (2005–2008) sought to make schools safer through self-help, cooperation, and education. The project engaged local communities, governments, and resource institutions in demonstration vulnerability assessments and school retrofit projects in four to six schools each, in Fiji, India, Indonesia, and Uzbekistan. In 2006, the state of Uttar Pradesh, in India, undertook large-scale disaster-resilient construction of new schools (Bhatia 2008). GeoHazards International also conducted small-scale screening and retrofit demonstration projects in vulnerable schools in Delhi, India (Rodgers 2012), and helped Bhutan's Ministry of Education develop the process and tools for a nationwide school vulnerability assessment program, which is currently underway.

More than a dozen countries have developed approaches, conducted significant vulnerability assessments, and/or made commitments made to school retrofit since 2000. Several of these were inspired by unacceptable levels of damage experienced in recent large earthquakes. Many are instructive or inspiring, in terms of their scope, methods, and limitations. Looking at these regionally allows an overview of both limited scope and adequacy.

Middle East and North Africa: In Algeria, vulnerability assessment was done on 526 buildings in 190 schools across 9 municipalities in Algiers, using simple survey forms (Rodgers 2012). In Syria, UNDP is supporting earthquake school safety program incorporated into 5-year plan and institutions for disaster risk reduction are being consolidated (UNISDR 2012). The Arab League is currently considering a regional approach to disaster risk reduction, which will hopefully include a comprehensive approach to school safety.

North America: In British Columbia, Canada, Vancouver school buildings were surveyed in 1990 (Rodgers 2012). Responding to advocacy efforts of the local "Families for School Seismic Safety," in 2004, the provincial government committed $1.5 billion Canadian to ensure that BC Schools meet acceptable seismic life safety standards by 2019.

In the USA, there has been detailed assessment of 26 school buildings in Kodiak, Alaska, with recommendation for retrofit of four. In California, a desk assessment of 9.659 pre-1978 school buildings found 7,537 potentially vulnerable buildings. Twenty thousand uncertified projects have been mapped (California Watch 2011). The state of Oregon conducted collapse risk assessment of 2,185 K-12 school buildings using FEMA 154 rapid visual screening (RVS) and produced structural engineering reports for more than 300 buildings. South Carolina has completed a prioritization exercise on all public schools; six

DOI 10.1007/978-3-642-36197-5_396-1

have been retrofitted. In Tennessee 49 buildings in 202 schools have been screened using ATC-21 plus local methods, and in Utah, RVS was used on a sample of 128 of 1,085 schools in the state (Rodgers 2012).

Latin America and the Caribbean: The Organization of American States began a commitment to school safety in 1992. A coordinated regional action plan was developed to benefit Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama. Development assistance donors and local organizations contributed to strategies and capacity to carry out retrofitting of educational facilities. School infrastructure experts from each country received training.

In Bogotá, Colombia, in 1997, seismic microzonation studies paved the way for seismic-resistant building codes in 1998. In 2000 the Directorate of Prevention and Attention of Emergencies in Bogotá found 434 of 710 schools vulnerable to earthquake damage, 3 in flood areas, and 20 in landslide-prone areas. Two hundred and one were prioritized for retrofit or replacement. Between 2004 and 2008, an investment of $460 m USD in school replacement, retrofit, and risk management promotion provided structural reinforcement of 172 schools, "nonstructural" risk reduction in 326 schools, and the construction of 50 new mega-schools, compliant with earthquake-resistance requirements. Three hundred thousand children are safer as a result (see entry "► School Seismic Safety: Case Studies" for case study of Colombia). In Ecuador, initial screening of 340 high-occupancy school buildings, and modified RVS of 60 most vulnerable, detailed analysis for 20, and retrofit designs for 15 have taken place (Rodgers 2012). In Lima, Peru, 28 schools in Barranco and 80 schools in Chorrillos were evaluated using ATC 21 RVS and EMS_98 estimation of damage potential (Rodgers 2012). A retrofit solution was developed to mitigate potentially devastating structural defect of "short columns." And in Venezuela, 50-year-old schools were identified as needing retrofitting in moderate and above seismic zones, whereas 20–30 year-old "box" schools only require retrofit in higher-risk zones. Practical retrofitting techniques were developed. As of 2007, 28,000 schools were being surveyed in a national program. Twelve schools were selected for pilot retrofits (Rodgers 2012).

Europe and Central Asia: In Europe, discussion has been robust in Italy and Portugal, innovations have been led by UNICEF and partners in Central Asia, and World Bank financing has supported Turkey to make significant progress in seismic safety (see entry "► School Seismic Safety Case Studies" for case study on Turkey).

In Yerevan, Armenia, full assessments have been conducted by teams of dozens of people, mobilized from as many as seven different government agencies, over several days. Every year 40 of Yerevan's 200 schools are slated for special maintenance, upgrading, and retrofitting. It has been noted that a 2-person expert team spending 2 h per conducting a rapid assessment would require 6 FTE years to assess Armenia's 1,500 schools. In Kyrgyzstan, a national school safety assessment of over 3,000 learning facilities with support from USAID found that more than 80 % were vulnerable to earthquake damage. Public access to this information is made possible through an online portal (UNICEF 2011).

In Uzbekistan 1,000 school buildings were assessed, revealing that 51 % require demolition and replacement, 26 % require capital repair and reinforcement, and 27 % are life safe and require no intervention (Khakimov et al. 2007). Eleven design institutes participated in building code revision for school building construction. Typical designs were created for new schools of different sizes. A database of typical construction and technical decisions seismic reinforcement were developed. UNCRD provided financial and technical support for demonstration projects on reinforced concrete frame, masonry, and frame panel buildings. The incremental cost of seismic reinforcement was shown to be between 3 % and 14 % depending on intensity zone, type of construction, number of floors, capacity, and ground conditions (Khakimov et al. 2007).

In Italy, a substantial contribution comes in the form of an overall risk management framework developed for retrofit prioritization (Grant et al. 2007). Some schools have now been assessed in Emilia-Romagna (Rodgers 2012). Portugal has demonstrated an important innovation by incorporating

DOI 10.1007/978-3-642-36197-5_396-1

school vulnerability assessment and retrofit into its ongoing modernization program. At least 330 public school buildings have been assessed and retrofits designed (Rodgers 2012; UNISDR 2012).

The Istanbul Seismic Risk Mitigation and Emergency Preparedness Project (ISMEP) (with loans from World Bank and EIB) allowed for retrofitting of 250 schools and reconstruction of 36 schools in 2007–2008 with 600 more undergoing assessment and feasibility studies. In 2009 the remaining 450 schools were slated for retrofitting.

South Asia: Bhutan has begun a nationwide vulnerability assessment of school buildings. The first phase, covering 5 of Bhutan's 20 districts, began in 2013, with funding from UNICEF.

In India there are several examples of large-scale seismic vulnerability assessments: In Gujarat a modified RVS was conducted for 153 schools following the 2001 earthquake (Rodgers 2012). In Shimla, SEEDS India took a stepwise approach: Step one was low-cost mass scale RVS of school buildings. From these, a smaller number were selected for simplified vulnerability assessment using limited engineering analysis. The highest-risk buildings were identified for detailed vulnerability analysis (SEEDS 2006). Retrofitting designs were drawn up for 20 schools and implementation carried out in ten schools. Guidelines were developed for retrofit and training of local masons and engineers and delivery of skill training. "Nonstructural mitigation plans" were carried out in 20 schools. An awareness campaign reached out to all 750 schools, including nearly 100,000 students, 7,500 teachers and local builders, engineers, and officials (SEEDS 2006). The Government of India's National School Safety Program plans to seismically retrofit more than 40 schools throughout the country as demonstration projects. The National Center for Peoples' Action in Disaster Preparedness (NCPDP), GeoHazards International, and others also carried out school assessment and retrofit programs.

Nepal has also made some strides in both vulnerability assessment and retrofit planning. There are an estimated six million children and 140,000 teachers at risk of death and injury in schools. In the Kathmandu Valley, 643 schools (1,100 buildings) have been inventoried and 378 (695 buildings) surveyed for vulnerability. Seventy-five percent are expected to be damaged beyond repair, in a scenario earthquake. A school day earthquake would kill 29,000 children and teachers and injure 43,000 (Dixit et al. 2013). The MoE has planned to retrofit 900 schools in the Kathmandu Valley over 5 years (Dixit et al. 2012). In Lamjung and Nawalparasi, vulnerability screening has covered 745 and 636 buildings, respectively, some with detailed assessments (Rodgers 2012).

In Pakistan, in 2008, the Aga Khan Planning and Building Services, Habitat Risk Management Program in Northern Pakistan, used retrofitting of four schools to demonstrate structural and nonstructural seismic retrofitting, to train builders and to train female village youth in mapping, land-use planning, and disaster management (INEE 2010).

Southeast Asia: There has been relatively sparse activity when it comes to seismic safety of schools in Southeast Asia. It may be that the frequency of cyclones and flooding and even the threat of tsunami precede thoughts of earthquake risks. It may also be that the rapid pace of development and the increasing numbers of new children being brought into school have led to natural prioritization of safe new construction rather than retrofit. In the Philippines, local authorities are responsible for school construction. However, assessment, design, and inspection functions are provided by Department of Education engineers who assist the principal during the procurement process. The Parent, Teacher, and Community Association and other community stakeholders are responsible for auditing procurements. Earthquake, typhoon, flood, and even volcanic ashfall resilience must often be factored in (INEE 2010).

East Asia: School seismic safety has been on the agenda in Japan for many years, but it is only since 2005 that 125,000 public school buildings nationwide have been assessed by the Ministry of Education (MEXT) (Rodgers 2012). Sixty-two percent of these were constructed before 1981, when the current anti-seismic code enforcement began. About 25 % of schools are considered safe, but 48,000 older school buildings were found needing assessment or retrofitting. 10,000 of these were found to be at high risk of

Encyclopedia of Earthquake Engineering
DOI 10.1007/978-3-642-36197-5_396-1

collapse in expected earthquakes. The Ministry of Education raised subsidies for vulnerable school buildings from 50 % to 67 % in 2008 when 229 billion JPY was allocated to meet the new goal of retrofitting of all highest-risk school buildings within 4 years.

Oceania: School seismic safety is also on the agenda in New Zealand, where a walk through survey of 21,000 buildings at 2,361 public schools in 1998 triggered a follow-up investigation in 2000 (Rodgers 2012). A World Bank GFDRR project demonstrated school retrofit in six schools in two districts (2008–2009).

Summary

In the course of the past decade, an approach to all hazards and all aspects of school safety has emerged in both the literature and practice of global advocacy. The Global Alliance for Disaster Risk Reduction and Resilience in the Education Sector (led by UNESCO, UNICEF, UNISDR, IFRC, INEE, Save the Children, Plan International, World Vision) use the shared Comprehensive School Safety framework. The framework takes a multi-hazard approach and addresses the many different factors needed to address safe school facilities, school disaster management, and disaster reduction education. While seismic vulnerability (and related secondary hazards) to school buildings are naturally of concern to earthquake engineers and many others, it is important to fit this into an all-hazard and comprehensive approach so that the solutions to seismic safety do not ignore coexisting vulnerabilities to cyclones, floods, and volcanic eruption nor conflated with the broader approach that also addresses disaster management and education (Global Alliance for DRRR in the Education Sector 2014).

Overall, the threat of earthquake damage to school buildings has not been sufficiently well appreciated. School safety issues have not featured in the major global campaign for increased school attendance ("Education for All" and the Millennium Development Goals). The full extent of the risk to school buildings and to students remains to be fully defined.

A global effort at mapping schools (by density of occupancy and quality of construction) in relation to seismic and other hazards has been proposed by the World Bank Global Facility for Disaster Risk Reduction and Recovery, to begin in 2014. The full impacts of earthquakes on the education sector cannot end with calculating the value of structural and nonstructural damage. The impacts on *children's education* are almost entirely unmeasured. Research is needed to understand how educational outcomes such as enrollment, attendance, and achievement are impacted by earthquakes.

There are strong arguments that support giving school seismic safety increased priority and a higher profile. An initial step in raising the visibility of this issue was the adoption of school safety as one of the focal points for advocacy in preparation for the Hyogo Framework for Action 2005–2015 adopted at the World Conference on Disaster Reduction held in Kobe, Japan, in January 2005. The development of the Comprehensive School Safety framework in 2013 has begun to articulate how school facilities safety can be understood within the wider context that includes school disaster management as well as risk reduction and resilience education. As a post-2015 agenda for both development and disaster risk reduction are currently under consideration, it continues to be extremely important to raise the profile of school safety. In preparation for this, child-centered organizations have formed a Global Alliance for Disaster Risk Reduction and Resilience in the Education Sector.

Based in part on the case studies (see entry "▶ School Seismic Safety: Case Studies"), it seems evident that low-cost, accessible technology and design exists with which to build new schools and to retrofit existing ones. A community-based approach holds great promise involving many stakeholders, including local buildings, masons, contractors, etc. Promising demonstration and large-scale projects in Nepal,

DOI 10.1007/978-3-642-36197-5_396-1

India, Turkey (see entry "▶ School Seismic Safety: Case Studies"), Central Asia, and the Caribbean islands all provide strong experience to build upon for case studies.

Case studies also make clear that child rights advocates, parents, and seismic safety experts together, lobbying for school seismic safety, can be extremely effective in achieving policy change, as case studies of British Columbia and Bogotá (see entry "▶ School Seismic Safety: Case Studies") show.

School seismic safety has been the subject of both research and policy since the 1933 Long Beach earthquake that spurred California's landmark *Field Act*, requiring that school construction meet seismic safety standards. As both seismic risk assessment and building codes have progressed, so too have expectations for selection of performance standards. However, globally, the application of these standards and codes falls short in several major respects: community-built schools are frequently constructed using high-tech materials intended for engineered construction, without the corresponding understanding, training, or supervision; where building codes exist they are not known, understood, or consistently applied; and safe site selection is frequently skipped, and site-specific hazards are not factored in. Privately built schools are often exempt from the same standards of construction as public schools. The need for programs and people that bridge the available engineering knowledge with scalable on-the-ground national programs is significant.

In 2009, *Guidance notes on safer school construction* (INEE 2010) was published to synthesize and kick-start systematic guidance. An important global resource for documents to guide safe school construction was initiated by UNESCO IPRED, immediately after the Haiti earthquake (UNESCO IPRED 2010). This resource database endeavors to compile both building codes and the now numerous documents produced by NGOs or at the national level with standard designs for safe school construction, and in some cases with construction guidance.

The past decade has seen several relevant scientific papers suggesting methods for vulnerability screening (e.g., in Italy, Grant et al. 2007), and detailing approaches to seismic retrofit. The challenge is whether or not the guidance and the science are put into practice. The written record does not suggest that these approaches are yet systematic, are supported with training, are monitored, or are applied to both public and private schools. Community-built and un-engineered construction has been addressed in far fewer publications and has not specifically addressed school construction.

There have been a small number of significant programmatic efforts to support seismic safety. UNICEF's regional office for Central and Eastern Europe and the Commonwealth of Independent States, with support from the World Bank and DIPECHO, has partnered with national governments in Central Asia and the South Caucasus to address school safety. Part of that work has included developing a broad regional framework for assessing and ranking school facilities based upon exposure and vulnerability to earthquakes and other natural hazards. Drawing upon INEE's *Guidance notes on safer school construction*, UNICEF elaborated a list of 17 simple indicators that local experts could use as part of a rapid visual assessment of school facilities in order to identify schools at risk of heavy damage in seismic events.

In 2012, engineers in Kyrgyzstan localized this framework and carried out a national school safety assessment of over 3,000 learning facilities with USAID funding. They reported to the national government that over 80 % of learning facilities were vulnerable to damage in seismic events and provided public access to the assessment through an online portal. Similar national assessment strategies are being piloted in Kazakhstan, Tajikistan, Armenia, and Azerbaijan.

Similarly, UNCRD (UN Centre for Regional Development) showcased community-based comprehensive school earthquake safety in selected countries of Asia Pacific. Under the program "Reducing Vulnerability of School Children to Earthquakes," school communities carried out seismic retrofitting of their school buildings with expert guidance from Bandung Institute of Technology (ITB) in Indonesia. The retrofitting works in public schools were used for community awareness on earthquake safety through community visits in the school premises during construction time. Pilot school assessment and retrofitting in Fiji led to the National Disaster Management Office (NDMO) adopting school safety program under regular government that also developed seismic retrofit guidelines and mason's training manual. Tashkent city government (Hokimiyat) in Uzbekistan appraised neighborhood associations on schools retrofitting programs and used school constructions for training of engineers on seismic safety.

The United Nations International Strategy for Disaster Reduction (UNISDR) launched the 2006–2007 biennial awareness campaign "Disaster Reduction Begins in Schools." This was followed up in 2010 with the *Resilient Cities Global Campaign* for *One Million Safe Schools and Hospitals Campaign*. The 10-point checklist that 1,643 Mayors have signed on for, includes assessing and upgrading the safety of schools. These successes deserve praise but should not induce complacency. There is a long way to go with respect to school seismic safety.

Initial programs and guidance for safe school facilities have been provided by OECD (2004), UNCRD (2008), INEE/World Bank GFDRR/UNISDR (2010), and several other programs, with modest support of donors and lenders. These approaches experiences are now ripe for implementation at scale. These include regional hazard mapping and revision (where necessary), the potential for crowd-sourced mapping of local hazards; enforcement of seismic building codes by national, provincial, and local governments; training of engineers and significant capacity-building efforts to train local masons and other builders; and invention of more innovative models for funding reinforcement of schools.

It is important, however, not to fetishize the safety of school *buildings* and to take care not to separate the safety of the community of users and educational continuity planning, which is not limited to the buildings themselves. Neither should the focus be solely on fatality prevention. There is much similar work to be done to prevent disability and injury especially by securing the contents of the buildings and to assure educational continuity. All-school, participatory school disaster management planning, local risk assessment and risk reduction, mastery of emergency response skills, and regular drills to practice and improve readiness are important. A culture of safety is necessarily multifaceted, and activism in one area encourages changes in consciousness, expectations, and demands.

The enthusiasm for making education accessible to all does not absolve duty-bearers from assuring that school is safe from infrequent but high-impact hazards such as earthquake and various secondary hazards. It would be an ironic and tragic result if the achievement of one Millennium Goal (increased school attendance) is marred by increased death and injury of young people, thus setting back the achievement of another Millennium Development Goal (reduction of child mortality).

Cross-References

► "Build Back Better," Principles of Reconstruction
► Building Codes and Standards
► Earthquake Mitigation Legislative Policy Development Activities
► Earthquake Protection of Essential Facilities
► Earthquake Risk Mitigation of Lifelines and Critical Facilities
► School Seismic Safety: Case Studies

References

Bhatia S (2008) Earthquake-resistant school buildings in India. Urb Plan Des 161(4):147–149

California Watch (2011) K-12/public safety/spotlight/on shaky ground. 22 Dec 2011. Accessed 3 Feb 2012

DOI 10.1007/978-3-642-36197-5_396-1

CNN (2014) Haiti earthquake fast facts. http://edition.cnn.com/2013/12/12/world/haiti-earthquake-fast-facts/index.html. Accessed 6 Jun 2014

Coalition for Global School Safety (2008) School disaster reduction: think globally, act locally. 'Mother' slide presentation

Dixit A et al (2012) Institutionalization of school earthquake safety program in Nepal. In: Proceedings of the 15th WCEE. http://www.iitk.ac.in/nicee/wcee/article/WCEE2012_5260.pdf. Accessed 16 Feb 2014

Dixit et. al. (2013) Public School Earthquake Safety Program in Nepal, Geomatics, Natural Hazards and Risk, DOI: 10.1080/19475705.2013.806363

Dowrick D, Rhoades DA (2004) Risk of casualties in New Zealand earthquakes. Bull N Z Soc Earthq Eng http://www.nzsee.org.nz/db/Bulletin/Archive/38(2)0053.pdf. Accessed 5 Mar 2015

EERI (1990) Earthquake Engineering Research Institute, Oakland. Loma Prieta Earthquake 17 Oct 1989. Preliminary reconnaissance report. https://www.eeri.org/wp-content/uploads/USA_CA_LomaPrieta_PrelimReport.pdf. Accessed 16 Feb 2014

FEMA (2011) Reducing the risks of non-structural safety – a practical guide, 4th edn. Washington, DC. http://www.fema.gov/media-library/assets/documents/21405?id=4626. Accessed 19 Feb 2014

Global Alliance for Disaster Risk Reduction and Resilience in the Education Sector (2014) Comprehensive school safety. http://preventionweb.net/go/31059. Accessed 15 Jan 2014

Global Education Cluster (2011) Disaster risk reduction in education in emergencies: a guidance note for education clusters and sector coordination groups. http://preventionweb.net/go/20366. Accessed 16 Feb 2014

Global Partnership for Education (2014) Results and data. http://www.globalpartnership.org/results/. Accessed 16 Feb 2014

Grant DN, Bommer JJ, Pinho R, Calvi GM, Goretti A, Meroni F (2007) A prioritization scheme for seismic intervention in school buildings in Italy. Earthq Spectra 23(2):291–314

INEE/World Bank GFDRR/UNISDR (2010) Guidance notes on safer school construction. INEE (Inter-agency network for education in emergencies), New York. http://www.preventionweb.net/go/10478

Khakimov S, Nurtaev B, Tursunov K (2007) School earthquake safety program in Uzbekistan, slide presentation. Tashkent

New York Times (2008) School-age children in earthquake zones, 27 May 2008. http://www.nytimes.com/imagepages/2008/05/27/science/27school.graphic1.ready.html. Accessed 16 Feb 2014

OECD (2004) Keeping schools safe in earthquakes. Organisation for Economic Co-operation and Development, Paris. http://www.oecd.org/document/36/0,2340,en_2649_201185_33630308_1_1_1_1,00.html. Accessed 19 Feb 2014

Pandey B (2013) Political economy study on safe schools, World Bank, Global Facility for Disaster Reduction and Recovery

Rodgers JE (2012) Why schools are vulnerable to earthquakes. In: Proceedings, 15th world conference on earthquake engineering, Lisbon, 24–28 Sept 2012

SEEDS (2006) Earthquake Safety in Mountain Regions. School Earthquake Safety Initiative. Shimla, Delhi

State of California, Seismic Safety Commission (2009) The field act and its relative effectiveness in reducing earthquake damage in California's public schools. http://www.seismic.ca.gov/pub/CSSC%2009-02%20Field%20Act%20Report.pdf. Accessed 16 Feb 2014

UNCRD (2008) Reducing school vulnerability to earthquakes. United Nations Center for Regional Development, Hyogo, Japan. http://www.hyogo.uncrd.or.jp/publication/pdf/Report/2008SESI/UNCRD%20SESI%20publication%202008.pdf. Accessed 16 Feb 2014

Encyclopedia of Earthquake Engineering
DOI 10.1007/978-3-642-36197-5_396-1

UNESCO (2004) 'Education for all week 19–25 April 2004: the extent of the problem', information from UNESCO's (United Nations Educational, Scientific and Cultural Organization) http://portal.unesco.org/education/en/ev.php-URL_ID=28702&URL_DO=DO_TOPIC&URL_SECTION=201.html. Accessed 25 Jan 2014

UNESCO IPRED (2010) Resource/database, disaster preparedness and mitigation. http://www.unesco.org/new/en/natural-sciences/special-themes/disaster-preparedness-and-mitigation/natural-hazards/earthquakes/ipred/unesco-ipred-database/. Accessed 25 Jan 2014

UNICEF (2011) Toward safer schools – methodology for nationwide benchmarking of school safety http://www.unicef.org/ceecis/towards_safer_school_FINAL.pdf. Accessed 5 Mar 2015

UNISDR (2008) Disaster prevention for schools – guidance for education sector decision-makers. Geneva. http://www.preventionweb.net/go/7344. Accessed 25 Jan 2014

UNISDR (2012) Assessing school safety from disasters, a global baseline report. http://preventionweb.net/go/35274. Accessed 15 Jan 2014

USGS (2003) 'Magnitude 8.3 – Hokkaido, Japan region 25 Sep 2003 19:50:06 UTC'. http://earthquake.usgs.gov/recenteqsww/Quakes/uszdap.htm. Accessed 25 Jan 2014

USGS (2015) Historic World Earthquakes. http://earthquake.usgs.gov/earthquakes/world/historical.php. Accessed 5 Mar 2015

WEF (2000) UNESCO World Education Forum. http://www.unesco.org/education/efa/wef_2000/. Accessed 5 Mar 2015