School Seismic Safety: Falling Between the Cracks?[1]

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THE RIGHT TO A SAFE EDUCATION

Access to education is a basic human right. It is one the Millennium Development Goals, and there is a strong drive to implement it (UN 1948; UN 2000; WB 2004; WCEA 1990; WEF 2000). However, in the rush to fulfil the right to education, are children being put at risk?

In common with other infrastructure, school buildings are subject to damage and collapse in earthquakes. In the recent past children and teachers have died at school in such disasters (Table 1).

[Table 1 here]

Also thought provoking are the near-misses. Recent studies document earthquake damage to schools from around the world, including many cases in which an earthquake destroyed school buildings out of school hours when they were empty (Table 2; FSSS 2004; NGDC 2004; OECD 2004). The potential magnitude of loss of life in these near-miss events highlights the importance of ensuring the seismic safety of schools.

[Table 2 here]

Education for All

At the present time around the world at least 100 million children of school age do not attend school.[2] They represent about 14% of the world's children (UNESCO 2004b). Providing facilities to educate them requires construction of schools and rapid expansion of building programs. For example, in 2004 it was estimated that more than 7,500 new schools were needed within the next three years solely in Afghanistan, a country with a significant seismic hazard (UNICEF 2004).

In this chapter we seek to call attention to the magnitude and urgency of the question of seismic safety in schools. In the next section we estimate the order of magnitude of the challenge. Then we offer a series of case studies from various countries. The third section discusses the arguments in support of making school seismic safety a major priority. Finally, we conclude with a note on the prospects for addressing the problem and the need for further study.

SOME THOUGHT EXPERIMENTS

In the absence both of world-wide data on the location of schools in relation to zones of high seismic hazard and a world-wide census of the quality of construction and number of children in schools, we have mounted some simple experiments in thought to provide a first approximation of the global risk. We must emphasize that the data are patchy and of uneven quality. In each case, we make our assumptions explicit and take a conservative view of the risk, thus avoiding the danger of overestimation. In a world with a wide variety of needs, where hundreds of millions of people live on less than one US dollar a day, and where public health, food security, and shelter compete with education for investment, it is not wise to overestimate the school seismic safety risk. Therefore, we have tried to take a realistic view and to relate the risk to other urgent priorities.

Table 3 provides a list of countries at high seismic risk, which we have used to provide an initial estimate of the number of primary- and secondary-level students who attend schools in seismically active countries.

[Table 3 here]

We used to following method to make the estimates:

- In examining the population age structure of countries, the relevant age band for which data are available is 0-14 years old (data are from ODCI 2004). The legal age at which children leave school in most countries is between 14 and 17 (Melchiorre 2004). Taking the upper bound as 14 yields a conservative but reasonable estimate for the numbers of school-age children.
- In most countries, compulsory education starts between the ages of 5 and 7, although pre-school (early childhood) education is becoming common in many countries (UNESCO 2004a). Thus, Table 3 may overestimate the upper bound for the numbers of school-age children.
- For the present purpose, we estimate that, as a reasonable starting approximation, the number of students aged 14-17 is probably slightly less than the number of children aged between 0 and 5 who will live to attend school and who do not attend pre-school.
- One limitation of Table 3 is that the numbers are given by country, not by seismic region. Thus, it is difficult to translate "school age children" into "school age

children in high-risk seismic zones". Countries with respect to which a significant overestimate is likely are marked in bold print in Table 3.

Despite these necessarily approximate assumptions and caveats, of the roughly one billion children aged 0-14 who live in countries at high seismic risk, several hundred million are at risk when they are attending school.

This is by no means a trivial problem. The great effort on the part of the donor nations and national authorities rapidly to boost the proportion of school-aged children who attend school could have the ironic and tragic consequence of putting more children at risk of death or injury in earthquakes. School seismic protection is not mentioned anywhere in the literature on "Education for All" (EFA) programs that we have reviewed. "Education for All" is a world-wide effort to increase school attendance that began in the 1990s, was formalized as one of the eight Millennium Development Goals in 2000, and has been repeatedly reaffirmed since (WCEA 1990; WEF 2000; WB 2004). Great efforts to increase the reach of education are being made, accompanied by a flurry of school construction. What attention is being given to seismic safety during the construction of this new educational infrastructure?

The situation is clarified further if we focus our attention on the 20 countries in the world that experienced the greatest number of earthquake fatalities over the period 1900-2000 (Table 4).

[Table 4 here]

If “Education for All” initiatives are successful in all of these 20 countries, but no special attention is paid to the seismic safety of school buildings, it is possible that at least another 34 million children will be placed at risk of earthquakes while they are attending school. Even if one allows for the particularly high standards of school construction in Japan and for the fact that in large and geologically diverse countries such as China and Mexico not all newcomers to school live in the zones of highest seismic hazard, a considerable number of the beneficiaries of “Education for All” campaigns will be vulnerable to seismic hazards. If EFA is successful, a mere six countries -- those with low diversity of geological hazard – would account for around 24 million new students enrolled and attending schools. These countries are highlighted in bold print in Table 4.

Finally, stretching the limits of our first approximation, we provide a conservative estimate per decade of the number of school children who may die in school buildings that collapse due to earthquakes in the near future. This approximation is based on Table 5, the numbers of earthquakes reaching VIII or higher on the Modified Mercalli scale of damage in selected countries for the period 1954-2003.

[Table 5 here]

On this basis, we would expect 30-60 earthquakes per decade to cause collapse or severe damage to school buildings. We assume that, in half of these earthquakes, the school buildings affected will have appropriate seismic resistance. Therefore, 15-30 earthquakes per decade will severely damage or cause to collapse school buildings that have not been either strengthened appropriately when constructed or retrofitted.

We also assume that earthquakes are distributed randomly in time. Moreover, we assume that on school days children occupy the buildings for 5-8 hours and that there are school days for 15-25 days per month and 7-10 months of the year. This gives a total of 105-250 days per year upon which schools are likely to be occupied fully. Thus, we assume that children are in school buildings for 6-23% of their time each year.

Consequently, between one and seven earthquakes per decade would cause severe damage to schools while children are present. Based on past observations, such earthquakes could cause collapse of or severe damage to something ranging from a handful to dozens of schools. In rural India schools may have ten students while those in Vancouver may have 1000. On average, if each school has 100 students (which is a geometric mean), then a lethal seismic event could kill between a handful of students to several hundred per school.

An approximate median value for any decade could be calculated as follows:

- 4 earthquakes × 30 schools collapsed or severely damaged per earthquake × 100 students per school × 40% mortality rate[3] (from Italy and Turkey cases) =
- 4,800 school children killed by earthquake-related school collapse or severe damage over the next decade.[4]

When 26 children died in the collapse of a school in Italy in 2002, this was regarded as an international tragedy. Imagine 480 each year. Ten thousand school children and many teachers are estimated to have died in their homes in the 2003 Bam earthquake in Iran. Should we accept the death as a result of a seismic event of half that number in schools, even if it happens only once in a decade?

CASE STUDIES

Italy

Of the 8,104 municipalities in Italy, all are classified as 'seismically active' and in 2,965 (36%) of them, all new construction must observe anti-seismic building codes. These communities are home to 40% of the country's population and therefore many of its schools. These are particularly at risk in two situations. There are 368 municipalities that are in the highest seismic classification, especially those located around the Strait of Messina in eastern Sicily and southern Calabria, where earthquakes are likely to be strongest. Also in the Apennine mountain areas, where earthquake risk is moderate to high, but modest local taxation revenues do not favour the processes of retrofitting and maintaining vulnerable buildings (Angotti 1977). If we take risk as a function of vulnerability and hazard, in the first situation risk is high because hazard is high. In the second, risk is elevated because vulnerability is high (that is, mitigation is low).

At Balvano in Potenza Province (central southern Italy) on the evening of Sunday, 23 November 1980, a magnitude 6.8 earthquake caused a dilapidated church to collapse and crush scores of young people who were participating in a service for children (Stratta 1981). This highlights the role of the Catholic church in education in Italy, a role that is qualified by the poor state of repair of much of church property. Some 1,300 religious buildings were seriously damaged in the central Italian earthquake swarm that lasted for three months starting on 26 September 1997. Moreover, at the time of writing, no large earthquake has occurred in Italy with an epicentre near to a major center of population since the Avezzano event of 1915 (Basili et al. 1990).

The event that for Italians most encapsulates the seismic risk to schools was a fairly modest one, with a body-wave magnitude of only 5.4. It occurred on Thursday 31 October 2002 at 11:40 a.m. local time, and its effects were concentrated on the Apennine town of San Giuliano Pugliese (population 1,195). The town's 11th Century castle was undamaged, but its infants' school collapsed onto a class of small children. Although 35 pupils were rescued alive, 26 children and three teachers were crushed to death (Augenti et al. 2004; Dolce 2004). The building had been constructed with regional development funds in the early 1960s and had had its roof renewed a year before the earthquake. Evidently, the roof, constructed in reinforced concrete with a ring-beam, was too rigid and too heavy for the underlying structure, a concrete frame building with hollow-brick infill. There were signs that the quality of the cement was poor and the reinforcing steel was not used as it should have been. Moreover, despite mounting evidence that the Molisan Apennines are significantly affected by periodic earthquake activity, local building codes had not been revised to take account of the new data on seismic risk, as the process requires data on actual events, and earthquakes have not been common there during the period of records (Valensise et al. 2003).

The school at San Giuliano di Puglia succumbed because it contravened simple, well-known laws of dynamic response in structures affected by seismic acceleration. Inertial forces applied to a heavy roof sitting upon a weak frame structure amount to a recipe for tragedy. The San Giuliano event calls to mind the earthquake swarm which affected the Apennines further north in 1997 (in the regions of Umbria and Marche), which killed 13 people. In many instances, buildings of mixed construction type were the worst affected. In other cases, poor state of maintenance was the critical factor.

Consider the schools of the Lunigiana, a surprisingly remote mountainous area of Tuscany north of Pisa and inland from the Tyrrhenian Sea coast. The Lunigiana has a sparse and dispersed population. Children attend elementary schools in the villages and secondary schools in major population centres, such as Aulla and Pontrémoli. Many of the school buildings were constructed in the 1950s and 1960s to cater for the post-War population boom, and, in a rural area of relative economic stagnation, they have neither been built to be fully anti-seismic nor retrofitted. Indeed, in the minor centers they are decidedly dilapidated, nor do their staffs seem to have much interest in continually practising evacuation drills. Yet the area awaits a magnitude 6 earthquake which, it is predicted, may kill up to 120 people and injure more than a thousand (D'Amico and Albarello 2003). How many of them will be school children? This situation is typical of the seismic risk that affects highland Italy. The areas may be rural backwaters, but their vulnerability to earthquakes is very significant.

Elsewhere in Italy, much more progress has been made. The civil protection departments of several Regional governments have introduced comprehensive *Scuola sicura* (school safety) programmes, notably in the northern regions of Lombardy, Piedmont and Emilia-Romagna, and in the autonomous Region of Sicily. The programmes involve a combination of structural measures and non-structural ones, such as evacuation drills and lessons in civil protection. In many of the major cities, fire brigades and volunteer civil protection services are heavily involved in the programmes. It is widely recognized that children's education is the key to sensitizing families about earthquake risk. Hence, with the collaboration of the Walt Disney Italia Corporation, the National Department of Civil Protection and some of the regions have invested in producing attractive safety literature for children. Interestingly, the Tuscan municipality of Campi Bisenzio has instituted a plan in which it is recognised that self-protective strategies may need to differ according to the hazard -- children practise different evacuation drills for flood and earthquake hazards.

Despite these developments, as in other seismic countries so in Italy, the building stock of schools continues to age and the civil protection educators must fight against the indifference of teachers, principles and administrators. In many respects, mass mortality in Italian schools during recent seismic events has been avoided mostly by the lack of major earthquakes during school hours, a situation that will not prevail forever.

Nepal

Schools in Nepal, both their buildings and its occupants, face extreme risk from earthquakes because of highly vulnerable building stock, high occupancy in it, and high seismic hazard. Nepal is located in one of the most seismically active regions of the world, due to the subduction of the Indian plate below the Tibetan plate. On average, Nepal is hit by a major earthquake once every 100 years and a medium-size earthquake once every 40 years. In 1988, eastern Nepal experienced an earthquake that measured 6.6 on magnitude scales. More than 950 school buildings were damaged (Thapa 1988). Fortunately, the earthquake happened at night, so the schools were not occupied.

A review of the seismic vulnerability of public school buildings and possible intervention options in the Kathmandu Valley showed a grim situation.[5] The study surveyed 900 public school buildings, of which 78% were normally constructed buildings and the remaining 22% were standard two-room steel sheds constructed by the government after the 1988 earthquake. The study showed that even in greater Kathmandu — economic, political and technological hub of Nepal — more than 60% of the schools are made of weak construction materials. These include mud, fired or unfired brick or stone in mud mortar. None of the school buildings in the survey were earthquake resistant. More than 25% were hazardous for use even in normal times because of their precarious condition, although some of these were not in use (NSET 2000).

The seismic assessment of these normally constructed school building shows that in the case of seismic shaking addressed by the building code,[6] more than 77% of the school building would suffer severe damage beyond repair, and other 25% would suffer repairable grade damage.

Most of the Nepalese school buildings are produced by the community itself, mostly employing local craftsmen who play a pivotal organizational and technical role. Most of these craftsmen have no formal training, and some are illiterate. The process is characterized by the high degree of informality. The local availability of the construction materials such as fired or unfired bricks, stone in mud mortar, timber, controls the construction process. The use of modern materials such as cement, concrete, and steel bars is limited by affordability and accessibility, and is confined to urban areas and areas accessible by transport. Most new school buildings in Nepal are built according to convention, rather than being specifically designed. Trained technical people in Nepal are generally not involved in school building construction process unless there is financing from government. This is because of the low budgets for most school construction and because of a lack of awareness and knowledge on the part of graduate engineers of traditional and informal construction methodology (Bothara and Sharpe 2003). As a result most school buildings lack earthquake resilience.

Since so much school construction in Nepal takes place locally in a decentralized, traditional, and informal manner, a Nepalese NGO, the National Society for Earthquake Technology Nepal (NSET) conducted a program to strengthen existing school buildings and promote earthquake resilient school building construction. The program incorporated strengthening of structural as well as non-structural components of the school buildings for seismic safety (Bothara et al. 2004). This program involved craftsman training, technology development and transfer, and community awareness raising. Such activity focused on schools has far reaching effects. By raising awareness in schools, the entire community is reached because lessons trickle down to parents, relatives, and friends.

When designing seismic retrofitting or earthquake resilience for new construction, NSET's focus has been on the socio-cultural and economic issues that affect acceptance by the community. An approach was developed, with outreach to all stake-holders -- school staff, students, local community, local clubs, local and central government. They have all been involved in the process so that they become aware of the risk and support the solution. School building construction was taken as an opportunity to train masons and to transfer simple but effective technology to others in the community, including house owners.

Following this approach NSET has already retrofitted four unreinforced masonry school buildings and engaged in construction of 16 new schools in and around Kathmandu Valley. The program was successful in transferring technology to local craftsmen who were quite keen to learn about the complete process and to adopt the technology. These masons became the propagators of the safety massage in the vicinity of these schools and the replication of earthquake resilient construction.

NSET's experience shows that seismic retrofitting and earthquake resistant new construction are affordable and technically viable.

Algeria

Ninety percent of Algeria's population of thirty million is concentrated in a band about 60 km wide and 1200 km long that extends along the coast of the Mediterranean Sea. The whole coast of Algeria is located on the African and Eurasian tectonic plate boundary. This region has repeatedly experienced moderate-to-strong earthquakes. During the 20th Century, earthquakes claimed at least 10,000 lives, injured about 27,000 and made homeless approximately 550,000 others. In addition to building collapse due to earthquakes, considerable damage from liquefaction and landslides was observed (Benouar 1994 & 1996).

School buildings have also suffered considerable damage in earthquakes. Factors explaining damage to schools can be best understood by considering the period during which they were built.

Algeria’s schools may be classified into three categories. The first category, which is characterized by a well advanced degradation by ageing and lack of maintenance, was built during the colonization era (1830-1962) and accounts for about 30% of the school building stock.

The second category, built after independence under the constraints of a rapidly growing population while also responding to the democratisation of educational opportunity, was designed and built without taking into account seismic risk. During the 1970s particularly, in what was called the ‘cultural revolution,’ the government had to build as quickly as possible at the expense of control and thus quality. There was no seismic building code in Algeria until 1981. Since independence education in primary school has been free and compulsory, thus the government has had to build numerous schools in cities and countryside. The cost of this school construction program accounted for the largest single item Algeria’s budget for many years.

The third category of school builing is that built after 1983. These schools were built according to the seismic building code and under technical supervision.

Schools in Algeria are all state owned and were built by the government. The government adopted one typical structure for all schools that could be duplicated easily across the country. The architectural design of schools involves two fundamental elements: the classroom and the circulatory corridors. The dimensions of a classroom are standardized to 7 meters for the length and 4 meters for the width. Circulatory corridors surround the classrooms and have a width of 2.5 meters. These standardized dimensions for schools in Algeria are far from those of an ideal seismically resistant structure as recommended by Algeria's own seismic codes. Other standard design elements also unfortunately reduce the resilience of these school structures.

Numerous reports show the deficiencies in design, construction techniques, and materials (poor quality of concrete) with respect to particular earthquakes at El-Asnam (1980), Chenoua-Tipaza (1989), Beni Chougrane-Mascara (1994) Ain Temouchent

(1999) and Boumerdes-Algiers (2003). The following typical damage to school buildings has been recorded in recent earthquakes:

- Rupture of staircases
- Destruction of joints
- Destruction of short columns
- Damage in Masonry
- 'Pancake' collapse due to weak columns, overly strong beams and heavy roofs composed of reinforced concrete slabs.

Table 6 shows the scope of school damage during recent (Bendimerad 2004).

[Table 6 here]

Such damage causes enormous financial loss to the government. For instance, according to the National Ministry of Education, after the Boumerdes earthquake disaster of 2003 in the provinces of Boumerdes and Algiers 100 primary schools had to be rebuilt completely for the sum of US$4.28 million and 253 rehabilitated for $10.65 million. In addition, 12 junior high schools were completely rebuilt for the sum of $10.28 million and 111 rehabilitated for $20.85.

Also, 10 high schools were rebuilt for the sum of $21.42 million, and 58 were rehabilitated for $12 million.

Fortunately, so far these destructive earthquakes have occurred after school hours or on weekends, and thus no loss of life or injuries have been recorded at schools in Algeria. This good luck may have made government and the civil society alike less aware of the high vulnerability of the schools. It may also go some way toward explaining why there has so far been no implementation of a Ministerial instruction dating from 1989 that required application of “[t]echnical expertise and the eventual reinforcement of all public buildings and in particular schools and universities”. As a matter of fact, the introduction of new materials such as reinforced concrete in the absence of proper seismic resistant design, building codes and enforceable regulations has increased the risk to structures and their occupants. Relatively minor reinforcements could reduce the potential for damage to these structures.

Colombia

The capital city of Colombia, Bogotá, is the most important political, administrative, economic and cultural center of the country. Bogotá's population was estimated to be around 6.9 million in 2003. Nearly half of these people live below the poverty line (46%); while nearly a million live in extreme poverty.

Among the most common hazards events affecting Bogotá are earthquakes and landslides, both of which may affect schools, where a student population of nearly one million young people spends considerable amounts of time (Asociación Colombiana de Ingenieria Sismica 1997; París 1993). Although there has not been a severe earthquake in Bogotá since 1917, there is certainly the potential for one (Ingeominas and Uniandes 1996; Ramírez 1975). Also, elsewhere in Colombia, 74% of the schools in the cities of Pereira and Armenia suffered damage in the 1999 earthquake (Garcia and Cardona 2000). Fortunately this occurred during the lunch hour, and no children were in the school buildings.

Several risk identification methods have been put in place in the city in the past few years. These include compilation of records of disaster hazard events, generation of hazard maps, studies of physical and social vulnerability, and studies of environmental degradation. One of the means of reducing risk from earthquakes and landslides in Bogotá is the assessment of seismic risk of bridges, hospitals, and schools. This has become a core part of the city's economic and social development plan. Of these assessment programs, the best-known is the Department of Education's effort to identify school seismic risk and to reinforce schools.

Much of the educational infrastructure in Bogota is more than 40 years old and does not meet minimal standards of safety. For this reason the Department of Education commissioned a systematic review of schools that ran from 1997-2003 (Secretaría de Educación del Distrito Capital de Santafé de Bogota 2000). This study covered approximately 2,800 buildings at 706 schools (including the addition of 16 schools resulting from new construction in 2004). Some 498,000 students attended these schools – a number that amounts to roughly 54% of the student population in Bogotá. The other 46% of the student population attends private schools and was not covered in this review.

By law in Bogotá only hospitals, and not schools, require inspection and seismic reinforcement. Some professionals and leaders in Colombia see this as a legal anomaly and want to extend the law to cover schools. However, in the meanwhile, and much to Bogotá's credit, the Department of Education launched its program for public school safety without legal mandate. However, this also means that there is no legal compulsion to force inspection and reinforcement of private schools until the law in changed. The shift in awareness of the importance of school seismic safety on the part of the city government came, in part, because of outreach by the Colombian Association for Earthquake Engineering and by Universidad de los Andes and other universities.

The school safety review found that 434 of the schools presented high risk to students. Some 772 buildings at these schools fell into this category (16%). The study also found that 60 schools had buildings in immediate and urgent need of reinforcement. In 2004, retrofitting was underway or under contract at half of these schools.

The cost of structural reinforcement at all 434 schools is estimated to be US$100 million; however, the Department of Education would like an additional $50 million invested at these problem school sites in addition to the basic structural retrofitting. As an additional demonstration of political will, the funds for reinforcing buildings at the first 31 schools has come entirely from the Bogotá city budget, and the school safety program has been supported by the prior as well as the current mayor of Bogotá. These are substantial sums of money, especially for a city that faces many other needs. However, it is axiomatic that the best way of guaranteeing the safety of students is to ensure that new school buildings are built properly in the first place.

Assessing and reducing the risk to schools in Bogotá takes place in a more general planning and management context. For example, zones of high risk of landslide, where no mitigation works are possible, are declared to be protected land. Human occupation is restricted in these areas as well as those considered at high risk to floods. In 2003 it was estimated that some 185,000 people lived in informal settlements in a total of 34,230 informal housing units. In Bogotá there are 173 illegal settlements that account for 14% of the total land area. The city administration has developed a massive legalization program since 1995, thus reducing the number of informal settlements from 1,451 to its current number, an eight-fold reduction in less than ten years. Nevertheless, as much as 60% of the population of the city lives in informally constructed dwellings. While most of these are located in legal settlements, they still represent a challenge to seismic safety. The year 2000 land use master plan for Bogotá contains hazard and risk maps that determinate land use, details of special treatment for high risk areas, and arrangements for issuance of building permits, as well as protection plans for utilities and services. The city also relies on community based networks to control illegal land occupation and has developed a large-scale relocation program for families living in high-risk conditions.

The city of Bogotá has disaster risk reduction at the center of its planning process, and in this context school seismic safety ranks very high. Having diagnosed the scale and urgency of the problem in Bogotá, steps are now being taken to reinforce the most hazardous school buildings. The challenges the city still faces include extending its school safety program to private schools that cover nearly half the school aged population and accelerating the rate of school reinforcement. At this writing (August 2004), Bogotá officials are in negotiation with the World Bank for assistance that would make accelerated school reinforcement possible.

Turkey

Turkey has more than 8 million children attending schools in 64 provinces in 1st and 2nd degree seismic risk zones (see Figure 1).

[Figure 1 here]

The 1999 Kocaeli (moment magnitude Mw 7.4) and Duzce (Mw 7.2) earthquakes with approximately 20,000 fatalities raised awareness of the school safety question, and the 2002 (Mw 6.0) Afyon-Sultandag and 2003 Bingöl (Mw 6.4) earthquakes kept awareness high.

During the 1999 earthquake in Kocaeli, 43 schools were damaged beyond repair, and 381 sustained minor to moderate damage (Erdik 2001). School was suspended for four months causing major disruption to the lives of families and children. In Istanbul, 60km away, there was damage at 820 of 1,651 schools. Damage at 131 of these sites necessitated at least temporary school closure. Thirteen were immediately demolished, and another 22 were later slated for demolition when retrofitting proved too costly. Fifty-nine schools were strengthened and 59 repaired.

In the Bingöl earthquake, out of 29 schools in the affected area 4 school buildings collapsed completely, 10 were heavily damaged, 12 slightly or moderately damaged and 3 undamaged (Gülkan 2004)

Public schools in the Kocaeli earthquake fared better than residential buildings and private schools (Erdik 2001). Had children been at school during the Kocaeli earthquake, far fewer would have lost their lives. The fatality rate in residential buildings in the Kocaeli earthquake was 1.5 per 100 in heavily damaged buildings and 16.5 per 100 in totally collapsed buildings (Petal 2004). Similar damage in higher occupancy buildings of the same type would cause higher fatality rates. In the single example of the school dormitory in the Bingöl earthquake where 84 children died, the fatality rate was 44 per 100. Average risks are theoretical and don't occur. Either school is not occupied and no one dies or it is occupied and the fatality rates are high, and the tragedy wholly unacceptable.

There is much that is right with school construction in Turkey. As a result of an assigned importance factor of 1.5, public schools are designed to withstand a 50% increase in earthquake design loads (Erdik 2001). Schools have regular symmetrical structural designs, and those that are only 1 or 2 storeys have fared well, for the most part meeting standards for life-safety, if not continuous occupancy. The lethality of school buildings is almost entirely attributable to shoddy construction, and is particularly lethal in taller buildings that may also have design defects.

For decades all public construction was under the authority of the Ministry of Public Works and Settlement. Earthquake building codes on the books since the 1930s were updated most recently in 1976 and 1998, yet the existence of these laws has not guaranteed the safety of construction. The reasons are numerous.

Beyond an undergraduate or graduate degree there have been no independent or non-academic professional qualifications, proficiency standards, continuing education requirements or licensure for architects or engineers nor any qualifications for building contractors. There are also no guidelines for reliable and systematic building inspection during construction. Penalties for non-compliance with building codes are beset with bureaucratic and social impediments, and often are simply not applied. Legal liability in some future event with low-frequency occurrence can hardly be a deterrent with so many to share blame. Public construction has also suffered from a standard (though not legally-required) preference for lowest bid in public tenders. The civil service employment system also lacks proficiency standards and qualifications for professional staff; so at the local level there is a wide variety in the capacity for project supervision and control. Wage and salary levels are low, and there has been opportunity for both favoritism and corruption. There are no ombudsman or advocacy services to support consumer whistleblowers.

Istanbul provides a dramatic example of three overlapping tasks:

- immediate response to damaged caused by the 1999 earthquake,
- implementation of a comprehensive retrofitting and replacement for seismic risk mitigation,

- follow through on an ambitious program of school expansion and construction initiated to respond to the acute shortage of class space occasioned by three additional years of compulsory education enacted in 1998.

After the 1999 earthquake responsibility for school construction was shifted to the Ministry of Education's Division of Investments and Facilities (DIF). In turn, DIF appointed consultants from the private sector to oversee the new facility design and construction. DIF also developed standard designs for the new facilities, and new school construction was financed by a combination of government funds and charitable contributions raised by not-for-profit foundations. New construction and procurement laws also went into effect; however the cumulative impact of these changes and pressures is not yet known (Gülkan 2004).

In Istanbul of all projects the highest priority is given to regional boarding schools, then to schools in the 12 highest risk districts and to those in proximity to the Marmara Sea coast. The overall mitigation and retrofit effort targets more than 1,800 buildings that constitutes the 80% of stock predating the 1998 Building Code. This ambitious program is budgeted for US$320 million (Yüzügüllü et al. 2004).

An additional problem in Turkey is that awareness of non-structural hazards remains low. Classroom doors often open inwards and shelving and laboratory equipment remains unfastened. However, concern that children advised to "drop, cover and hold" might be injured by flimsy wooden desks led to production and distribution of 80,000 steel desks to more than 500 schools in the most vulnerable areas.

Schools are a well-distributed means of public education, and children can play a leading role in the dissemination of public safety messages. Thus, Professor Isikara, former head of KOERI, a major earthquake research institute in Istanbul,[7] toured the country visiting schools, becoming known as “Grandpa Quake,” and produced the first children's books and popular educational and rap music cartoons for earthquake awareness. Both the Istanbul Governor's Office and KOERI's newly established Istanbul Community Impact Project (ICIP) produced handouts distributed to all school children. Schools also received books and CDs. At the national level an introduction to natural hazards was integrated into the primary school curriculum in Environmental Studies in 2002. Annual school-wide earthquake drills and preparedness and remembrance activities were initiated on November 11th 2001, to coincide with Duzce earthquake anniversary.

Between 2001 and 2003, a cascading model of training and instruction called "ABCD Basic Disaster Awareness" was implemented by KOERI's Istanbul Community Impact Project. A curriculum was developed to address specific assessment and planning activities, physical risk reduction and response preparedness measures to be taken prior to a disaster. This was a significant reorientation from previous "awareness" programs that began with what to do "during the shaking.” A single full day of instructor training for 3,600 teachers was provided in collaboration with Ministry of Education Provincial Directorates and outside donors. These teachers in turn communicated with 121,000 school personnel and through them with 1.68 million school children as well as with 700,000 parents. The project established an internet-based monitoring system to monitor dissemination.

Following the success of this effort, the National Ministry of Education has committed to taking the program nationwide. A distance learning curriculum will support dissemination to 50 high risk provinces with the goal of teaching 25,000 school-based instructors and 5 million children. In Istanbul 70 lead trainers continue to train new teachers and reached 750,000 children in a second year.

Canada

British Columbia's (B.C.) west coast is Canada's region of highest seismic hazard. Two-thirds of the province's 3.9 million people live within the zone of highest risk (Atkinson and Beresnev 1998; Clague 2002; Levson and Jonnes 2003; and Rogers 1996). The region has experienced ten moderate-to-large earthquakes since 1870. In recent millennia, an earthquake on the order of the largest magnitude experienced globally in the last 100 years, has struck approximately every 500 years. In addition to potential building collapse induced by ground shaking, significant damage from liquefaction, tsunami, and landslides are expected.

Older B.C. schools were built from some of the most seismically vulnerable materials -- in the early 1900's, unreinforced masonry and then, in the mid-1900's, non-ductile concrete frame. Thus, in many communities, the school might be one of the buildings at highest risk for earthquake damage. A formal risk assessment of all B.C. school buildings was initiated in June 2004 with the full report due in October 2004. Initial estimates from the provincial government suggest that 800 of BC's schools might need some form of seismic upgrading.

In Vancouver, B.C.'s largest city with a core population of about 560,000 and a metropolitan population of about 2 million, a 1989 rapid seismic risk assessment found that 30% of the city's school buildings were at high risk of experiencing structural damage in an earthquake, and 15% were at moderate risk (Taylor 1989). Between 1990 and 2004, eleven schools have been upgraded, so if the current pace continues, this work would be completed in 2064.

While the seismic hazard facing schools in greater Vancouver is similar to that in Seattle, Washington, school safety has not been a priority on the Canadian side of the border. Indeed, differences in seismic hazard mapping techniques used by Canadian and US geoscientists may actually underestimate the risk to Vancouver schools (Halchuk and Adams 1999).

The current National Building Code of Canada ranks buildings according to their priority as critical infrastructure (NBCC 1995). The higher the number assigned, the higher the priority. Average houses are assigned an Importance Factor of 1.0, schools are designated 1.3, and hospitals, police stations, and prisons are assigned 1.5. Schools – unless they are designated as post-disaster shelters, get a lower priority than hospitals, police stations, and prisons. Vancouver City Council is funding the seismic upgrading of community centres so that they could be used as post-disaster receiving centers. Due to the differences in funding sources, some community centers are being upgraded while nearby schools, which might be less seismically resistant, are sometimes not.

In general in B.C. there is high awareness of earthquake risk. For example, the City of Vancouver has seismically upgraded its water supply system and bridges, and the electric utility, B.C. Hydro, is systematically upgrading its buildings and infrastructure, including dams (Scawthorn 2004; for details, see B.C. Hydro 2004; Horyna et al. 1999; Horyna et al. 1999). Even some provincially run liquor outlets have been seismically upgraded. With seismic safety so clearly on the policy agenda in many sectors in British Columbia, why have public schools received so little attention?

The answer is that in B.C. funding for public school seismic upgrades has been part of the capital budget of the provincial Ministry of Education. Local school boards oversee this work and must proactively request provincial funding for projects that they deem to be high priority. Advocacy work by one of the authors on behalf of Families for School Seismic Safety British Columbia (FSSS)[8] identified and tackled concerns with this funding system. These include the following.

First, there was no district-to-district standardization of approach. Each local school district was individually approaching the issue of seismic safety for only their schools. FSSS pressed government to unify the approach taken by centralising expertise. The earthquake engineering community, through its professional association, the Association of Professional Engineers and Geoscientists of B.C., is now advising government on standardized, peer-reviewed methods for assessing and addressing seismic risk to schools.

Second, there was a concern about the potential for panic. Local Authorities were concerned that informing parents of the seismic risks to local schools could cause panic and could be politically damaging. FSSS's and others' work has ensured that Vancouver parents are now well-informed about the issue and are actively involved in trying to solve it. This process did not cause panic. Instead, bringing parents into the consortium has yielded an active and effective lobbying group.

Finally, there is the problem of setting priorities. The primary concern of school boards – quite rightly – is the day to day education of children. Seismic safety of a school building does not lead to improved education, hence school boards have sometimes had difficulty making the issue a high priority. FSSS is trying to help public officials see school seismic safety as an infrastructure, public health, and human rights issue and to obtain new funding from outside of the Ministry of Education, that is, from provincial and national authorise with mandates in those areas. The aim is that this work be seen as an infrastructure project for children and not perceived as competing for funding with their day to day educational needs.

Ultimately, the two basic human rights of children, to an education and to physical safety, should not be competing for the same funds. The expert community is now driving the initiative and government appears to be listening. Many positive steps have been taken in B.C., but there is much work left to be done.

MAKING THE CASE FOR SCHOOL SEISMIC SAFETY

Many public buildings and different sorts of critical infrastructure are threatened by earthquakes. What case can be made for giving priority to schools? This is not an academic question. Policy makers and citizens who wish to influence public policy make use of a variety of arguments. Such arguments may appeal to moral obligations and rights (e.g. the school administrator's obligation to protect students or students' right to a safe learning environment). In more affluent countries arguments may also attempt to show that investments in school safety bring benefits that are of an order of magnitude similar to the health benefits of other investments in public safety. Finally, a third kind or argument focuses on the school facilities themselves. This kind of case hinges on the multiple uses of school buildings as multi-purpose community centers and disaster shelters, thus asserting that loss of a school (even when children are not harmed) has cascading social and economic consequences beyond the loss (replacement cost) of school building itself.

In most cases public discussion and debate on these issues tend to mix and to blur these three kinds of arguments – elements of which are ethical; while other elements are pragmatic. What we attempt to do in this part of the chapter is to sharpen understanding of these three kinds of case that can be made for school seismic safety, with the hope that clarity will improve the quality and effectiveness of public discourse.

Human Rights Argument

The human rights argument suggests that no society should tolerate the necessity of choosing 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, children of the very poor and marginalized groups in society. As we noted at the beginning, there may be as many as 100-115 million school aged children who presently do not attend school. The 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." Another of these MDG targets is to "[r]educe by two thirds, between 1990 and 2015, the under-five mortality rate" (World Bank 2004). It would be ironic and tragic if in the course of achieving one MDG, another is undermined.[9] Such a situation would also involve a conflict of human rights: the right to education and the right to life. 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.

Isolated from such lofty philosophical reflections, educational authorities who are changed with the construction and maintenance of schools are also the ones tasked with many other functions, as made clear in the case study from British Columbia. 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. Retrofitting schools for seismic safety is perceived to compete for funds with the rest of the educational process.[10] 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?"

While we sympathize with the educational authorities making such difficult decisions, there is no doubt that student safety is a human right. Handmer (2001) reminds us of some of the relevant treaties.

> Everyone has the right to life, liberty and security of person (Article 3, *Universal Declaration of Human Rights* adopted and proclaimed by the UN General Assembly, 10 December 1948). While this has traditionally applied to arbitrary arrest and detention, it may be arguable

> that protecting the "security of the person" requires protection from other forms of harm. The *Convention on the Rights of the Child* is more specific. It requires signatory states to "ensure to the maximum extent possible the survival and development of the child." The Convention emphasizes the right of children to the highest attainable standard of health (Art 24.1), and requires states to "pursue full implementation of this right" (Art 24.2).

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. Teachers, social workers, and parents advocate on their behalf. However, as children move through the school system, they often attend various schools in different locations. As they move, so also the attention of parents and perhaps even the social worker shifts from building to building. In contrast, an office worker has a single work location which they have often known for several years. When hazardous conditions become evident, the office worker is on the spot and can inform and collaborate with colleagues in dealing with the problem. Often such workers are backed up by a union. Office workers can refuse to go to work until the identified health and safety issue is resolved.

Teachers, cleaners, administrators, and others work in schools, and in this way share the circumstances of the office worker. They have continuity of occupancy and their concern for their own physical well being overlaps with an interest in the well being of their students. Should teachers, therefore, be advocates for school seismic safety as a human right?

Some difficult questions arise. Should the burden be placed on them to advocate for a safe work place? To what extent should unions be involved in the issue of infrastructure safety in schools? Would putting this responsibility on teachers add yet one more burden to an often undervalued career while absolving parents, government, and other members of society of their responsibility for child safety in schools?

Cost-Effectiveness Arguments

There are two forms that cost-effectiveness arguments may take. One is straight forward. It assserts 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 the cost of building in anti-seismic features or even of retrofitting older or poorly built schools.[11] The data in the case study form Algeria underscore this point.

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. Such arguments apply differently to different countries. In cases where child and infant mortality is high, longevity is shorter, basic vaccinations are not universall, or safe domestic water and sanitation facilities are inadequate, then the relative ranking of school safety as a cost-effective public health intervention will decrease. 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, labour 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, such a stark juxtaposition between rich and poor countries may be too hasty. First, the probability of an earthquake occurring in each year is often a misleading consideration in determining whether or not to implement seismic safety measures. 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. As we pointed out earlier, if earthquakes happen with equal probability around the clock, then approximately a 6-23% chance exists of schoolchildren being in the school during the earthquake, even if the generation of schoolchildren affected is unlikely to be the current one. Second, as some of our case studies showed, knowledge exists to protect schools at low cost, and in most circumstances, seismic safety should add only marginally to the cost of a school.[12] No doubt one aspect of the tragedy and dilemma of poverty is real-world juggling by governments of equally vital needs and priorities. However, it may be that school seismic safety does not have to lose out in these calculations.

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.

Also, a difference between seismic safety and other public health measures such as vaccinations, cancer screening, or use of seat belts in vehicles is that the other interventions work only with compliance by the individual who must choose to cooperate. By contrast, society collectively decides that schools should be seismically safe, and society pays for that. Thus, when society chooses to pay for seismic safety, society is ensuring that the measure will be implemented and effective. Social investment in making vaccinations available to everyone does not ensure that the measure will be effective because individuals can choose to opt out.[13] Thus, the cost-effectiveness of seismic safety interventions does not depend on individual compliance rates. Of course, such a seismic fix is not certain, since unanticipated earthquakes can occur or builders may be corrupt or incompetent. However, similar difficulties arise with medical tests and vaccines.

The juxtaposition of societal concern with school transportation safety and the relative lack of concern with school seismic safety is curious and telling. Transporting children to and from school has become a highly regulated process in Canada and the U.S. In the majority of jurisdictions in those countries, school buses are colored a distinctive yellow and have flashing lights when stopping for children to embark or disembark. When the flashing lights are on, it is illegal in many places to drive past the bus in either direction. Recent years have also seen the introduction of bars or gates that swing out in front of the bus to prevent children crossing directly in front where they would be hidden from the driver. In addition to legislation, extensive material is available for parents advising how to keep their child safe with regards to the bus (e.g. Kraemer 2004). This approach to child safety has made school buses one of the safest forms of transport in Canada and the U.S. (Hall 1999; Transport Canada 1998).[14]

Argument From the School's Multiple Functions

The symbolic, cultural, economic, and political significance of schools to a community 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 serve as makeshift hospitals or vaccination centres even in normal times. Hence, schools have a value in maintaining social networks, in providing adult education, in promoting public health, and in building and maintaining sustainable livelihoods. Accurately estimating the monetary value of those social gains would difficult, but clearly these added functions add value to the school building.

Schools in many post-disaster settings schools may provide temporary shelters, first aid or rescue operation staging areas or other disaster response functions in addition to their normal education and social network functions. Earlier, in the case studies, we referred to such post-disaster functions (in Canada and Colombia). After an extreme event such as an earthquake, a coordination center or headquarters is needed in addition to emergency accommodation for people who no longer have safe houses. The advantages of using schools include that they are already spread throughout the community; people know where they are; they are generally surrounded by open space such as playing fields or playgrounds; and, in urban areas, a school usually exists within walking distance of most houses. Little debate occurs when suggesting that local civil defence centers should withstand extreme events. Where the role of the school in serving also potential disaster shelter is acknolwedged, the school should logically be afforded the same level of protection.

If the benefits of a safe school go beyond the health and education of children, teachers, and auxilary staff present in school buildings, one might ask why school safety usually must come from the education budget rather than the budget for community development, for civil protection, or funds for protecting critical infrastructure? Rather than being a competing interest, school safety is one of a series of complementary activities, all of which deserve to be fully funded by society. Since these functions all take place at a single site (the school), there should be economies of scale in securing all these functions by investments in the safety of that single building.

Admittedly, some of the benefits we refer to are intangible. For example, a functioning school gives a sign of normality following a disaster -- an immense psychological boost for the community. Nevertheless, these intangible benefits are real. To take another example, retrofitting a school spreads a message far beyond the school. When children see their school being seismically retrofitted, they tend to tell their relatives and neighbors who in turn tell others (as mentioned in the case studies from Nepal and Turkey). Thus, by seismically retrofitting one building, the safety message reaches a significant proportion of the community, whether or not they have school-age children. Individuals are encouraged to learn about and to act upon the seismic safety message in their home and workplace. The school has served as a community center for propagating the seismic safety message. School seismic safety not only protects a community's children, but educates a community to protect themselves.

CONCLUSIONS

Our first conclusion is that a surprisingly large number of school aged children are at risk from earthquake damage to the school buildings. This threat has not been sufficiently well appreciated. School safety issues do not feature in the major global campaign for increased school attendance ("Education for All" and the Millennium Development Goals). In fact, the full extent of the risk to school buildings and to students has not yet been full defined. A global effort at mapping schools (by density of occupancy and quality of construction) in relation to seismic hazard is required.   Also, damage to schools costs governments and insurers a large amount of money. These are costs that governments can not afford if they are struggling with many public health priorities and other needs.

Our second conclusion is that there are strong arguments that support giving school seismic safety increased priority and a higher profile. One step in raising the visibility of this issue was the report of a OECD meeting on school safety held in 2004 in Paris, co-sponsored by the non-profit, NGO, GeoHazards International. The full report of the working group behind that meeting was presented at the 13th World Conference on Earthquake Engineering, held in Vancouver during August 2004 (OECD 2004). Another step was the adoption of school safety as one of the focal points of the World Conference on Disaster Reduction to be held in Kobe, Japan in January 2005 (ISDR 2004a).

Our third conclusion, based in part on the case studies we presented, is that low cost, accessible technology and design exists with which to build new schools and to retrofit existing. A community-based approach holds great promise involving many stakeholders, including local buildings, masons, contractors, etc. In addition to the successes in Nepal described above, there are other examples of a community-based investment in school safety, among others:

- application of techniques developed in Nepal to school reconstruction in Gujarat, India (UNCRD – Kobe & SEEDS; http://www.hyogo.uncrd.or.jp/activity/projects/07pny.htm);
- design of earthquake and wind resistant primary school for Gujarat, India (http://www.onlinevolunteers.org/relief/earss0315-school.html) and also http://www.hyogo.uncrd.or.jp/activity/training/01hgff.htm and Shaw (2002).
- development of a "consumers' guide" to safe concrete construction for use in Turkey (American Friends Service Committee Middle East Office and Bogazici University, Istanbul http://www.hyogo.uncrd.or.jp/publication/proceedings/2003workshop/materialjan31/petal.PDF);
- adaptation of a "consumers' guide" to a Central Asian disaster mitigation project (GeoHazards International and U.S. Office of Overseas Disaster Assistance http://www.geohaz.org/newsletter2002/ghifunded.html);
- community-based school maintenance and seismic protection in Indonesia through the Asian Urban Disaster Mitigation Program of the Asian Center for

Disaster Preparedness and UNCRD (http://www.adpc.net/audmp/projectoutputs/indo/report-june-04-00-tr.html);

- school seismic and wind safety surveys and pilot projects on several Caribbean islands with the assistance of the Organization of American States and Office of Foreign Disaster Assistance (USAID) (http://www.oas.org/CDMP/schools/schlrcsc.htm).

Our fourth conclusion is that lobbying for school seismic safety by civil society can be effective. The cases of British Columbia and Bogotá provided examples.

Fifth, and finally, we have seen that a variety of other steps need to be taken. Detailed guidelines for national school safety programs are provided by OECD (2004: 232-237). These include hazard mapping, revision (where necessary) and – above all – enforcement of seismic building codes by national, provincial, and local governments, training of engineers so that they understand and can engage with local masons and other builders, and invention of more innovative models for funding reinforcement of schools. Other institutional, enabling measures are part of a 'package' on which the consensus has been reached since the end of the International Decade for Natural Disaster Reduction (1990-1999; see UNDP 2004; ISDR 2004b; Wisner et al. 2004; Wisner and Fordham 2001).

The safety of school buildings should also not be separated from the safety of the community of users and is not limited to the buildings themselves. Although we have focussed on fatalities, there is much similar work to be done to prevent disability and injury especially by securing the contents of the buildings. School personnel need disaster management plans, emergency response skills, regular drills to cope with expected disasters. A culture of safety is must be multi-faceted, and activism in one area encourages changes in consciousness, expectations and demands.

We share the enthusiasm for efforts to make education accessible to all. However, we believe that the implementing authorities, foundations, donors, and NGOs involved in this great effort should take school seismic safety as a major concern. Otherwise, an ironic and tragic result of achieving one Millennium Goal (increased school attendance) may end up marred by increased death and injury of young people, thus confounding the achievement of another Millennium Development Goal (reduction of child mortality).

TABLES AND FIGURE

Table 1: School collapses in earthquakes yielding mass casualties

Date (Source)	Location	Consequences/ schools	Consequences/ children
7 December 1988 (NGDC 2004)	Armenia.	Extensive damage to schools	Likely thousands of schoolchildren killed including 400 at an elementary school in Dzhrashen which collapsed.
10 May 1997 (CNN 1997)	Ardakul, Iran	Primary school collapsed	110 students killed
9 July 1997 (FSSS 2004)	Cariaco, Venezuela	Two schools collapsed	46 students killed
26 January 2001 (FSSS 2004)	Swami Narayana School, Ahmedabad, India	School collapsed	At least 25 children killed
31 October 2002 (Augenti et al. 2004; Dolce 2004)	San Giuliano di Puglia, Italy	Primary school collapsed.	26 children and 3 adults killed. 35 children rescued alive from the building but some reports suggest that one child died later.
24 February 2003 (Harmsen 2003)	Bachu, Xinjiang, China.	Middle school collapsed.	At least 20 students killed
1 May 2003 (Gülkan et al. 2003)	Bingöl, Turkey	Middle/secondary school dormitory collapsed.	84 students killed; more than 114 in the dormitory survived. 4 school buildings collapsed but only one was occupied.

Table 2: School collapses in earthquakes when few people were in the building

Date (Source)	Location	Consequences / schools	Consequences/ children
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 hundred.
10 March 1933 (FSSS 2004; NGDC 2004)	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.
31 October 1935 (NGDC 2004)	Helena, Montana. USA	Secondary school collapsed	No one was in the building at the time of the earthquake.
4 March 1952 (USGS 2003)	Sapporo, Japan	400 schools collapsed in Sapporo	The low number of casualties suggest that no one was at school at the time of the earthquake.
27 March 1964 (FSSS 2004; NGDC 2004)	Alaska, USA	Primary school destroyed by an earthquake-induced landslide. Half of Anchorage's schools significantly damaged	The earthquake struck on a holiday, Good Friday, so schools were closed.
10 October 1989 (Bendimerad (2004; NGDC 2004)	El Asnam, Algeria	70-85 schools suffered extensive damage or collapsed	The earthquake occurred out of normal school hours, so children were not at school.
19 September 1985 (FSSS 2004)	Mexico City, Mexico	Several schools collapsed	The earthquake happened in the morning, so the children were not yet at school.
25 January 1999 (Garcia & Cardona, 2000)	Pereira & Armenia, Colombia	74% of schools damaged	Earthquake took place at the noon hour; so children were not in the buildings.
21 September 2001 (Angelier et al. 2003)	Taiwan	A three-storey school collapsed	The earthquake happened in the middle of the night, so no one was in the building.
24 February 2003 (Harmsen 2003)	Xinjiang, China	Dozens of schools collapsed	The earthquake struck 27 minutes before thousands of children would have been in classrooms.
21 May 2003 (Bendimerad 2004)	Boumerdes, Algeria	130 schools suffered "Extensive to complete damage"	The earthquake occurred out of normal school hours, so children were not at school.

Table 3: Countries of High Seismic Risk & Their School Aged Population

Countries of high seismic risk are defined by taking all countries with significant populated areas in the "High" or "Very High" seismic hazard zones from Giardini et al.

(2000). Several Small Island Developing States do not appear below because determining the exact level of seismic hazard in populated areas from Giardini *et al.* (2000) was impossible. Thus, the totals presented here are conservative, because they are likely to be higher than reported here once the Small Island Developing States are added in. In contrast, countries which are in bold have significant populated areas in areas not marked as "High" or "Very High" seismic hazard zones in Giardini et al. (2000) thereby making the totals here overestimates.

Country	% of population 0-14 years old	Number of males 0-14 years old	Number of females 0-14 years old
Afghanistan	44.70%	6,525,929	6,222,497
Albania	26.40%	489,363	446,586
Algeria	29.90%	4,893,971	4,705,933
Armenia	22.70%	357,094	323,396
Azerbaijan	27.00%	1,081,579	1,046,270
Bhutan	39.30%	445,548	414,338
Bosnia and Herzegovina	18.90%	389,062	368,721
Bulgaria	14.40%	553,801	526,856
Canada	18.20%	3,038,800	2,890,579
Chile	25.80%	2,090,165	1,996,972
China	22.30%	153,401,051	135,812,993
Colombia	31.00%	6,644,080	6,489,677
Costa Rica	29.50%	597,332	570,008
Croatia	16.60%	383,729	364,287
Cuba	20.00%	1,163,741	1,102,391
Cyprus	21.40%	84,850	81,235
Dominican Republic	33.30%	1,502,062	1,435,135
East Timor	37.80%	196,007	189,584
Ecuador	33.90%	2,285,775	2,199,356
El Salvador	36.80%	1,237,262	1,185,750
Georgia	18.70%	461,967	416,898
Greece	14.50%	792,938	746,119
Guadeloupe	24.40%	55,386	52,977
Guatemala	42.60%	3,118,396	2,970,729
Honduras	41.20%	1,434,555	1,376,216
Iceland	22.50%	33,522	32,489
India	31.70%	173,869,856	164,003,915
Indonesia	29.40%	35,635,790	34,416,854
Iran	28.00%	9,935,527	9,411,647
Israel	26.70%	847,591	808,399
Italy	14.00%	4,181,946	3,935,565

Jamaica	28.20%	390,966	372,961
Japan	14.30%	9,337,867	8,876,996
Kazakhstan	24.40%	1,884,369	1,807,585
Kyrgyzstan	32.30%	835,599	804,384
Lebanon	26.90%	517,356	496,888
Mexico	31.60%	16,913,290	16,228,552
Mongolia	29.70%	415,735	400,560
Nepal	39.40%	5,500,698	5,151,705
New Zealand	21.70%	443,211	422,507
Nicaragua	38.10%	1,038,887	1,001,518
Pakistan	40.20%	32,919,441	31,058,929
Panama	30.20%	461,427	443,932
Papua New Guinea	38.30%	1,053,940	1,019,492
Peru	32.10%	4,496,146	4,340,580
Philippines	35.80%	15,758,255	15,152,291
Romania	16.20%	1,861,801	1,770,746
Russia	15.00%	11,064,109	10,518,595
Serbia and Montenegro	18.30%	1,027,479	956,681
Solomon Islands	42.40%	113,183	108,816
Taiwan	19.90%	2,359,467	2,167,438
Tajikistan	39.20%	1,384,035	1,361,137
Turkey	26.60%	9,328,108	8,990,742
Turkmenistan	36.20%	904,627	857,601
United States	20.80%	31,122,974	29,713,748
Uzbekistan	34.10%	4,583,228	4,418,003
Vanuatu	34.10%	35,281	33,785
Venezuela	30.50%	3,930,413	3,687,744
WORLD TOTAL	28.20%	925,276,767	875,567,830

Table 4: Primary Education Data on Top 20 Countries for Earthquake Fatalities 1900-2000 (in order)

Source: http://www.unesco.org/education/efa_report/tables_excel/Table5.xls

All numbers refer to a single year between 1999 and 2001. Note that Afghanistan, in particular, will have changed immensely since these data were collected.

Country	Age Group	School-age population	Children out of school who should attend
China	7-11	110,499,000	8,054,600
Japan	6-11	7,335,000	300,000

Italy	6-10	2,789,000	6,400
Iran	6-10	9,221,000	**2,436,300**
Turkey	6-11	7,969,000	no data
Peru	6-11	3,416,000	4,600
Armenia	7-9	199,000	no data
Pakistan	5-9	19,535,000	**7,785,400**
Indonesia	7-12	26,081,000	**2,046,300**
Chile	6-11	1,751,000	**1,956,000**
India	6-10	112,469,000	no data
Venezuela	6-11	3,286,000	394,600
Guatemala	7-12	1,869,000	293,300
Afghanistan	7-12	3,372,000	no data
Mexico	6-11	13,070,000	78,400
Nicaragua	7-12	810,000	155,900
Morocco	6-11	4,071,000	**8,952,000**
Nepal	6-10	3,065,000	**846,800**
Taiwan	no data	no data	no data
Philippines	6-11	11,330,000	822,600

Table 5: Earthquakes with Modified Mercalli Intensity ≥ 8, 1954-2003, Selected Countries

All earthquakes with MMI ≥ 8 (focal depth not considered) were extracted from the NGDC database (http://www.ngdc.noaa.gov/seg/hazard/earthqk.shtml). Duplicates were manually removed. Events were also removed if they occurred in countries not classified by us as high seismic risk: Antigua and Barbuda, Argentina, Australia, Austria, Burma, Egypt, Ethiopia, France, Germany, Guam, Guinea, Kermadec Islands (NZ), Netherlands, Portugal (Azores), Tunisia, and Yemen.

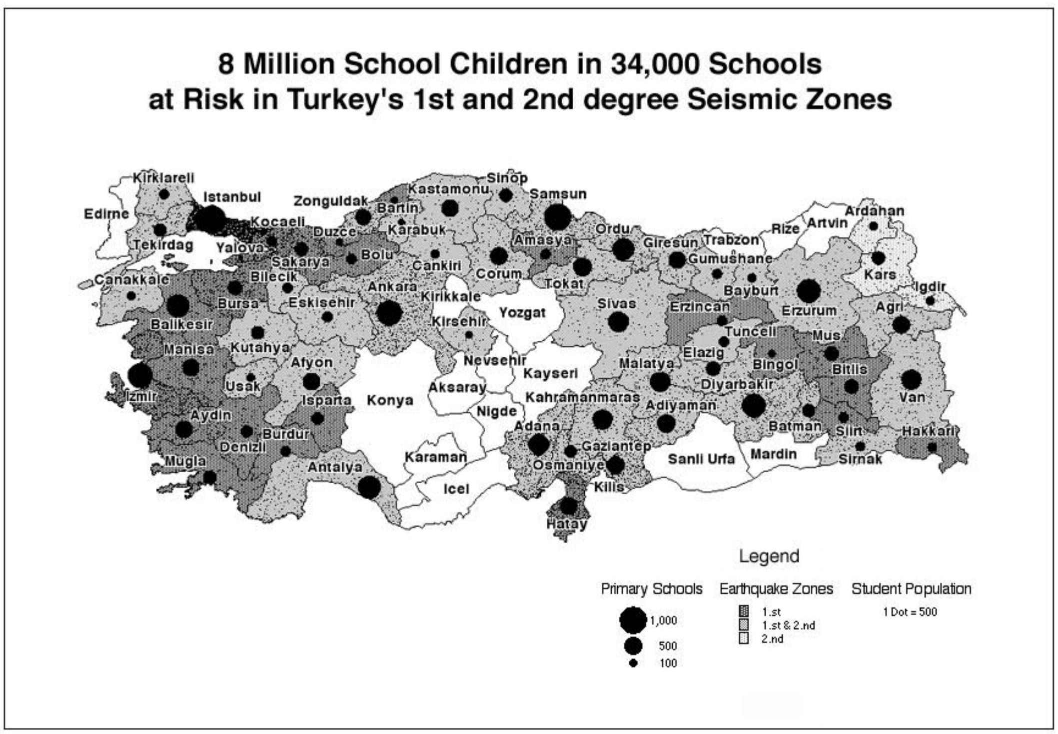
decade ↓ MMI →	8	9	10	11	12	Total
1954-1963	9	13	14	3	12	51
1964-1973	27	19	13	3	0	62
1974-1983	34	18	6	0	0	58
1984-1993	38	8	3	0	0	49
1994-2003	17	10	9	0	0	36

Table 6: School damage in the last destructive earthquakes in Algeria

Earthquake	**Mag.**	**No/Light Damage**	**Moderate Damage**	**Collapse**	**Total affected**	**Damage Ratio %**
1980 El-Asnam	7.3	5	25	70	100	95
1989 Chenoua	5.7	167	36	7	210	20
1994 Mascara	5.6	30	16	4	50	40

1999 Temouchent	5.8	36	17	6	59	39
2003 Boumerdes	6.8	1304	753	103	2160	58

Figure 1: School Children At Risk in Turkey



Source: Suha Ulgen, IMAGINS, Inc. (sulgen@imagins.com), by permission.

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ENDNOTES

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[2] DFID (2004) states "More than 113 million children do not go to school"; DG (2004) states "More than 100 million children around the world do not have access to primary school education"; and according to UNESCO (2004), "Worldwide, an estimated 104 million children are not enrolled in primary school". (World Bank 2004) uses the number 115 million.

[3] Coburn et al. (1992: 5-6) give an immediate death rate of 20% for masonry and 40% for concrete frame. They add an additional 30% with life threatening injuries in masonry and 10% in concrete frame. This brings the total close to 50% fatality unless there is excellent medical treatment immediately available and good search and rescue. Therefore the 40% figure we use for mortality seems a defensible estimate on the basis of other empirical experience as well as the two recent (Italian and Turkish) cases we mention.

[4] As we stated at the beginning, we want to guard against overestimation. Since there is much variation in the survival rates observed depending on the type of construction and the nature of the damage, as well as a good deal of ambiguity in the way that terms such as 'severe damage', 'moderate damage', 'partial collapse', and 'collapse' are used, we offer a variation on our final thought experiment. If, instead of 30 collapsed school building in ten years, we assume only 10 collapsed and 20 ~~severely damaged,~~not collapsed by only 'severely damaged', this would yield a lower total fatality. That is because the death rate is so much higher in collapsed buildings. Thus, assuming 40% death rate in collapsed buildings but only 5% in severely damaged ones, we would have:

- (4 x 10 x 100) x ~~40%)~~40% mortality = 1,600 + (4 x 20 x 100) x ~~5%)~~5% mortality = 400
- = 2,000 rather than 4,800.

So it might be reasonable and prudent to plan to avoid a loss of student life in earthquakes of somewhere between 2,000-5,000 in a ten year period.

[5] This study (NSET 2000) was part of the Kathmandu Valley Earthquake Risk Management Project implemented by National Society for Earthquake Technology, Nepal (NSET).

[6] In Nepal the Medveder Sponheuer Karink (MSK) intensity scale is commonly used. Design level earthquake shaking is IX MSK as defined by the National Building Code. Since there are many intensity scales used in various parts of the world, we have adopted one of them, the Modified Mercalli, in this chapter (see, for example, the list of intensity

scales in EQTAP (2000). See also Gruenthal (1998) where many other intensity scales are discussed.

[7] Kandilli Observatory and Earthquake Institute http://www.koeri.boun.edu.tr//defaulteng.htm .

[8] FSSS, see http://www.fsssbc.org .

[9] "According to a World Bank study, only 37 of 155 developing countries analyzed have achieved universal primary completion. Based on trends in the 1990s, another 32 are likely to achieve that goal. But 70 countries risk not reaching the goal unless progress is accelerated. In several of them completion rates have stagnated or even fallen in recent years" (World Bank 2004).

[10] Where capital and recurrent budgets are separate, there may be no actual conflict over funding between teacher salaries, books, supplies, etc. and funding for seismic protection; however, as pointed out in the case of British Columbia, many members of the public and educational system perceive a funding conflict.

[11] Of course in some cases demolition of damaged schools is more cost effective than repair, a decision mentioned in the case studies from Algeria and Turkey. Studies of the benefits and costs of retrofitting schools include DRM (2004), Smyth et al. (2004), Kunreuther et al. (nd).

[12] Pate-Cornell (1985) Schulze et al. (1989) think it would add at most 5 per cent to the cost of a school.

[13] Even when there is a large scale, publicly funded vaccination effort, the question of participation may arise. For example, the World Health Organizations worldwide effort to eradicate polio seemed in question during 2004 because some state governments in northern Nigeria were refusing to participate (WHO 2003).

[14] Concern with the safety of school transportation is not confined to affluent nations. In Botswana, standard practice has been for children to be taken to school in open-backed trucks. When one overturned killing five children and injuring 86 in August 2003, Mmegi (2003) highlighted the danger of this practice and accused the country's Ministry of Education of ignoring the concerns raised.