Construction Design, Building Standards and Site Selection

Guidance Note 12

Tools for Mainstreaming Disaster Risk Reduction *is a series of 14 guidance notes for use by development organisations in adapting programming, project appraisal and evaluation tools to mainstream disaster risk reduction into their development work in hazard-prone countries. The series is also of relevance to stakeholders involved in climate change adaptation.*

This guidance note focuses on construction design, building standards and site selection, and their role in the mitigation of risk due to natural hazards. The note provides general guidance for design professionals and funding organisations involved in development projects concerning the construction of new infrastructure, strengthening intervention on existing infrastructure and post-disaster reconstruction. It provides guidance for analysing the potential threat posed by poor construction and inappropriate land use in hazard-prone areas. Only formal constructions (mainly buildings) are considered and some guidance is given on designing structural intervention (construction or strengthening) plans to help mitigate risk from natural hazards to vulnerable people, their livelihoods and the local economy. No specific technical solutions for the latter are proposed as each location and hazard requires a solution tailored to local needs and resources. However, references for further reading on technical issues are provided. Hazard risk mitigation infrastructure is not covered by this guidance note.

1. Introduction

A significant part of development assistance is spent on the construction of infrastructure in developing countries. However, these investments and associated development gains can be lost in seconds in the event of a natural hazard event (see Box 1). The majority of human and direct economic losses from a natural hazard event occur as a direct result of damage to the built environment and/or ineffective early warning and evacuation systems. The negative impact of natural hazards on communities can be limited by taking such hazards into consideration when selecting sites, designing new infrastructure and strengthening existing infrastructure.

The exclusion of hazard mitigation measures in development projects is unacceptable in view of the increasing disaster risk in developing countries caused by environmental degradation (**see Guidance Note 7**) and growing urbanisation, with the accompanying rapid increase of poorly built housing, uncontrolled use of land, overstretched services and high population densities. Consequently, development organisations should be accountable for the hazard-proofing measures they include in their construction projects, and for the losses resulting from their non-inclusion. This applies to projects where a hands-on approach is adopted or where the work is carried out by others.

Box 1 **Consequences of ignoring hazards in construction**

The following examples show how the lack of hazard measures or reliance on local best practice only can lead to large human and economic losses and set back development goals in the event of a natural disaster:

- In the years preceding the May 2000 floods, the World Bank financed the construction of 487 schools in Mozambique according to local building practice. However, during the floods 500 primary schools and seven secondary schools were damaged or destroyed,[1] severely setting back development goals.

1 World Bank. *Hazards of Nature, Risks to Development: An IEG Evaluation of World Bank Assistance for Natural Disasters.* Washington, DC: World Bank, Independent Evaluation Group, 2006. Available at: http://www.worldbank.org/ieg/naturaldisasters/

- The Caribbean Development Bank, the United States Agency for International Development (USAID) and the government of Dominica funded the construction of a deep-seawater port in Woodbridge Bay, Dominica. The Delft Hydraulics Laboratory (Netherlands) carried out a specialised study of the hazards at the port and submitted a report. The contractors who designed the port ignored the maximum wave height indicated in the report and built the port to withstand waves of less than half that height. In 1979, one year after the completion of the project, port structures and facilities were severely damaged by Hurricane David. Repair costs amounted to US$ 3.9 million (estimated for 1982), 41 per cent of the port's construction costs. The Caribbean Disaster Mitigation Project (CDMP) determined that strengthening the port structures at the design stage would have cost only 10 per cent of the construction costs.[2]
- The 2001 Bhuj earthquake in India led to widespread damage, including the collapse of 461,593 rural houses of rubble masonry construction. Good seismic codes of practice exist in India, but their non-enforcement, combined with poor inspection procedures, led to the failure and heavy damage of 179 high-rise reinforced concrete buildings in Ahmedabad, 230 kilometres away from the epicentre. Damage to port operations and industry resulted in approximately US$ 5 billion of direct and indirect losses.[3]
- Hurricane Mitch, which hit Honduras in 1998, resulted in a loss equivalent to 41 per cent of the country's gross domestic product (GDP).[4] Hurricane Luis in 1995 caused losses to Antigua and Barbuda equivalent to 65 per cent of their GDP.[5]
- In January and February 2001, two major earthquakes devastated El Salvador. More than 165,000 homes were destroyed and 110,000 damaged. In the most affected areas, up to 85 per cent of the houses were destroyed. The degree of destruction can be attributed to two main factors: the building material used and the quality of construction and maintenance.[6]

2. Current state of the art

In past development initiatives involving the construction of infrastructure, the option of designing and building to reduce the vulnerability of infrastructure to natural hazards has often been ignored due to the perceived higher costs and lack of appropriate expertise. Furthermore, the selection of the location for services or critical facilities has often been made on the basis of land cost and availability, rather than from consideration of safety from potential natural hazards. Typically, development organisations rely on 'best local practices' in hiring contractors to undertake construction work. Problems arise when best local practice does not incorporate the use of any building codes for hazard resistance or uses building codes that inadequately account for local hazards. The latter type of code typically exists in countries where infrequent natural hazards occur or where there is an incomplete historical record of past natural disasters. This results in hazard or zoning maps that do not adequately represent the frequency of occurrence or potential magnitude of natural hazards (**see Guidance Note 2**). Even when appropriate building codes exist, their correct application requires skilled engineers, architects and builders and effective enforcement and inspection procedures. Poor governance and corruption, leading to, for example, abuse of land use controls and building permits and codes, and illegal expansion of buildings, often exacerbate damage caused by disasters. In addition, most developing countries lack certification and licensing processes for professionals and enforcement procedures are non-existent. Enforcement procedures have, however, also been found to be ineffective in some developed countries, as was highlighted by Hurricane Andrew (1992) in Florida, USA, and the Izmit earthquake (1999) in Turkey.

The adoption of best local practice and of opportunity-based land use can, therefore, lead to a promotion of existing weaknesses in buildings and infrastructure. Funding and development organisations alike need to ensure that experienced hazard specialists and engineers coordinate or implement construction projects (by either employing them directly or ensuring that the contracted work will be led by such people). This specialist (or team of experts, depending on the number of hazards and scale of the project) should set a framework for the design and construction, which may then be executed by other engineers, builders and workers.

2 CDMP. *Costs and benefits of hazard mitigation for building and infrastructure development: A case study in small island developing states.* Caribbean Disaster Mitigation Project publication series. Washington, DC: Organization of American States, 2004. Available at: http://www.oas.org/CDMP/document/papers/tiems.htm
3 MAE. *The Bhuj Earthquake of 2001.* CD Release 01-04. Mid-America Earthquake Center Reconnaissance Report, 2001.
4 Gunne-Jones, A. *Land-use planning: How effective is it in reducing vulnerability to natural hazards?* Institute of Civil Defence and Disasters Studies, 2006. Available at: http://www.icdds.org/
5 Gibbs, T. *How can the resilience of infrastructure be increased?* Proceedings of the 682nd Wilton Park Conference, Wiston House, West Sussex, England, 9–11 September 2002.
6 Dowling, D.M. 'Adobe housing in El Salvador: Earthquake performance and seismic improvement'. In Rose, W.I. et al. (eds), *GSA Special Paper 375: Natural Hazards in El Salvador.* Geological Society of America, 2004, pp 281–301.

Contrary to common perception, the implementation of hazard-proof measures in building can be relatively inexpensive in terms of construction costs. What can be expensive is the provision of an effective framework for the take-up of these measures (e.g., the provision of skills training, appropriate hazard studies, research into low-cost strengthening solutions). However, if an effective mechanism exists for the enforcement of quality control and codes of practice, these costs will all be covered by the construction industry. The problem in many cases is the lack of legal mandating of building codes and consequent lack of their enforcement, which puts the onus on agencies commissioning and funding development projects also to provide the necessary research and development, training and education. However, CDMP[7] found that the development and enforcement of appropriate building codes and standards do not make development costs prohibitive. An investment in disaster mitigation can result in a manifold saving in disaster relief and development setbacks (see Box 2). Where development agencies have invested in the promotion of hazard-resistant construction, many of the projects have been well thought out and have shown large benefit (see Box 3).

Box 2 **What is the cost?**

The implementation of hazard-proof measures in building can be relatively inexpensive and provide long-term benefit to development projects:

- The implementation of simple modifications to improve the cyclone-resistance of (non-masonry) *kutcha* or temporary houses in Bangladesh is only 5 per cent of the construction costs.[8]
- Introducing earthquake-resistance principles (optimum layout, use of capacity design principles and more stringent criteria for the design of connections) in the design stage of modern infrastructure will increase the construction costs by 5 to 14 per cent.
- The retrofit for hurricane resistance of the Victoria Hospital (St Lucia) in 1993 and the Princess Margaret Hospital (Dominica) in 1980 was estimated by Consulting Engineers Partnership to be, respectively, 1 per cent and 2.2 per cent of their contemporary replacement costs.[9]

3. Merging hazard-risk considerations in construction projects

An integrated and comprehensive approach is necessary to improve the safety of buildings from natural hazards. This includes investing in strengthening existing structures and promoting safer building in development projects and post-disaster reconstruction projects. In hazard-prone countries, it is essential that both funding and development organisations ensure that engineers specialised in hazard-resistant construction be consulted in the initial stages of construction projects.

Box 3 **Some observed successes**

Ascertaining whether the use of safe building or strengthening techniques successfully provides adequate hazard resistance is not easy, as the constructions have not been subjected to the hazard they were designed for. Some exceptions do, however, exist:

- In 1977, following a cyclone that devastated coastal areas of Andhra Pradesh, India, a voluntary group, AWARE, built 1,500 houses in Krishna District. These houses followed the Central Building Research Institute's cyclone-proof designs, which consisted of concrete block (made of cement and granite rubble) walls with a reinforced concrete slab roof. Of these houses, 1,474 withstood the stronger cyclone that hit the region in 1990.[10]

7 CDMP (2001).

8 Lewis, J. and Chisholm, M.P. 'Cyclone-resistant Domestic Construction in Bangladesh'. In Hodgson, R.L.P., Seraj, S.M., and Choudhury, J.R. (eds), *Implementing hazard-resistant housing.* Proceedings of the First International Housing and Hazards Workshop to Explore Practical Building for Safety Solutions, Dhaka, Bangladesh, 3–5 December 1996.

9 Gibbs (2002); see footnote 5.

10 Sri, A.V.S. and Reddy, I.A.S. 'The cyclone-prone coastal region of the State of Andhra Pradesh, India – A state-government approach'. In Aysan, Y. et al., *Developing building for safety programmes: Guidelines for organizing safe building improvement programmes in disaster-prone areas.* London: Intermediate Technology Publications, 1995.

- In Peru, sheets of welded steel mesh covered in cement–sand mortar were applied to the walls of existing adobe houses during a prototype strengthening programme. When the Arequipa earthquake shook Peru in 2001, these houses survived undamaged, while nearby houses collapsed or were severely damaged.[11]
- Only two schools were left standing in Grenada after the passage of Hurricane Ivan (September 2004). Both had been subject to retrofit through a World Bank initiative. One of the schools was used to house displaced persons after the event.[12]
- After the passage of Typhoon Sisang in the Philippines in 1987, the Department of Social Welfare and Development, in consultation with the Asian Disaster Preparedness Center (ADPC), constructed 450 housing units. They were designed with a core shelter consisting of concrete footings with steel post straps bolted onto four wooden corner posts and frames, roof frames and trusses. Indigenous materials were used for all roof and wall cladding. The houses resisted two subsequent typhoons without significant damage.[13]
- Between 27 August and 18 September 1995, Hurricanes Luis and Marilyn caused damage to 876 housing units in Dominica causing a total loss of US$ 4.2 million. The small wooden houses that were destroyed did not comply with local building codes. But all the buildings that had been retrofitted, which consisted of simple modifications to local construction, through the CDMP Safer Construction Programme successfully withstood the hurricanes.[14]
- On 29 May 1990, an earthquake of magnitude 5.8 struck the Alto-Mayo in north-eastern Peru. The poor standard of construction (mainly houses made of *tapial* or rammed earth) resulted in the loss of over 3,000 houses; 65 people were killed and 607 injured. Tecnologia Intermedia (IT Peru)[15] introduced an improved *quincha* house, which slightly modified traditional technology in order to reduce vulnerability to future earthquakes. When a second earthquake of magnitude 6.2 hit the region in April 1991, 70 *quincha* houses had been built and local people could see for themselves that they were more hazard resistant. A further 1,120 *quinchas* were built with aid from IT Peru over the next five years and later, local people built another 4,000 similar houses.

In order to set the design criteria for a risk reduction project, the hazards, the current risk and level of risk that is socially acceptable must be identified. A multi-hazard appraisal should be carried out at an early stage to identify the types of hazards, their likely severity and recurrence (**see Guidance Notes 2 and 7**). An evaluation of the current risk includes identifying locations most likely to become unsafe in the event of a natural hazard (e.g., areas prone to flooding, landslides or earthquake-induced liquefaction) and assessing their land use, as well as assessing the ability of local construction to resist the identified hazards. A survey of existing buildings and infrastructure can identify significant vulnerabilities prior to the occurrence of a hazardous event. In a post-disaster scenario, lessons can be learned from the behaviour of different construction types during the event. Post-disaster diagnostic surveys should be integrated into disaster reconstruction programmes. In order to determine the socially acceptable risk,[16] local and national building codes,[17] international legislation and good practice should be examined to obtain an idea of current accepted levels of risk for different hazards and infrastructure. For example, in the case of most earthquake engineering codes, structures of normal importance are designed to withstand an earthquake with a 10 per cent probability of being exceeded in 50 years (i.e., an event with a return period of 475 years). The local government and community should then be consulted and a level of risk determined for the design. It is important to note that the level of socially acceptable risk will vary according to the use and importance of the facility and the desired post-natural hazard event performance. Finally if, for the identified hazards, the level of current risk is greater than that which is socially acceptable, then the need for hazard-proofing (and/or re-siting) is established, and the socially acceptable risk and identified hazards become the design criteria for the new construction or strengthening works.

---

11 Blondet, Garcia and Brzev (2003).

12 World Bank. *Grenada, Hurricane Ivan: Preliminary Assessment of Damages, September 17, 2004.* Washington, DC: World Bank, 2004. Available at: http://siteresources.worldbank.org/INTDISMGMT/Resources/grenada_assessment.pdf

13 Diacon, D. 'Typhoon resistant housing in the Philippines: The Core Shelter Project'. *Disasters,* 16 (3), 1992.

14 CDMP. *Toolkit: A Manual for Implementation of the Hurricane-resistant Home Improvement Program in the Caribbean.* Caribbean Disaster Mitigation Project publication series. Washington, DC: Organization of American States, 1999. Available at: http://www.oas.org/cdmp/document/toolkit/toolkit.htm

15 Based on Maskrey, A. 'The Alto-Mayo reconstruction plan, Peru – an NGO approach'. In Aysan et al. (1995) and in Ferradas, P., 'Post-disaster housing reconstruction for sustainable risk reduction in Peru', *Open House International,* 2006, 31(1).

16 Socially acceptable risk is the probability of failure (damage) of infrastructure that is acceptable to governments and the general population in view of the frequency and size of natural hazards, and the infrastructure use, importance and potential consequences of its damage. For example, it is unacceptable that a nuclear power station be damaged by any natural hazard event; the acceptable risk is, therefore, zero. In most cases constructing buildings and infrastructure that can fully resist the largest possible natural hazard is uneconomical (and often unjustified due to the rare nature of some natural hazards). Hence a limited risk is accepted.

17 Building codes are defined as standards and guidelines for the construction of buildings and infrastructure to a minimum level of safety for the occupants. See CDMP, *Hazard-resistant Construction.* Washington, DC: Organisation of American States and USAID's Unit of Sustainable Development and Environment, 2006. Available at: http://www.oas.org/CDMP/safebldg.htm

Box 4 Challenges, opportunities and good practice in post-disaster reconstruction

Post-disaster reconstruction projects present a real opportunity for the introduction of hazard-proof measures in construction and land use planning. Heightened hazard awareness and increased funding for construction can be harnessed to promote these measures and to achieve the legislative reforms required for regulating land use, hazard-resistant building code change, enforcement and construction quality control.

Development and humanitarian agencies should take a coordinated approach to reconstruction in a post-disaster scenario. Furthermore, local or national governing bodies must support major reconstruction initiatives. It is important that viable institutional frameworks and appropriate funding partnerships are established. Reconstruction should not be precipitate. Immediate needs can be addressed with temporary measures and a realistic timescale should be established which will allow hazard-proof design experts to be consulted and long-term goals to be considered in the reconstruction. Social needs, land availability and economic constraints mean that it is not always possible to secure land that is safe from all hazards in post-disaster reconstruction. However, it is still possible to reduce future losses from disasters through appropriate construction and planning measures.

It is important to note that resources made available immediately after a disaster for reconstruction will probably not be available for longer-term capacity building or to bring about a change in practice. One solution, contained in the United Kingdom's Department for International Development (DFID) Disaster Risk Reduction policy paper,[18] is to set aside 10 per cent of disaster funds to reduce the impact of related future disasters.

Throughout the project design and implementation it is essential that local stakeholders are actively involved. Local stakeholders include the direct beneficiaries, the wider affected community, local authorities, government and local academic and building experts. This will aid in the development of a truly sustainable technical solution (for infrastructure strengthening or reconstruction) and will increase acceptance of the project. A sustainable and successful project goes beyond site selection, the choice of a sustainable solution and training of local builders, to also involve issues of land tenure, finance, education for risk awareness and future maintenance (see Box 5).

Box 5 Beyond building

Proposing safe building or repair and strengthening practices is not sufficient to ensure take-up by communities. Integrated, community-based approaches for safer building should be promoted by:

- raising hazard awareness through education;
- community participation in developing the project, in decision-making and in design selection;
- developing locally acceptable, affordable and sustainable technological improvements;
- developing effective ways of communicating technical messages to target groups;
- skills development training for local builders and craftspeople;
- improvement of general living conditions;
- training architects and engineers (in both public and private sectors), building officials and building by-law enforcement officers; and
- community-based disaster preparedness planning.[19]

Hospitals are critical facilities for post-disaster relief, and it is not only the loss of structural integrity that can compromise operation but also damage to hospital equipment and to surrounding infrastructure (e.g., loss of access, water supply and electricity). Full structural, contents and systems network risk analyses should be carried out. The Pan American Health Organization (PAHO)[20] provides a series of guidelines for such analyses. Apart from the enormous emotional impact of student deaths, damage to schools and the loss of teachers have a negative impact on the education of survivors. Schools can provide community shelter and organisational foci in the aftermath of a disaster and are essential for a return to normality after the event. This is being increasingly recognised in both engineering and development communities:

- The United Nations Educational, Scientific and Cultural Organization is launching a campaign called Disaster

18 DFID. *Reducing the risk of disasters – Helping to achieve sustainable poverty reduction in a vulnerable world: A DFID policy paper.* London: Department for International Development (UK), 2006. Available at: http://www.dfid.gov.uk/pubs/files/disaster-risk-reduction-policy.pdf
19 Aysan et al. (1995).
20 For example, PAHO (2003 and 2004).

Reduction Begins in School which promotes disaster reduction education in schools and encourages the application of more stringent construction standards in schools.

- In October 2005, ActionAid, the Institute for Development Studies, Pamoja and the United Nations International Strategy for Disaster Reduction (UN/ISDR) started the Disaster Risk Reduction through Schools Project. The five-year project, which involves seven countries, aims to make schools safer and have them act as focal points for disaster prevention, preparedness and mitigation initiatives in the community.

Box 6 **Schools and hospitals**

Recent events have once again highlighted the vulnerability of schools and hospitals to natural hazards:

- Hurricane Ivan (category 3) hit Grenada on 7 September 2004, causing major losses to public infrastructure, in particular schools and hospitals. Only two of 75 primary and secondary schools survived with minimal damage, the largest hospital on the island, the Princess Alice Hospital, was more than 70 per cent damaged and St. Georges, the second largest hospital, suffered some roof damage and loss of laboratory equipment.[21] Windows were broken, which meant that even minimally damaged infrastructure could not be used immediately after the hurricane.
- The earthquake of magnitude 7.6 that struck Pakistan on 8 October 2005 caused severe damage to or the collapse of 95 per cent and 53 per cent of the educational buildings in the regions of Azad Jammu Kashmir and North-West Frontier Province, respectively; 18,095 students and 853 teachers died in these provinces. In addition, 423 health facilities sustained full or partial damage. Health-care staff were killed or injured and information records and systems lost, which resulted in a complete breakdown of the health system.[22]
- The Kobe General Hospital situated on Port Island, Kobe, Japan, was operational following the January 1995 earthquake. However, its functionality was compromised by the collapse of the bridge linking Port Island to the mainland.[23]

A technique to strengthen constructions or make them hazard-safe should consider all potential hazards, not just the natural hazard that has caused the most recent disaster. In many cases, design features intended to enhance resilience to one type of natural hazard will augment resilience to others, for example, the provision of good connections between foundations, frames, walls and roofs of buildings. However, in certain cases, design features that help resist one type of hazard may be detrimental to the resistance of another. For example, heavy roofs help withstand strong winds due to cyclones, storms or typhoons, but will increase the forces on buildings subjected to earthquakes.

In developing countries it is often not necessary to implement completely new building methods and materials in order to provide a safe solution. Local building practice should be assessed and weaknesses and strengths identified considering the local type and recurrence of natural hazards. Simple and inexpensive structural improvements, combined with good-quality construction methods and continued maintenance can overcome major weaknesses.[24] If new materials are introduced care must be taken to ensure that an adequate skills base exists for their use, or that training is provided, in order to avoid increased vulnerability from poor construction.

The siting and design of critical facilities and infrastructure that are essential for relief and recovery purposes in the event of a disaster should be given special consideration (see Box 6 above). The adoption of hazard-proof criteria set out in codes of practice for normal structures are not adequate in these cases as the non-operation of these facilities is not socially acceptable. New developments (e.g., FEMA 356[25] and PAHO, 2004) advocate the 'performance-based design' of critical facilities to allow for the lower level of socially acceptable risk. This involves the association of desired performance objectives (e.g., operation and severe damage but life-safety ensured) with different hazard-event return periods (e.g., a very rare event and largest possible event) for the determination of the loading for the building design. In the case of wind hazard, it is feasible to aim for a 'zero (damage) tolerance' approach in the design and construction of critical facilities. Tested technologies (such as base isolation) might also be promoted for use in the design of new facilities that are required to remain operational after a hazard event. Often, simply by considering natural hazards in the siting of critical facilities and the design of the infrastructure serving them,

21 World Bank (2005).
22 EEFIT. *EEFIT mission: October 8, 2005 Kashmir earthquake.* EEFIT: 2006. Available at: http://www.eefit.org.uk
23 Davis, I. *Location and operation of evacuation centres and temporary housing policies.* Committee for Global assessment of earthquake countermeasures. Hyogo Prefecture, Kobe Disaster Management Division, Japan, 2001.
24 Aysan et al. (1995).
25 ASCE. *Prestandard and commentary for the seismic rehabilitation of buildings, FEMA 356.* Washington, DC: American Society of Civil Engineers, 2000.

their resilience and post-disaster functionality can be significantly improved. For example, the de-concentration of critical services introduces redundancies and avoids the 'domino' effect of service outage in communities affected by disasters. Most importantly, all critical facilities should be designed by professionals with appropriate certification and specialised expertise. In California, for example, the design of schools and hospitals is limited to professionals with a special licence and is strictly controlled by a state organisation.

4. A step-by-step approach

Several organisations have suggested procedures for hazard-proof construction and strengthening initiatives based on the success or failure of projects they have been involved in. From a review of these procedures,[26] engineering sources[27,28,29,30] and successful past initiatives (e.g., Box 3), the following table has been drawn up. It presents a summary of the considerations that need to be made in the appraisal stages of such a project. These considerations are in addition to those outlined in **Guidance Note 1**.

Table 1 A summary of considerations to be made in the programming, identification and appraisal stages of a construction or strengthening project for hazard-risk reduction

Stage	*Key considerations*
Define roles and responsibilities	■ Clearly define the roles and responsibilities with regard to the main aspects of the project (i.e., the hazard risk assessment, design and siting of appropriately hazard-resilient infrastructure, enforcement of design and quality control of construction, operation and maintenance) of the various individuals, agencies and organisations involved in the project: ■ Coordinate with other development or relief (humanitarian) organisations working in the area to avoid duplication of research effort into hazard-proof construction and to promote a harmonised use of hazard-proof construction standards ■ Set up a system of consultation and collaboration with engineers, academics, local government and the affected community ■ Ensure that engineers and other infrastructure service providers participate fully in the design of projects, rather than merely building/supplying to order
Hazard assessment	■ Assess the frequency and 'size' of all potential sources of natural hazards (geological, meteorological or hydrological) in the area (**see also Guidance Notes 2 and 7**) and determine the most likely hazard scenarios for consideration in the infrastructure design: ■ Ideally, the development organisation's country strategy paper should already provide some overview of the significance of disaster risk in a particular country (**see Guidance Note 4**) ■ Existing academic studies and hazard maps may provide information for the hazard evaluation. However, depending on the prevalent hazards and the site, it may also be necessary to conduct site-specific risk analysis or micro-zonation studies ■ The possibility of local secondary effects (e.g., landslides from excessive rain or ground shaking) should be considered
Review of legislation and good practice	■ Assess existing codes of practice for hazard resistance and determine whether they are adequate for use: ■ Ideally, this review would have already been completed at the national level, by a development organisation or by a local research/academic body. This can then be drawn upon as relevant to the specific project context ■ If an existing review does not exist, effort must be spent in researching existing codes of practice for hazard resistance. This exercise might include: ■ Exploring the history of the code development and level of hazard inclusion

26 Aysan et al. (1995); UNDRO (1982); World Bank (2005).
27 Coburn, A. and Armillas, I. 'Earthquake Reconstruction for Future Protection'. In Aysan, Y. and Davis, I. (eds), *Disasters and the small dwelling: Perspectives for the UN IDNDR.* Oxford: James and James Science Publishers Ltd., 1992.
28 EERI/IASPEI. *International norm for seismic safety programs. Draft. Working group of the International Association of Earthquake Engineering and the International Association of Seismology and Physics of the Earth's Interior.* EEFIT/International Association of Seismology and Physics of the Earth's Interior, 2006. Available at: http://www.world-housing.net
29 Davis, J. and Lambert, R. *Engineering in emergencies: A practical guide for relief workers.* Bourton-on-Dunsmore: ITDG Publishing/Red R, 2002. 2nd ed.
30 Lubkowski, Z. and da Silva, J. *Aceh and Nias post-tsunami reconstruction: Review of Aceh housing program.* London: Arup, 2006. Available at: http://www.arup.com

Stage	Key considerations
	■ Looking at the performance of buildings/infrastructure designed to the codes during past hazard events ■ Comparing loading and design criteria to building codes developed for countries with similar hazards and neighbouring countries with similar construction practice ■ Reviewing good practice and international building codes, designing guidelines appropriate to the identified hazards and assessing their applicability

Review of construction methodologies and local capacity	■ Identify the main local construction practices for the relevant type of infrastructure. A fairly rapid assessment may be made in the case of new constructions, but a more detailed analysis is required in a retrofitting project:
	  ■ Weaknesses in the structures and the vulnerability of infrastructure to the identified natural hazards must be assessed. This will be obvious in a post-disaster scenario. This may include a study of the rate of degradation of the structure and its materials over time to assess resilience against projected hazards
	  ■ The strengths and durability of materials need to be determined
	  ■ Identify who carries out the design and construction (engineered, non-engineered, self-build or contractor build) and the level of code compliance
	■ Assess the resistance of local construction to the determined hazards and the level of risk these pose

Set hazard safety objectives	■ Establish clear and measurable objectives for hazard-safety, based on the level of risk that can be supported by the affected public and government agencies. Take into account development agency accountability issues ■ Consider different performance objectives for critical facilities and infrastructure, in particular factoring in the potential impact on the users or clients who would be negatively affected to varying extents by loss of service

Site selection	■ The site for development will typically be defined by local government based on availability and economic criteria. The suitability of these sites needs to be assessed. This can be done by following checklists (such as Corsellis and Vitale,[31] and the Sphere Standards,[32] among others). Any hazard assessments carried out in previous stages should also be considered
	■ Determine whether additional works are required to render the site viable for development or whether land use should be restricted to reduce vulnerability to natural hazards
	■ Consider whether re-siting to a location of reduced risk is an option:
	  ■ Topographical features and landscape can be used to reduce the impact of potential natural hazards (e.g., to minimise flood risk or modify wind-speed and wind direction)
	  ■ Land swaps might be a potential solution in collaboration with local government, although there is probably a stronger track record in terms of environmental protection

Design and procurement	■ Design a sustainable and socially acceptable strengthening/building solution that satisfies the hazard safety objectives:
	  ■ Consider limitations of finance, construction skills and material availability
	  ■ In a strengthening initiative take into account disruption to normal activity
	  ■ Ensure that the environmental and social impacts of the proposed solution are acceptable (**see Guidance Notes 7 and 11**)
	  ■ Ensure (e.g., through testing and research) that the proposed solution will yield the performance objectives determined in the previous step
	■ Develop a procurement strategy that provides overall value for money and resources during the entire life of the service/facility
	■ Assess the competency of the contractor:
	  ■ Consider the level of necessary site supervision
	  ■ Address any skills training issues necessary for the implementation of the proposed solution (e.g., possible on-the-job training included in the implementation stage)
	■ Develop building aids and guidelines, accounting for local hazard conditions, building material characteristics, construction skills and quality, using the results of the studies above

31 Corsellis, T. and Vitale, A. *Transitional settlement displaced populations.* Cambridge, UK: University of Cambridge Shelter Project and Oxfam, 2005.
32 Sphere Project. *Humanitarian Charter and Minimum Standards in Disaster Response.* Geneva: Sphere Project, 2004. Available at: http://www.sphereproject.org/content/view/27/84/lang,English/

Stage	Key considerations

Construction	■ It is essential that the quality of the construction does not compromise the design intent. A procedure must therefore be established for the multidisciplinary inspection and checking against specifications of works throughout the building process:
	  ■ Test materials and check adherence to design guidelines
	  ■ Ensure implementation of the quality assurance system

Operation and maintenance	■ Guidelines for operation and maintenance should be provided to maintain the design level of hazard resilience ■ Set up a funding and management structure for operation and maintenance ■ Define a procedure to be followed for the approval of any structural alterations carried out through the design life of the structure

Evaluation	■ The adequacy of the chosen infrastructure design and the success of the project as a whole must be carried out. The many considerations include:
	  ■ Functionality, social acceptability and sustainability
	  ■ Project cost with respect to the potential benefits of hazard-proof design in future events, of any skills provided to builders and of new construction guidelines introduced
	  ■ Reporting of the performance of the infrastructure under any hazard events that have occurred
	■ Lessons learned regarding strengthening hazard resilience should be summarised, divulged and drawn on for future projects

5. Critical factors for success

The critical factors that need to be addressed for ensuring the successful mainstreaming of safer construction are:

- *Incorporating design checks, enforcement and quality control*. Appropriate policies, effective implementation measures and relevantly trained technical personnel are necessary for the checking of designs, enforcement of good building practices and inspection of construction quality throughout the building process. Effective checking of designs cannot be carried out by individuals less knowledgeable and less experienced than the designers. The satisfaction of quality goals can be tied to criteria for payment, schedules for contractors and performance bonds. Enforcement and quality control are generally the weakest part of the system, often due to lack of human and financial resources allocated to this function and political interference with the regulatory system.[33] However, it is estimated[34] that checking and monitoring of the design and construction of infrastructure amounts to an additional cost of 1 to 2 per cent of the construction cost. This is a small sum if it is considered spread over the lifetime of the construction and to be offset by maintenance cost savings.
- *Consultation of hazard and construction experts*. A major factor for the success and mainstreaming of hazard-proof measures in development construction projects is the recognition by development and funding agencies that hazard specialists and civil/structural engineers need to be engaged in the coordination and design of the project and construction works. A small input by such people at the outset of the project can ensure that the design incorporates the correct levels of risk and that appropriate technical solutions/construction practice are being employed. Lack of expert involvement and reliance on best local practice can lead to the re-creation or promotion of vulnerability.
- *Land use planning and improving building codes for hazard-resistance*. Development organisations may need to provide support to governments, professional institutions and other national bodies to improve hazard assessment and representation in building codes, adjust codes to account for increasing hazards due to climate change (if codes were based on historical precedent), and improve structural design criteria and land use zoning.
- *Improving practice*. In developing countries, technical guidance, training and education may need to be provided to local engineers, builders and architects. This requires cooperation with hazard-proof construction experts for the development of appropriate educational and training materials and appropriately trained technical people to transfer the knowledge. A recent example of such a project was the GOAL Pakistan housing construction training following the 2005 earthquake.[35]

33 CDMP (2001).
34 Gibbs (2002); see footnote 5.
35 See http://www.goal.ie/newsroom/report0306.shtml

- *Encouraging local uptake and community participation*. Unsuccessful development schemes involving hazard-proof construction (or strengthening) of housing have mainly failed due to a lack of local take-up. This has occurred mostly when the proposed strengthening, building or repair techniques have been developed without consulting the affected community and are, therefore, unsustainable and do not meet local needs. Common faults are that the proposed solutions are too expensive or adopt new materials and building techniques for which local construction skills are inadequate, or that the materials and forms introduced are socially, economically, culturally or climatically inappropriate.
- *Guidelines for performance-based design of structures subject to natural hazards with different recurrence.* This involves the determination of acceptable risk levels for different types of structures, on the basis of their desired performance in the case of a range of frequencies of occurrence of natural hazards. This concept, proposed in the earthquake engineering field,[36] should be extended to include multiple hazards and policies introduced to ensure that schools and hospitals are designed for increased hazard resistance. Risk posed by the failure of non-structural components (e.g., the loss of a facility's serviceability due to damage to equipment) should also be considered when doing this. Consideration of desired post-natural hazard event performance at the design stage would result in the prioritisation and more stringent design of hospitals, schools and other critical infrastructure.
- *Adequate operation and maintenance expenditure.* This is required to maintain the designed hazard-resilience of infrastructure. The annual maintenance budget for a public building will be about 4 per cent of its contemporary capital cost.[37] Funding for operation and maintenance may with time be diverted to other uses. This may result in the facility no longer being suitable for normal use and its increased vulnerability to natural hazards. A method for ensuring continued operation and maintenance expenditure is to link it to insurance, which would cover the eventual damage due to a natural hazard if the infrastructure were maintained.
- *Promoting research into non-engineered structures and the effects of natural hazards.* There is a need for a better understanding of the performance under natural hazard events of non-engineered structures and traditional building materials and technologies. The effects of different natural hazards on buildings have been researched to different degrees. Cyclones, typhoons, storms, floods, landslides and earthquakes have been the subject of active research. But recent events in the Indian Ocean have highlighted the lack of research into the effects of violent flows and tsunami on the built environment.[38]
- *A technological solution is insufficient on its own.* Hazard-proof construction is only one part of disaster-risk mitigation project and must be linked to other types of risk reduction, including evacuation planning and other community preparedness measures.

Box 7 Hazard and disaster terminology

It is widely acknowledged within the disaster community that hazard and disaster terminology are used inconsistently across the sector, reflecting the involvement of practitioners and researchers from a wide range of disciplines. Key terms are used as follows for the purpose of this guidance note series:

A *natural hazard* is a geophysical, atmospheric or hydrological event (e.g., earthquake, landslide, tsunami, windstorm, wave or surge, flood or drought) that has the potential to cause harm or loss.

Vulnerability is the potential to suffer harm or loss, related to the capacity to anticipate a hazard, cope with it, resist it and recover from its impact. Both vulnerability and its antithesis, *resilience*, are determined by physical, environmental, social, economic, political, cultural and institutional factors.

A *disaster* is the occurrence of an extreme hazard event that impacts on vulnerable communities causing substantial damage, disruption and possible casualties, and leaving the affected communities unable to function normally without outside assistance.

Disaster risk is a function of the characteristics and frequency of hazards experienced in a specified location, the nature of the elements at risk and their inherent degree of vulnerability or resilience.[39]

36 SEOAC. *Performance-based seismic engineering of buildings, Vision 2000 Committee.* Sacramento, USA: Structural Engineers Association of California, 1995.
37 Gibbs (2002); see footnote 5.
38 EEFIT. *The Indian Ocean Tsunami, 26th December 2004. Earthquake Engineering Field Investigation Team Report.* EEFIT, 2005. Available at: http://www.istructe.org/eefit/files/Indian_Ocean_Tsunami.pdf
39 The term 'disaster risk' is used in place of the more accurate term 'hazard risk' in this series of guidance notes because 'disaster risk' is the term favoured by the disaster reduction community.

Mitigation is any structural (physical) and non-structural (e.g., land use planning, public education) measure undertaken to minimise the adverse impact of potential natural hazard events.

Preparedness is activities and measures taken before hazard events occur to forecast and warn against them, evacuate people and property when they threaten and ensure effective response (e.g., stockpiling food supplies).

Relief, rehabilitation and *reconstruction* are any measures undertaken in the aftermath of a disaster to, respectively, save lives and address immediate humanitarian needs; restore normal activities; and restore physical infrastructure and services.

Climate change is a statistically significant change in measurements of either the mean state or the variability of the climate for a place or region over an extended period of time, either directly or indirectly due to the impact of human activity on the composition of the global atmosphere or due to natural variability.

Further reading

Building, strengthening and repair projects must be tailored to the individual needs, hazards and resources of the affected community. Numerous technical solutions exist and guidelines have been drawn up by various associations based on past project experience. A list of some key literature and web resources for further information is provided here.

Managing hazard-proof construction projects

Aysan, Y., Clayton, A., Cory, A., Davis, I. and Sanderson, D. *Developing building for safety programmes: Guidelines for organizing safe building improvement programmes in disaster-prone areas.* London: Intermediate Technology Publications, 1995.

Balamir, M. 'Methods and tools in urban risk management'. In Komut, E. (ed.), *Natural Disasters: Designing for Safety.* International Union of Architects and the Chamber of Architects of Turkey, 2001.

OAS. *Primer on Natural Hazard Management in Integrated Regional Development Planning*. Washington, DC: Organization of American States, Department of Regional Development and Environment Executive Secretariat for Economic and Social Affairs, 1991. Available at: http://www.oas.org/dsd/publications/Unit/oea66e/begin.htm.

UNDRO. *Shelter after disaster: Guidelines for assistance.* Office of the United Nations Disaster Relief Coordinator, 1982. Available at: http://www.sheltercentre.org/shelterlibrary/publications/172.htm

Wamsler, C. 'Mainstreaming risk reduction in urban planning and housing: A challenge for International aid organisations'. *Disasters,* 30(2)151–177, 2006.

World Bank. *Lessons from natural disasters and emergency reconstruction.* Washington, DC: World Bank, Operations Evaluation Department, 2005.

Hazard-proof designs and practical building guides

Blondet, M., Garcia, G.V. and Brzev, S. *Earthquake-resistant construction of adobe buildings: A tutorial. Contribution to the World-Housing Encyclopedia.* International Association for Earthquake Engineering, 2003. Available at: http://www.world-housing.net/Tutorials/Tutorial.asp

CDMP. *Hazard-resistant construction.* Caribbean Disaster Mitigation Project, Organization of American States Unit of Sustainable Development and Environment, USAID Office of Foreign Disaster Assistance and the Caribbean Regional Program, 2001. Available at: http://www.oas.org/CDMP/safebldg.htm

Coburn, A., Hughes, R., Pomonis, A. and Spence, R. *Technical principles of building for safety.* London: Intermediate Technology Publications, 1995.

Federal Emergency Management Agency (USA) website: Guides for safer building. http://www.fema.gov/rebuild/recover/build_safer.shtm

IAEE. *IAEE guidelines for earthquake resistant non-engineered constructions.* Second edition. 2004. Available at: http://www.nicee.org/IAEE_English.php

Shelter Library website: Resource for books on practical building with low-cost material and guides for post-disaster shelter. http://www.sheltercentre.org/shelterlibrary/index.htm

United Nations HABITAT website: Reports on materials and construction. http://www.unhabitat.org/programmes/housingpolicy/bmct.asp

USAID–OAS. *Basic minimum standards for retrofitting.* United States Agency for International Development and Organization of American States, Caribbean Disaster Mitigation Project, 1997.

School and hospital safety
PAHO. *Guidelines for the vulnerability reduction in the design of new health facilities.* Washington, DC: Pan American Health Organization, World Health Organization, World Bank, ProVention Consortium, 2004. Available at: http://www.paho.org/english/dd/ped/vulnerabilidad.htm

PAHO. *Protecting new health facilities from natural disasters: Guidelines for the promotion of disaster mitigation.* Washington, DC: Pan American Health Organization, World Health Organization, World Bank, 2003. Available at: http://www.disaster-info.net/viento/books/ProtNewHealthFacEng.pdf

Wisner, B. et al. 'School seismic safety: Falling between the cracks?' In Rodrigue, C. and Rovai, E. (eds), *Earthquakes.* London: Routledge, 2004. Available at: http://www.fsssbc.org/downloads/SchoolSeismicSafetyFallingBetweentheCracks.pdf

This guidance note was written by Tiziana Rossetto. The author would like to thank Yasemin Aysan (independent consultant), Murat Balamir (METU Ankara), Fouad Bendimerad (Earthquakes and Megacities Initiative), Tony Gibbs (Tony Gibbs Consulting Ltd.), Jo da Silva (Arup, London), Alistair Wray (DFID), members of the project Advisory Group and the ProVention Consortium Secretariat for their invaluable advice and comments. Financial support from the Canadian International Development Agency (CIDA), the United Kingdom's Department for International Development (DFID), the Royal Ministry of Foreign Affairs, Norway and the Swedish International Development Cooperation Agency (Sida) is gratefully acknowledged. The opinions expressed are those of the author and do not necessarily represent the views of the reviewers or funding bodies.

Tools for Mainstreaming Disaster Risk Reduction is a series of 14 guidance notes produced by the ProVention Consortium for use by development organisations in adapting project appraisal and evaluation tools to mainstream disaster risk reduction into their development work in hazard-prone countries. The series covers the following subjects: (1) Introduction; (2) Collecting and using information on natural hazards; (3) Poverty reduction strategies; (4) Country programming; (5) Project cycle management; (6) Logical and results-based frameworks; (7) Environmental assessment; (8) Economic analysis; (9) Vulnerability and capacity analysis; (10) Sustainable livelihoods approaches; (11) Social impact assessment; (12) Construction design, building standards and site selection; (13) Evaluating disaster risk reduction initiatives; and (14) Budget support. The full series, together with a background scoping study by Charlotte Benson and John Twigg on *Measuring Mitigation: Methodologies for assessing natural hazard risks and the net benefits of mitigation*, is available at http://www.proventionconsortium.org/mainstreaming_tools

PROVENTION CONSORTIUM

ProVention Consortium Secretariat
PO Box 372, 1211 Geneva 19, Switzerland
E-mail: provention@ifrc.org
Website: www.proventionconsortium.org