GLOBAL PROGRAM FOR SAFER SCHOOLS

CHARACTERISTICS OF SAFER SCHOOLS

GFDRR
Global Facility for Disaster Reduction and Recovery

ARUP

WORLD BANK GROUP

ACKNOWLEDGEMENTS

This report was developed by Arup International Development for the Global Program for Safer Schools (GPSS) in collaboration with the Global Facility for Disaster Risk Reduction and Recovery (GFDRR).

The characteristics were developed in 2013 and subsequently used to inform various guidance notes and technical assistance to World Bank education infrastructure programs. This work is ongoing and several illustrative examples are included in this reformatted version of the report produced in 2016.

We are grateful for the input of World Bank and GFDRR staff throughout this ongoing process. Their willingness to engage and provide access to information is very much appreciated.

Many of the tools and examples presented in this report were developed by Arup and builds on an extensive track record of involvement with safer schools. Insight and reflections received from colleagues within Arup have been critical to the formation of these characteristics and the report more broadly.

This report is available here: https://goo.gl/A73G7C

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EXECUTIVE SUMMARY

Each year, school buildings collapse or incur significant damage due to natural disasters. This has resulted in deaths and injuries to teachers and children, and disruption to their education which prevents rapid recovery and can translate into long-term socio-economic consequences. There is global recognition of the need to carry out repairs and retro-fitting in order to make existing schools safer, as well as to ensure that the large numbers of schools planned or under construction, particularly in developing countries, are inherently safe.

School safety can mean different things to different people depending on their perception of risk. Typically, it is assumed that a safer school is able to withstand extreme events without collapsing, and that whilst there may be extensive damage, the risk to loss of life is low as the occupants are able to exit safely and/or failure of the building is localised. However, in many instances it is desirable to minimise damage since school buildings play an important role in creating resilient communities; continuity of schooling is critical to rapid recovery and schools have potential to act as a community refuge, distribution or resource centre in the immediate aftermath of a disaster.

Performance objectives (PO), such as those developed by organisations such as FEMA are used to define the maximum level of risk that can be tolerated in terms of damage and disruption.

The extent to which a school is safe will depend on its location and construction and operation. There are four factors that contribute to reducing (or increasing) risk: hazards, site location, physical planning and quality of buildings.

The procurement of the building(s) (i.e. who is responsible for design and construction) will have a direct impact on the means of quality assurance. The procurement process needs to be determined at the earliest stage possible and will depend on the maturity of the construction industry, the availability of local skills and capacity as well as the complexity of the school design.

Image. Classroom in Indonesia

INTRODUCTION

BACKGROUND

Each year, school buildings collapse or incur significant damage due to natural disasters. This has resulted in deaths and injuries to teachers and children, and disruption to their education which prevents rapid recovery and can translate into long-term socio-economic consequences. There is global recognition of the need to carry out repairs and retro-fitting in order to make existing schools safer, as well as to ensure that the large numbers of schools planned or under construction, particularly in developing countries, are inherently safe. (e.g. within the Rift Valley in East Africa where a significant seismic hazard exists.) Systematic, replicable and scale-able approaches are needed which address this two-fold challenge, whilst recognising the diversity of typologies, contexts and implementation methods.

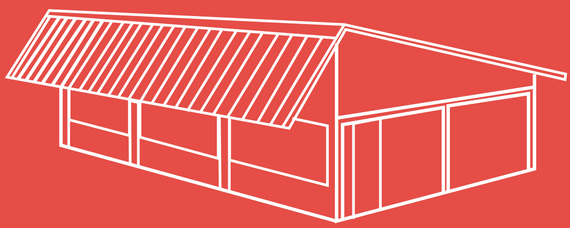
To date, global efforts by UN agencies, the Red Cross, NGOs and bi-lateral and multi-lateral donors to make schools more resilient have typically focussed on improving awareness of natural hazards so that teachers and children are better prepared and able to take appropriate action; examples being the inclusion of hazard risk in the school curricula, emergency drills and contingency plans. Less attention has been given to the physical aspects of safer schools resulting from their location, construction and operation. Yet, site-planning, quality of design, materials, workmanship and ability to carry out regular maintenance play a critical role in determining the ability of a school to withstand extreme events and the extent of damage that may occur.

Recent guidance on creating safer schools covers the assessment of existing facilities, as well as identifying specific measures needed to make new schools safer is a step in the right direction. However they fall short of defining what a safer school is and what it looks like in straightforward non-technical terms that can be used as a global framework for both assessment and delivery; also to identify the strengths and weaknesses of different methods of implementation. (See Figure 1).

CHARACTERISTICS OF A SAFER SCHOOL

Delivery
Map measures that need to be take during the following stages:

- Planning
- Design
- Construction
- Maintenance



Assessment Process
Design a process that can be used to assess whether existing school construction is safe

Implenmentation Methods
Understand and identiry different implementation methods and consider their impact on delivering safer schools

Figure 1. Scope of the Report

SCOPE

This report has been prepared by Arup International Development (Arup) on behalf of the Global Facility for Disaster Risk Reduction (GFDRR). It focusses on the physical (or 'structural') aspects of safer schools as background to inform the final design of the Global Programme for Safer Schools (GPSS). Although the issues covered are technical, the report has been written so as to be accessible to a wider non-technical audience.

The objectives of this report are to:

- Define the characteristics of a safer school facility (Section 2)
- Design a process that can be used to assess whether existing schools are safe (Section 3)
- Identify measures that need to be taken during planning, design, construction and operationof new schools (Section 4)
- Discuss the implications for different implementation methods (Section 5)

The content reflects global best practice and lessons learned about assessment and construction of schools in disaster prone countries based on a review of existing guidelines. It is also informed by Arup's wide-ranging experience designing, delivering and evaluation schools in over 40 countries, some of which are included as examples to illustrate key issues.

TWO-FOLD CHALLENGE

- Making existing schools safe - or at least safer - through repair, retro-fitting or if necessary, reconstruction.
- Ensuring that the large numbers of new schools that are planned or under-construction in developing countries are safer from the outset.

Image. Earthquake damage to a school in Nepal, 2015

DEFINING A 'SAFER' SCHOOL

A SAFER SCHOOL

School safety can mean different things to different people depending on their perception of risk. Typically, it is assumed that a safer school is able to withstand extreme events without collapsing, and that whilst there may be extensive damage, the risk to loss of life is low as the occupants are able to exit safely and/or failure of the building is localised. However, in many instances it is desirable to minimise damage since school buildings play an important role in creating resilient communities; continuity of schooling is critical to rapid recovery and schools have potential to act as a community refuge, distribution or resource centre in the immediate aftermath of a disaster. Consequently, a safe and resilient school is a more useful construct that reflects a desire to minimise disruption as well as prevent loss of life or assets.

PERFORMANCE OBJECTIVE

Performance objectives (PO) are used to define the maximum level of risk that can be tolerated in terms of damage and disruption. Figure 2 identifies four levels of performance that reflect the extent to which a school is safe or safe and resilient based on the approach and terminology developed by FEMA (Federal Emergency Management Agency). International codes of practice (e.g. Eurocode 8, Part 1, BS EN 1998-1 and International Building Code: 2009) use Importance Factors (I) which typically classify a school as critical infrastructure and imply a performance objective comparable to PO3. For a school to meet PO2/PO1 designs will exceed code requirements. Generally codes do not address the performance of non-structural elements although their failure can also cause death, injury and disruption; notably the collapse of masonry partitions and facades.

PERFORMANCE OBJECTIVE			LEVEL OF RESILIENCE	IMPACT	
PO1	Continuous Occupancy	• No structural damage. The building is safe to be used during and after the natural disaster. • Damage to contents is minimal and services will continue to function without alteration.	High Resilient School	Mild	Continuous education in the school or use as a community / emergency Shelter
PO2	Immediate Occupancy/ Operational Continuity	• Minor damage to structure which is repairable at a reasonable cost and in a reasonable amount of time. • Specified assets are protected. • Non-structural components and systems needed for the building to operate are fully functional (with utilities available possible from stand by sources) although some clean-up and repair may be required.	Moderate Resilient School	Moderate	Delayed start to education in school whilst repairs are carried out
PO3	Life Safety	• Damage to both structural and non-structural components but risk to loss of life is low. • Building systems and utilities are damaged and inoperable. • Building may be beyond economic repair.	Safe School	High	Extensive delays or building to be demolished
PO4	Collapse Prevention	• Building is near collapse and significant hazard to life may exist. • Building and emergency systems are extensively damaged and inoperable. • Building beyond technical repair.	Unsafe School	Severe	No Use – building to be demolished

Figure 2. Performance objectives used to determine the maximum level of rist that tolerated in terms of damage and disruption

UNDERSTANDING RISK

The extent to which a school is safe will depend on its location and design construction and operation. There are four factors that contribute to reducing (or increasing) risk: **hazards, site location, physical planning** and **quality of buildings**. These are shown on Figure 3 and discussed in more detail below.

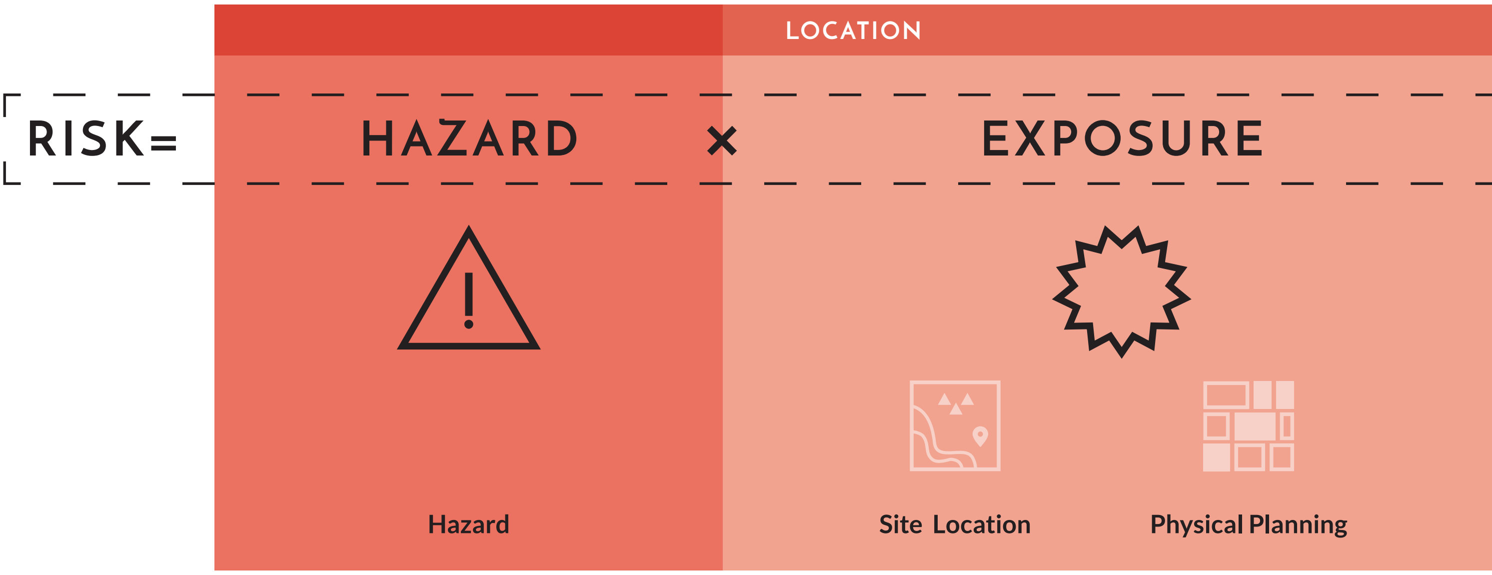


Figure 3. Factors contributing to a safer school mapped against the definition of risk

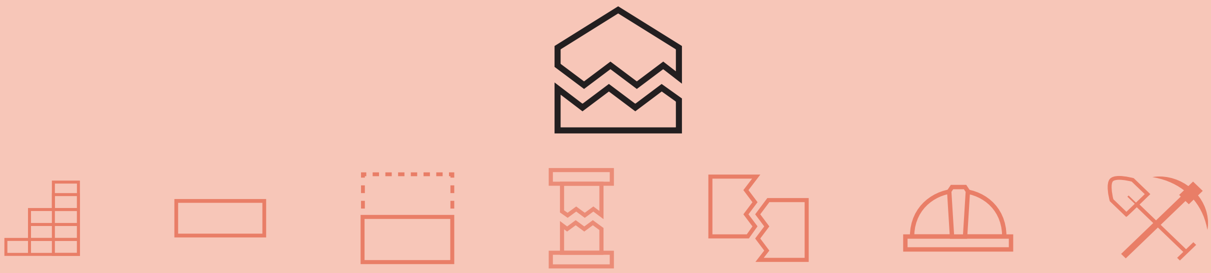
Hazard
The risk posed by natural hazards is determined in the first instance by the likelihood of a particular type and magnitude of event occurring. A major earthquake with potential to devastate a community may present a comparable risk to annual hurricanes which cause relatively minor damage more frequently. Multi-hazard assessments that identify and quantify risk are a prerequisite for achieving safer schools.

Site Location
At a local level how hazards are experienced relates to exposure. This will depend on the site location and physical characteristics including: soil conditions, topography, vegetation and its proximity to water bodies or fault lines. For instance, areas characterised by sandy soils and a high water table may be prone to liquefaction following an earthquake; while proximity to water bodies or de-forested slopes may increase flood risk following periods of heavy rainfall.

Physical Planning
Exposure can be mitigated (or compounded) by the physical planning of the site. For instance, wind loads on buildings can be significantly reduced as a result of their orientation, and civil engineering works such as retaining walls, slope-stabilization, and drainage, can substantially mitigate exposure to landslides and flooding

CONSTRUCTION AND OPERATION

VULNERABILITY



Building

Building

The vulnerability of a school relates to the quality of buildings taking account of structural, non-structural elements and building services. Inappropriate design and/or poor quality materials or workmanship, resulting from limited resources, corruption and a move away from vernacular construction methodologies have all contributed to high levels of vulnerability leading to the collapse of numerous schools over recent decades.

Some structural typologies are more suitable in relation to particular hazards; for instance lightweight timber construction is well-suited to areas subject to earthquakes but not necessarily high winds. The configuration of the building, the size of structural elements, how they are connected, and the quality of materials and workmanship will all impact on the structural capacity which determines its ability to withstand extreme loads.

Significant modifications, including extensions, large openings, and additional storeys may compromise the original design and also increase vulnerability; likewise if there is deterioration in the building's condition, for instance due to corrosion, settlement or cracking.

Additional vulnerability results from non-structural elements. Signage, pipes and ducts or water tanks on the roof that are inadequately fixed to the structure, inadequate protection of hazardous materials, and combustible materials can all contribute to increased vulnerability.

The choice of structural typology will have an effect on the ability to carry out maintenance and repairs which will impact on safety if it results in deterioration.

For a safer and resilient school, damage that may be costly or time-consuming to repair is unacceptable. Greater emphasis should be placed on the quality of design and construction, as well as the ability to maintain, repair and adapt facilities without compromising the structural integrity. Lack of maintenance budgets or clarity over who is responsible, and imported construction technologies are factors which may prevent this. Maintaining access and continuity of basic services post-disaster, particularly water and power, is also important and may be achieved through protective measures or stand-by (or back-up) systems.

Image. School undergoing retrofit in Nepal

CHARACTERISTICS OF A SAFER SCHOOL

We have identified ten characteristics of a safer school which are based on a review of best practice literature and Arup's experiences designing, delivering and evaluating schools. These are summarised in Figure 4.

Characteristic 1 relates to the measurements needed in order to establish the design criteria. Characteristics 2 and 3 relate to the site location, whereas characteristics 4 to 10 apply to the buildings (including building services and non-structural elements).

In countries where there is a mature regulatory framework that is enforced, these characteristics will already be incorporated in building codes and practices so that compliance becomes the pre-dominant issue in achieving safer schools. Elsewhere the characteristics provide a basis for developing Assessment Methods (Section 3), identifying the action that needs to be taken at various stages of the Project Delivery Cycle (Section 4) or to support different methods of implementation (Section 5).

Figure 4. Characteristics of a Safer School

HAZARD

1 Hazard Assessment
A hazard assessment has been undertaken to identify the types of hazard that the school may experience (e.g. tsunamis, volcanoes and earthquakes).

EXPOSURE

2 Site Location
A site assessment has been undertaken to identify key features that may impact exposure to specific hazards including topography, soil conditions, proximity to water bodies/fault lines, vegetation.

3 Physical Planning
Appropriate mitigation measures have been taken in the physical planning of the site to adequately mitigate against the risks identified as a result of the hazard and site assessments.

VULNERABILITY

4 Structural Typology
An appropriate structural typology has been used for the buildings which takes account of the most prevalent hazards.

5 Building Configuration
The building configuration is reasonably symmetric, allows safe egress, avoids irregular features

6 Building Modifications
Significant building modifications (e.g. openings, canopies, additional storeys) have not been constructed unless allowed for specifically in the building design.

7 Structural Capacity
The structural capacity of key elements of the building (e.g. foundations, beams, columns, walls, roof, connections) have been assessed for their ability to transfer vertical and lateral loads.

8 Non-Structural Capacity
The selection of non-structural elements of buildings (e.g. façades, internal walls, storage of hazardous materials, equipment, and signage) has taken account of the prevalent hazards and are adequately fixed to the main structure.

9 Materials And Workmanship
There are systems in place to assure the quality of materials and workmanship during construction and / or there are no signs of structural deterioration (e.g. settlement, cracking, corrosion) in key elements of the building (e.g. foundations, beams, columns, walls, roof, connections) that might impair the structural performance.

10 Maintenance / Repairs
There is adequate funding and local skills available to carry out regular maintenance and repairs of the school buildings and site infrastructure (e.g. drainage channels, access and evacuation routes).

ASSESSING EXISTING SCHOOLS

Even though schools vary widely, from being single classrooms to multi-storey buildings which may be located in rural communities, urban centres, on steep hillsides or low lying areas, the characteristics can be used as the basis for assessing existing schools. The four stage Assessment Process for existing schools (shown in Figure 5) can be used to determine whether or not a school is safe or requires retrofit, repair or reconstruction. Details of each step in the assessment process can be found in Appendix A. An indicative assessment tool for site selection has been developed for the purpose of this report with preliminery indicators based on existing assessment methodologies (Figure 6). Similar tools have been developed as a result of wider consultation and in providing technical assisstance to the GPSS.

The first two steps of the process can be carried out at a national level and are critical as they establish the baseline characteristics; Performance Objectives and Hazard Assessment which then inform the subsequent stages of the assessment process. The Hazard Assessment requires research and consultation with key stakeholders but can be applied to large groups of schools within a country or region that are of similar type. The successive stages apply to individual schools and assess the Exposure (location) and Vulnerability (construction and operation) (see Figure 7). The Vulnerability Assessment (stage D) is only applicable for high winds, flooding and earthqvuakes as the impact of other hazards, such as, landslides, volcanoes and tsunamis is determined by exposure and cannot be meaningfully reduced at building scale (see Figure 8).

Figure 5. Assessment of Existing Schools

ASSESSMENT STAGE		PURPOSE	CHARACTERISTIC (NUMBER)
A	Performance Objective	• To understand the performance objectives based on what key stakeholders consider to be an acceptable level of risk in relation to loss of life, and damage to property that may prevent the school being used for education or as a community facility.	
B	Hazard Assessment	• To identify the frequency and intensity of hazards in the school vicinity which the design of the school needs to account for.	1
C	Exposure Assessment	• To identify whether the physical characteristics of the site make the hazards worse. • To identify the mitigation measures relating to the layout of buildings and site-wide civil engineering works compound or reduce exposure to specific hazards.	2 3
D	Vulnerability Assessment	• To determine whether the design and construction of buildings reduces disaster risk (flood, earthquake and high winds) to an acceptable level based on the performance objectives defined in step 2, or whether there are aspects that make it inherently vulnerable therefore unsafe. • To identify further features which may contribute to the resilience of a school. • Note: This assessment is not applicable for schools exposed to volcanoes, tsunamis or landslides). Schools over two storeys need to be assessed by an appropriate technical expert.	4 5 6 7 8 9 10

An assessment of this calibre is sufficient to identify key features that may compromise the safety of a school, or where more detailed technical assessment is required.

This four stage process can be developed in to a robust and replicable assessment by understanding who will be undertaking the assessment and establishing quality training, reporting and communication tools.

The results of an assessment can be used to populate a database of schools infrastructure and inform the initial planning and design of large scale repair, retro-fitting and reconstruction programs.

Potential Indicators		HAZARDS	Tsunami	Volcano	Landslide	High Winds	Flooding	Earthquake
	TOPOGRAPHY	Elevated Site	●				●	
		Site away from base of slope		●	●		●	●
		No deep cuts in to a hill/slopes			●			●
		Sites away from escarpments		●	●	●	●	●
	PROXIMITY TO WATER BODIES	Sites away from flood hazard areas as shown on flood hazard maps					●	
		Sites away from body of water					●	
		Sites away from storm surge inundation zones	●				●	
	FAULTS/SOIL CONDITIONS	No fault lines on the side						●
		Sites with firm sub soil/rock (avoid liquefaction)						●
		Sites with ground water level below foundation					●	●
	VEGETATION	Sites with minimum exposure to wind. e.g. with natural wind barriers (trees)				●		
		Sites located where regular maintenance of surroounding areas is undertaken			●	●	●	
		Adequate vegetation			●	●	●	●
		Avoid large trees that could blow over				●		

Figure 6. Indicative site selection/assessment tool with potential indicators

REQUIREMENTS

A rigorous assessment process requires

- Clarity on the purpose of the assessment and the action to be taken based on the outcomes
- Competent assessors with appropriate training
- A robust and replicable assessment process
- A standard reporting format that records the basis of the assessment and the key findings

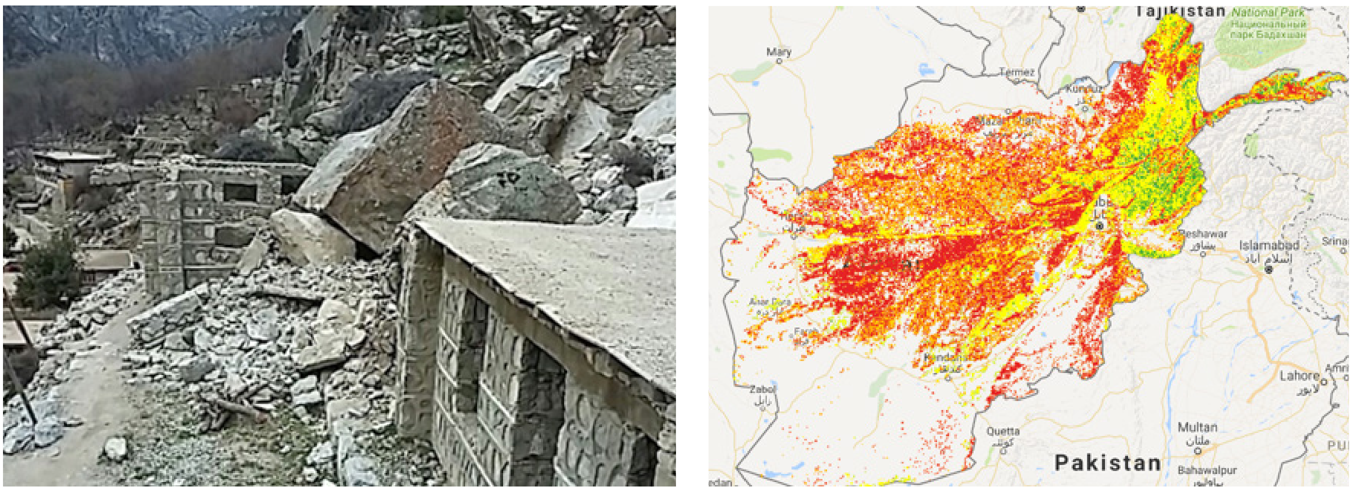


Figure 7. GLOBAL PROGRAM FOR SAFER SCHOOLS – Afghanistan Assessment: Landslide hazard map from the Deltares Geonode database; and an example of a school exposed to landslide and rock fall

Image. A school in Samoa

DELIVERY OF NEW SCHOOLS

There is an implicit assumption in much of the existing guidance that schools are being constructed within the context of a regulatory framework or that technical expertise is available. The reality is that even where codes and standards exist they are often out of date or not enforced and very many school buildings are 'non-engineered' as they are built by local contractors or communities.

Understanding the type of hazards that are present is a prerequisite to the delivery of a safer school or identifying whether or not a school is safe.

Early warning systems (EWS) have proven to be effective in reducing loss of life for most hazards, but not in reducing risk to physical assets. To achieve more than preventing loss of life or injury we must aim to reduce either exposure and/or vulnerability.

The emphasis will depend on the type of hazards most prevalent in that location: (see Figure 8)

- For tsunamis the most effective means to reduce risk is to minimise **exposure** by locating schools away from the coast on high ground; a similar approach can be applied to schools near active volcanoes.
- Sites prone to landslides should be avoided, although in some cases engineering measures can be taken to stabilise slopes, likewise to reduce flood risk.
- In areas prone to high winds (typhoons, cyclones, hurricanes) the orientation of buildings can significantly reduce the level of **exposure**, where as it is impossible to mitigate the exposure of a school due to earthquakes other than locating buildings away from fault lines.
- The design and construction of buildings can significantly reduce **vulnerability** due to high winds, flooding and earthquakes.

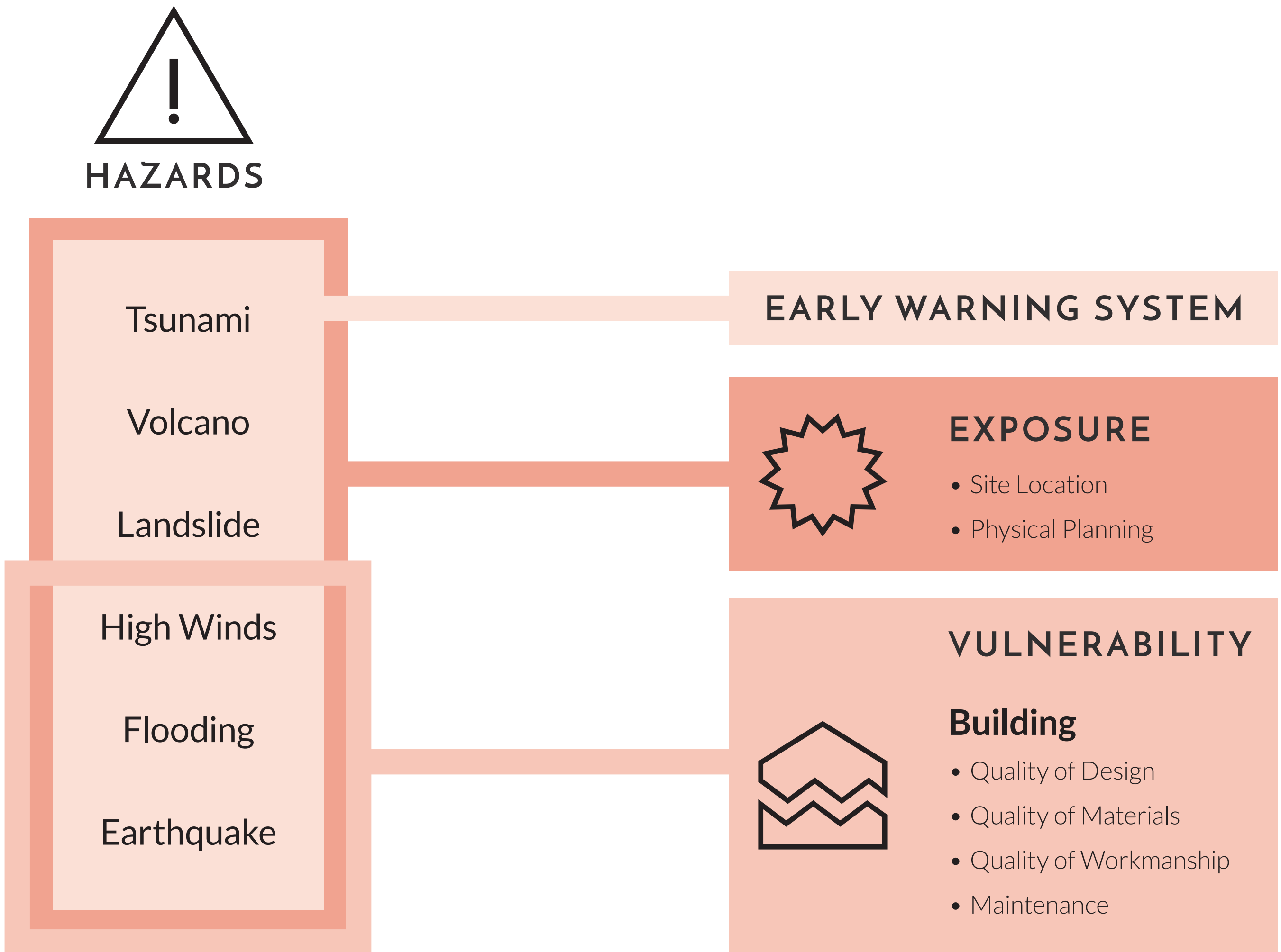


Figure 8. Reducing risk of life and physical assets

PROJECT DELIVERY CYCLE

A typical project cycle compromises 4 key stages; Planning, Design, Construction and Operation. Figure 9, illustrates at which stage of the project cycle - planning, design, construction, and during operation - the characteristics of a safer school can be addressed.

The rest of the section describes in more detail the objectives of each stage and the measures to be undertaken to fulfil the objectives.

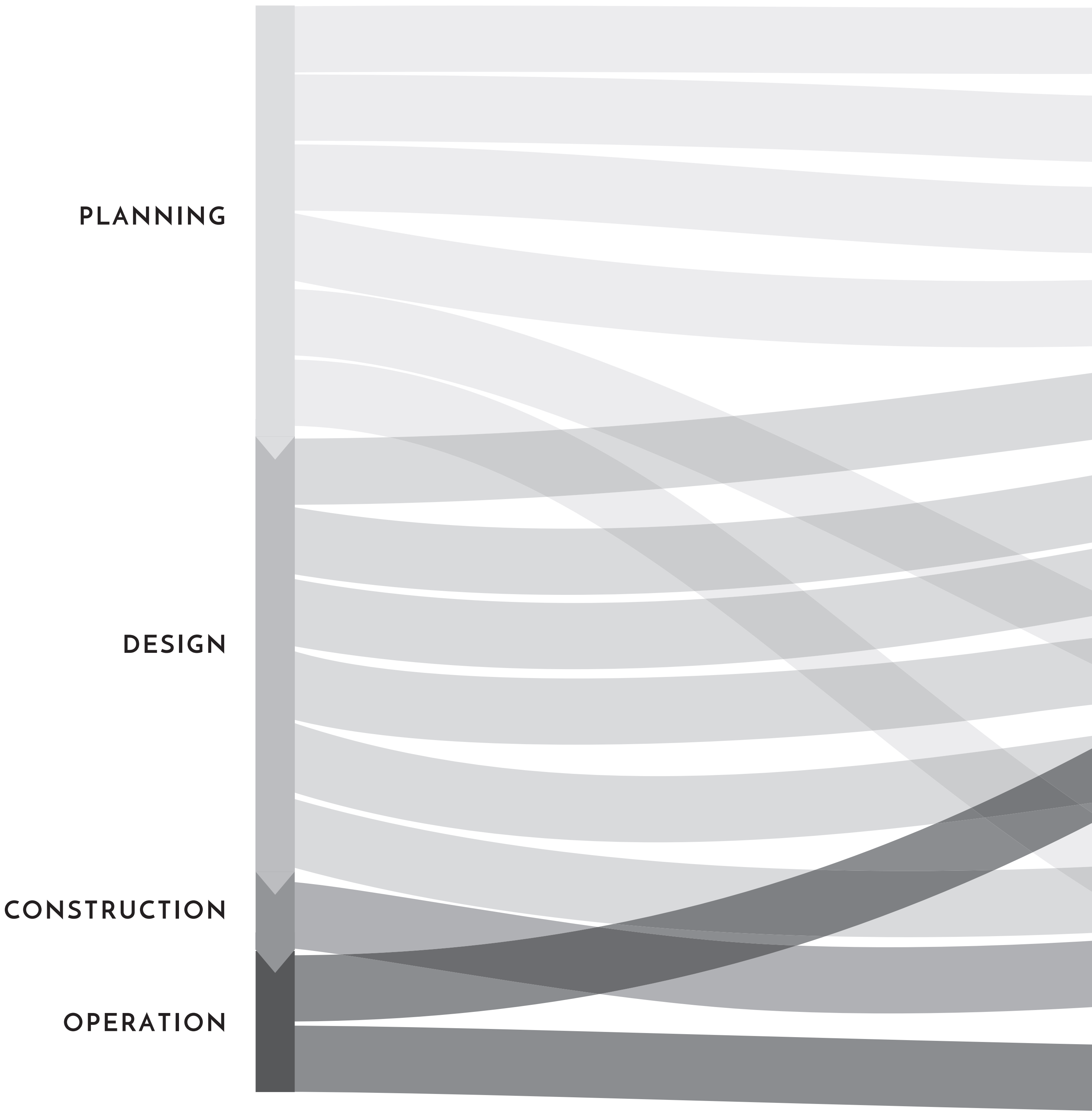
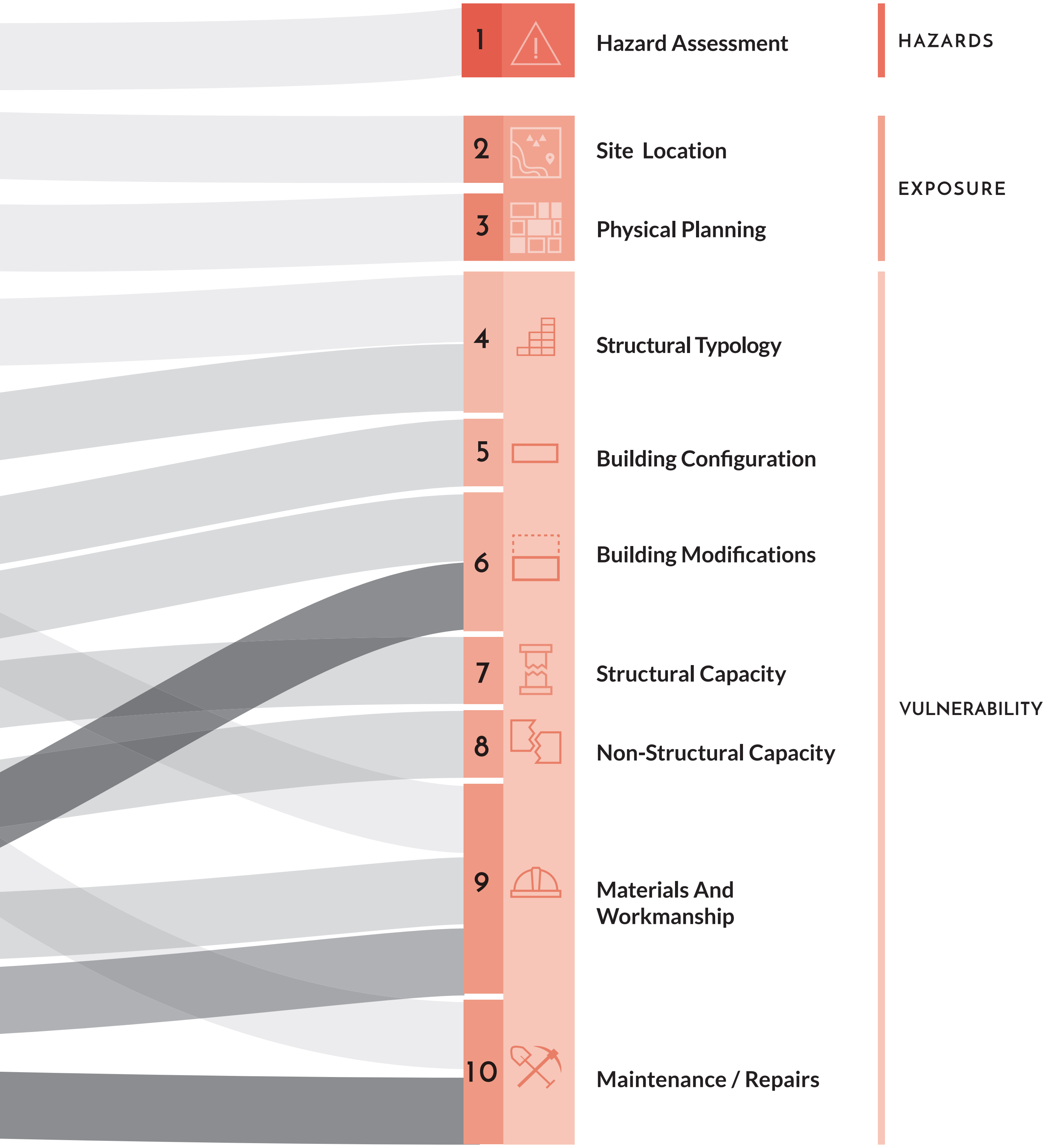


Figure 9. Safer School Characteristics to be addressed at different stages of the cycle.


1
Hazard Assessment
HAZARDS
2
Site Location
3
Physical Planning
EXPOSURE
4
Structural Typology
5
Building Configuration
6
Building Modifications
7
Structural Capacity
8
Non-Structural Capacity
9
Materials And Workmanship
10
Maintenance / Repairs
VULNERABILITY

PLANNING

This stage is critical yet often overlooked. The planning stage identifies the critical parameters which should be considered before deciding whether, where and how to construct a safer school. During the planning stage an understanding of the hazards at a macro scale and how those hazards play out locally at a site level will determine the physical planning and mitigation measures required to reduce the risk of exposure. (See Figure 11)

Figure 10a. SOUTH EASTERN UNIVERSITY, SRI LANKA. The proposed masterplan incorporated an evaluation of natural hazard risk including a geo-hazard and flood assessment.

Figure 10b. SCHOOL RECONSTRUCTION, PAKISTAN. Although the school building was designed to reduce vulerability to earthquakes the risk was still high due to the exposure of the site. Therefore major earthworks were required to protect the school from potential landslides.

CHARACTERISTIC (NUMBER)	PLANNING OBJECTIVE	PLANNING MEASURES
	• To establish a performance objective in consultation with key stakeholders that as a minimum ensures the risk to life is low, but also considers the implications of significant damage to the school facilities.	• Research and stakeholder engagement should be carried out to understand an acceptable level of damage and the role of the school during and after different types of disasters to inform the design requirements.
1	• To undertake a hazard assessment to identify the types of hazard that the school may experience.	• Every country or region is unique. Understanding the local context in terms of hazards, geography and climate is a key consideration in developing a safer and appropriate school. (See Figure 10a)
2, 3	• To carry out a site assessment to identify key features on the site that may impact exposure to specific hazards including topography, soil conditions, proximity to water bodies/fault lines, vegetation. • To plan the site and establish mitigation measures required to adequately alleviate the risks identified as a result of the hazard and site assessments.	• The focus of this stage is to reduce exposure in terms of where the school is located and the physical planning of the school site. The choice of sites is often limited and a site appraisal should be carried out to identify key risks and where mitigation measures may be necessary to reduce exposure to acceptable levels. (See Figure 10b)
4, 9, 10	• To consider appropriate construction methodologies for the design and construction of the school buildings that takes account of the most prevalent hazards. • To understand the quality of the materials and workmanship locally available. • To ensure there is adequate funding and local skills available to carry out regular maintenance and repairs of the school buildings and site infrastructure.	• Strategic assessments should be carried out to understand the local construction capacity and the potential of local markets to provide materials to inform the design process. • Up to date and enforced regulatory frameworks can be effective in enabling the delivery of a safer school. Sufficient resources must be dedicated to understand what the regulatory framework is within a country and whether enforced or whether there are gaps in the national standards or inconsistencies with international law and local and international best practice. If inadequate, an alternative reference must be identified as the basis to justify the design. (See Figure 14)

Figure 11. Planning Stage

DESIGN

During the design stage the emphasis is on ensuring that the building design reflects the hazard profile, performance objectives, and exposure identified during the planning stage. This typically requires specialist technical expertise in seismic areas. (Figure 13)

Figure 12a. SCHOOL RECONSTRUCTION IN PAKISTAN. Access to appropriate technical expertise ensured that inadequate seismic detailing was identified and amended during design review.

Figure 12b. SAFE SUSTAINABLE KINDERGARTEN SCHOOL MODEL, GHANA. A seismic hazard assessment for Ghana was undertaken to understand magnitude of seismic level the school needed to be designed for. Further analysis was undertaken to establish the most appropriate international code to be used for the seismic design analysis. The school was designed to meet Eurocode 8, the Earthquake design code.

CHARACTERISTIC (NUMBER)	DESIGN OBJECTIVE	DESIGN MEASURES
4	• To establish a performance objective in consultation with key stakeholders that as a minimum ensures the risk to life is low, but also considers the implications of significant damage to the school facilities.	• The choice of construction method is critical in determining the impact of the construction. • The choice of building system should reflect local construction capabilities and use local materials as far as possible in order to create livelihood opportunities, ownership and ensure skills exist for future repair and adaptation. • There may be opportunity to invest in improved construction practices, new materials or technologies. However, this needs it be balanced with cultural acceptability and the requirements for skilled labour to ensure quality construction and the ability to repair and undertake future adaptations. (see Figure 12).
5 6	• To design an appropriate building arrangement that is reasonably symmetric, allows safe egress, and avoids irregular features. • To consider in the design of the school buildings future building modifications.	• The design of the building form should be determined early in the design stage. Features that contribute to vulnerability; asymmetry, soft story, etc. should be avoided. • Consultations with the community to understand their future needs will enable provision to be made in the design of future modifications, such as openings, additional floors.
7 8 9	• To design the key elements of the building to ensure they have enough structural capacity to transfer vertical and lateral loads. • To consider the non-structural elements in the design of the buildings and ensure they are adequately fixed to the main structure. • To consider the material quality and labour resource in the design of the buildings and communicate requirements clearly in the design documentation.	• Technical expertise should be sought to develop the detail design and construction drawings as well as material specifications for the main building elements (both structural and non-structural). (See Figure 12a). • Relevant national/ international standards or best practice guidelines should be adhered to for the design of key elements and connections, alternatively they should be analysed from first principles to ensure structural capacity. • Resilient school (PO1/ PO2) should be designed to include in-built redundancy to ensure continuation of operation after an event as well as minimise damage. • The design of services and equipment, in terms of water, sanitation and power require expert input. Specialist equipment or trained personnel required to ensure the operation of school should identified and included in an operation and maintenance Plan (O&M). • There is a need to produce comprehensive drawings and specification appropriate for whoever is building the school.

Figure 13. Design Stage

CONSTRUCTION

In the construction phase every effort should be made to ensure that the school is built correctly using good quality materials so that the design intent is not compromised. Drawings and specifications, adequate financing and availability of skilled labour are as important as site supervision. Quality relies as much on effective contract administration as appointing a competent contractor or investing in training. (Figure 15)

Figure 14. MALAWI SCHOOL PROTOTYPE. A low-cost, high performing primary school design for the Malawi Education Ministry to be rolled out throughout the country. The construction methodology was chosen to improve local construction practices specifically for seismic performance using locally available materials.

CHARACTERISTIC (NUMBER)	CONSTRUCTION OBJECTIVE	CONSTRUCTION MEASURES
9	• To employ systems during construction that assures the quality of materials and workmanship.	• Care should be taken to ensure materials used are consistent with the design specifications/ assumptions. This requires verification of materials on delivery, appropriate storage and testing. • Workmanship depends on the availability of suitably skilled labour. Sufficient resources must be dedicated to ensure the recruitment of a competent contractor, skilled labour or provide training. • The construction phase provides an opportunity to invest in developing construction skills through training and also showcase safer building practices that can influence future construction projects (see Figure 14). • Labour turnover can impact on training requirements and can be reduced by ensuring labourers have appropriate equipment, welfare and working conditions. • Effective site management is critical to ensuring health and safety and quality assurance procedures are in place throughout the construction process. • Site supervision by an appropriate technical expert is a good way to check quality of materials and workmanship and to advise on corrective actions as soon as sub-standard works have been identified. This avoids having to carry out extensive repair or remedial works at a later date which can be costly and time consuming.

Figure 15. Construction Stage

OPERATION

Maintenance of the school buildings and infrastructure requires appropriate budgets and clarity in terms of who is responsible. (Figure 16)

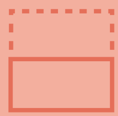
CHARACTERISTIC (NUMBER)	OPERATION OBJECTIVE	OPERATION MEASURES
6  9 	• To ensure clarity of responsibility and resources for maintenance. • To ensure significant building modifications have not been constructed unless allowed for specifically in the building design.	• At the end of construction there should be a formal handover to whoever is responsible for future operation and maintenance. It is important to facilitate the handover process by ensuring that the Operation and Maintenance manual requirements are understood, including what modifications have been designed for and therefore will not compromise the structural integrity and budgets and resources are available to carry out maintenance and repairs. • For the long term durability of the school it is also critical to ensure that maintenance is being done.

Figure 16. Operation Stage

IMPLEMENTATION METHODS

This chapter discusses the implications of different implementation methods and whether they are more likely to result in safer and potentially resilient schools.

How the building will be procured i.e. who is responsible for design and construction needs to be determined as soon as possible. It will depend on the maturity of the construction industry, the availability of local skills and capacity as well as the complexity of the school design.

CONTRACTOR BUILD

A contractor-build process places the responsibility for the quality of construction (and sometimes the design) with the contractor.

The safety of the school will be reliant on assurance that the design being undertaken by competent technical experts and verified; that it is either in accordance with international or local building codes or an alternative method of justification is used (e.g. prototypes, testing etc.). Good quality design documentation that clearly communicates what needs to be built will facilitate construction. This requires engineering plans, sections (1:20), construction details and connection details (1:10 or 1:5) as well as clear specifications. Provided the contractor is competent, employs suitably skilled sub-contractors, site staff and labourers with appropriate site management and supervision there is a strong likelihood the construction will comply with the design intent. Competent contractors are expected to have suitable quality assurance (QA) procedures in place, such as, material verification certificates and site supervision by a technical expert to monitor quality of materials and workmanship (see Figure 17).

The disadvantage of the contractor build method is that in some countries there is a risk of corruption especially in public procurement, and functional control mechanisms can be absent in ministries and levels of the government. Another disadvantage is that the community can feel excluded, particularly if the designs, labour and materials are imported. This creates a lack of ownership and may impact on the ability of the community/ end users to maintain the building, carry out repairs during operation of the school or if damage occurs, unless mechanisms are put in place to involve communities in the early planning stage and construction stage.

Figure 17. SADAR - E - KABULI GIRLS SCHOOL, KABUL AFGHAISTAN. To enable quality construction of a school of this scale detailed construction drawings we produced to communicate clearly the design intent, in particular the complexity of seismic detailing. The design was passed on to a competent contractor who was responsible for building the schools.

COMMUNITY BUILD

Community build refers to “self” build or use of community labour in construction projects. The advantage of community build is it provides an opportunity for people to develop skills and construction practices which provide livelihood opportunities. It is also an effective means to generate ownership of the building within a community which encourages maintenance.

Communities typically have a good local knowledge of the hazards that exist within their community which can be enhanced by public databases and hazard maps. They also have a good local understanding of risk and so can easily define the performance requirements of the school and choose suitable sites. Moreover they have a vested interest in ensuring that the level of risk is acceptable.

Site selection guidelines and site assessment tools can help facilitate these early decisions regarding location and physical planning of the school. Locally, craftsmen may be highly skilled in specific building practices. However within a community it is unlikely that the skills exist to verify designs of a safer school. For vernacular methodologies it is unlikely guidelines or codes exist. Therefore if the intention is to use community labour to build schools then it is essential that appropriate measures are taken so that the design of the school is sound (Figure 18).

Ensuring that construction information is conveyed clearly is key. This could be in the form of a construction manual which uses 3d imagery, pictures to illustrate the construction information. Drawings/models will need to be read and understood by a non-technical, often unskilled and /or illiterate work force. As well as step by step guidance on how to build safer schools detailed information on material quantities and quality should be given; such as, concrete mix ratios, the risks associated with using sea sand in concrete, how to mix concrete, make soil blocks and undertake simply verification tests such as slump tests for concrete (Figure 19). Quality of construction and materials on self-build sites can only really be verified if there is site supervision.

Figure 20 summarises where the responsibility lies for both the contractor and community build processes at each stage of the delivery process and highlights the level risk associated with each where lightest pink is low risk, pink moderate risk and red is high risk.

Figure 18. SELF HELP SCHOOL CONSTRUCTION PROGRAM, PAKISTAN. Guidance was issued on seismic construction detailing and site selection procedures.

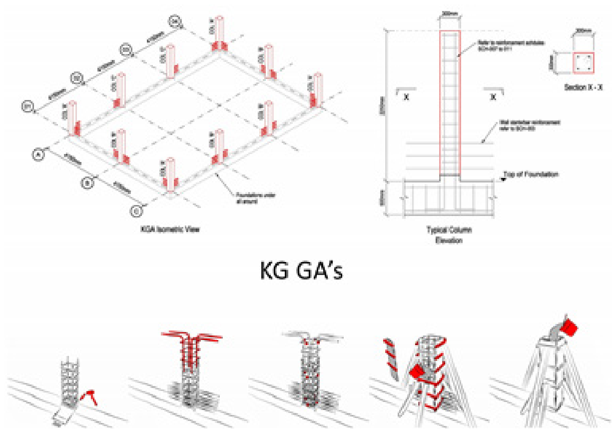


Figure 19. SAFE SUSTAINABLE KINDERGARTEN MODEL SCHOOL, GHANA. The drawings were updated to produce a “construction manual” which consisted of a number of chapters and building drawings which illustrated how to build the school using 3D graphics, photos and step by step construction sequences.

DELIVERY STAGE	CONTRACTOR BUILD	COMMUNITY BUILD
PLANNING	The contractor will have no vested interest in ensuring level of risk is acceptable and often they won't have knowledge of local risks. Contractors are more likely to choose alien construction methods and materials.	Typically communities have a lack of awareness of macro-hazards, but a good knowledge of local hazards and the performance requirements of the school. Communities will have an inability or lack of resources to provide appropriate civil engineering works to mitigate risk on site.
RESPONSIBILITY FOR QUALITY OF DESIGN	The designs to be built by a contractor are typically undertaken by one of the following; • Technical experts (Engineers and Architects) that are passed to the contractor) • The Contractor • Use Standard government design • Good quality construction drawings and specifications will need to be produced which document the engineering design and are either code compliant or verified that the design is safe for the hazards that exist.	Designs will need to be undertaken by a third party (technical experts) e.g. model schools. Even if vernacular/ local practice construction methods are used these will need to be reviewed by technical experts.
RESPONSIBILITY FOR QUALITY OF CONSTRUCTION	A quality construction built by a contractor relies on; • a competent contractor with suitably skilled site staff, management, supervision, labourers, sub-contractors • QA procedures in place e.g. material certifications • a contract in place between the client and contractor that can be used to ensure the contractor delivers on time, on budget and to quality • a Contract Manager who administers the contract between the client and contractor. • Communities can be trained to monitor the construction process which creates ownership	Communities can build quality schools if there is a provision of skilled labour, oversight during the construction process, training and construction drawings are communicated in a different form to that of a contractor build process. Construction manuals with simple illustrative construction sequences should be produced.
MAINTENANCE	Contractors have little vested interest on how the building operates. If the community haven't been involved in the planning stage it will create a lack of ownership and the community will be unlikely to maintain or repair the school. It could also lead to the community adapting the building which could impact its structural integrity e.g. unsafe extensions	If the community have been part of the decision making process during the delivery stages they will have a good knowledge of how to maintain the building during its operation.

Figure 20. Summarises where the responsibility lies during the contractor and community build processes

CONCLUSIONS

In this report we have attempted to define the characteristics of a safer school and show how these might be used to inform the assessment, design and delivery of schools in the future. In doing so, we have tried to make the physical (or 'structural') issues associated with safer schools understandable for a non-technical audience. Those who come from a technical background may feel that we have over-simplified the issues but until there is wider awareness of the physical factors (hard), efforts to promote Safer Schools are likely to focus on non-physical (soft) measures.

We have highlighted the measures that need to be undertaken to deliver a safer school; acquire knowledge of hazards at a macro and micro level, understand the issues associated with the site and the issues associated with the design of the school. We have focussed on creating safer schools as part of Disaster Risk Reduction; however all of these measures provide opportunities to interface with non-structural DRR measures. Furthermore many of the issues identified are relevant to improving access to education and the quality of teaching environments, or sit within the context of wider efforts to improve construction standards and practices which may provide entry points for action.

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APPENDIX A: ASSESSMENT OF EXISTING SCHOOLS

ASSESSMENT PROCESS

An overview of each stage of the assessment process is provided below. The characteristics are referred to in square brackets e.g. physical planning [4].

Step 1: Performance Assessment
The performance objectives and acceptable level of risk may vary according to the type of hazard. Furthermore a school is often made up of a number of assets which have different uses therefore different performance objectives may apply.

Step 2: Hazard Assessment [1]
Typically good information exists in relation to macro-level hazards, for instance whether an area experiences seasonal cyclones or high, medium or low levels of seismicity. This information exists at a country or provincial level and is usually based on a combination of historical, geological and geotechnical data. The results of such studies can be obtained through global public databases such as GEM (Global Earthquake Model), GSHAP (Global Seismic Hazard Assessment Program), NATHAN or local universities and meteorological centres.

Climate change creates uncertainty in accurately predicting the magnitude of weather-related hazards in the future events, but is only one of many aspects that are altering hazard profiles. Others include environmental degradation and rapid urbanization. For an initial assessment it is sufficient to identify trends associated with changes to rainfall, temperature or extreme events based on local consultation cross-referenced to published climate-change scenarios if available.

Often sites are subjected to more than one hazard so it is useful to compile the multi-hazard data in a standardised format in order to compare the different hazard characteristics, such as, their magnitude, likelihood of occurrence, duration, distribution and warning. This can be done by creating a Hazard Matrix, or by plotting this information on a map using GIS (Geographical Information Systems).

Step 3: Exposure Assessment
Depending on the hazards identified in Step 2, only some of the 20+ indicators that have been identified as good practice from a review of safer school guidance will apply. For instance proximity to fault lines is only relevant to earthquakes, while elevated sites are advisable in areas subject to tsunami, storm surge or in flood plains.

If the relevant indicators for site assessment [2] have not been fully met, an assessment will need to be undertaken to determine whether the appropriate mitigation measures [3] in terms of civil engineering works have been taken. For example, if the site is exposed to landslides and the school has been built at the base of a slope then the assessment must establish whether the slope has been stabilised or a retention wall constructed to counter slope movement.

If the physical planning [3] indicators relating to mitigation measures and building arrangement have not been met the site will need to be assessed by an appropriate technical expert to see whether further mitigation measures are feasible.

Schools with inherently high levels of exposure to hazards due to their location need to be relocated unless the risk has been sufficiently reduced as a result of further civil engineering works or the building arrangement. For instance, constructing site-wide drainage or removing unsafe structures.

Step 4: Vulnerability Assessment
A number of characteristics need to be assessed to determine the vulnerability of buildings. Typically this requires technical expertise but preliminary assessments can be made using qualitative indicators. A traffic light system (red – amber –yellow- green) is used to indicate whether a building is unsafe, requires a more detailed review by a technical expert or is acceptable.

Chose the appropriate indicator that corresponds to the construction methodology [4] (construction typology) to assess its suitability for the hazard that exists.

Review the building configuration [5] indicators to check whether the building form and arrangement is appropriate.

Check whether modifications to the building [6] that were not originally part of the design may have made the school more vulnerable can.

Assess the structural capacity [7] of each of the key building elements; foundations, lateral and vertical load systems, floor and roof needs to be undertaken to ensure they have capacity to withstand the relevant hazard. This can be based on empirical evidence, available drawing, calculations and observation, though testing may be needed.

Assess the condition and durability of the individual building elements for obvious signs of deterioration or poor quality of materials and workmanship [9].

Assess the non-structural systems [8]. These include the checking the building envelope, internal walls, services and plant and other internal/ external building components that can have an impact on the building performance in the event of a natural disaster.

Buildings over two storeys need to be assessed by an appropriate technical expert as they are likely to be more vulnerable particularly in areas of high wind and seismic activity.

Schools that are vulnerable due to poor design, materials or workmanship may be able to be repaired or retro-fitted. Likewise if schools are in poor condition due to lack of maintenance or because there is minor damage then they should be able to be repaired.

The age of the building should always be considered in relation to its design life. Older buildings will be more vulnerable and may have sustained damage through previous hazards that may have weakened the structure. However evidence of having survived or experienced minimal damage in previous events is a positive indication of a building's performance. This frequently applies to vernacular construction which has evolved empirically based on events.

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