Disaster Risk Reduction Architecture

KEY PRACTICES

for DRR Implementers

Humanitarian Aid
and Civil Protection

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Disaster Risk Reduction Architecture: Key Practices for DRR Implementers

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This brief is part of the series, *A Field Guide for Disaster Risk Reduction in Southern Africa: Key Practices for DRR Implementers*, coordinated by the FAO Subregional Office for Disaster Risk Reduction/Management for Southern Africa. This series has been produced with contributions from COOPI, FAO, OCHA and UN-Habitat, and comprises the following technical briefs:

- Information and Knowledge Management (COOPI)
- Mobile Health Technology (COOPI)
- Safe Hospitals (COOPI)
- Disaster Risk Reduction for Food and Nutrition Security (FAO)
- Appropriate Seed Varieties for Small-scale Farmers (FAO)
- Appropriate Seed and Grain Storage Systems for Small-scale Farmers (FAO)
- Farmer Field Schools (FAO)
- Irrigation Techniques for Small-scale Farmers (FAO)
- Management of Crop Diversity (FAO)
- Community-based Early Warning Systems (OCHA and FAO)
- Disaster Risk Reduction Architecture (UN-Habitat)

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Humanitarian Aid and Civil Protection

The European Commission’s Humanitarian Aid department funds relief operations for victims of natural disasters and conflicts outside the European Union. Aid is channelled impartially, straight to people in need, regardless of their race, ethnic group, religion, gender, age, nationality or political affiliation.

Foreword by ECHO

The southern Africa and Indian Ocean region is extremely vulnerable to cyclones, floods, droughts and tropical storms. These recurrent climate-related shocks negatively affect the highly sensitive livelihoods and economies in the region, and erode communities' ability to fully recover, leading to increased fragility and vulnerability to subsequent disasters. The nature and pattern of weather-related disasters is shifting, becoming unpredictable, and increasing in frequency, intensity and magnitude as a result of climate change. Vulnerability in the region is further compounded by prevailing negative socio-economic factors, such as high HIV rates, extreme poverty, growing insecurity and demographic growth and trends (including intra-regional migration and increasing urbanization).

The European Commission's Office for Humanitarian Affairs (ECHO) has actively engaged in the region through the Disaster Preparedness ECHO (DIPECHO) programme since 2009, supporting multi-sectorial disaster risk reduction interventions in food security and agriculture, infrastructure and adapted architecture, information and knowledge management, water, sanitation and hygiene, and health. This programme operates with two objectives, notably:

- Emergency preparedness by building local capacities for sustainable weather-hazard preparedness and management, including seasonal preparedness plans, training, emergency stocks and rescue equipment, as well as Early Warning Systems.
- Empowering communities through multi-sectorial and multi-level approaches with DRR mainstreamed as a central component and improved food and nutrition security as an outcome.

This is done in alignment with national and regional strategies and frameworks.

For DIPECHO, one of the main measures of success is replicability. To this end, technical support through guidelines established for DRR implementers is a welcome output of the DIPECHO interventions in the region. ECHO has supported regional partners, namely COOPI, FAO, UN-Habitat and UN-OCHA, to enhance the resilience of vulnerable populations in southern Africa by providing the funding to field-test and establish good practices, and to develop a toolkit for their replication in southern Africa. It is the aim of the European Commission Office for Humanitarian Affairs and its partners to fulfil the two objectives sustainably and efficiently through the practices contained in this toolkit to ensure the increased resilience of the most vulnerable populations in the region.

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Foreword by UN-Habitat

In the last decade, the United Nations Human Settlements Programme (UN-Habitat) has developed innovative approaches for disaster resilience in human settlements and the built environment of southern Africa, and witnessed an impressive number of risk reduction practices. The cornerstone of the adaptive approach to human settlements is to demonstrate through practical implementation that this approach to disaster-prone human settlements can go a long way in reducing risks.

It is timely that these practices are taken stock of, acknowledged and reproduced at a larger scale, included in policies and become common practice, so that communities in countries exposed to recurrent cyclones, floods, earthquakes and droughts learn how to live with the hazards, and become more resilient. It is also important, however, that emerging needs such as Urban Risk Reduction and Resilience are recognized and tools progressively developed in this fast urbanizing subregion. In fact, the most recent studies, and our own experience as an urban agency both conclude that the urban challenge will likely become a main concern for the region. Cities and towns are not yet equipped to mitigate and adapt to the impacts of climate change and increased natural hazards, while they are becoming more and more vulnerable due to their fast growth, mostly unplanned, and the concentration of people.

This publication documents some of the practices which follow UN-Habitat's strategic policy on Human Settlements in Crisis, which promotes a sustainable approach to relief and reconstruction. It also contributes to the City Resilience Profiling Programme through the guidance it provides to practitioners, decision-makers and field workers in the field of disaster risk reduction.

This resource tool is the summary of a larger study documenting adaptive architecture, *Taking Stock of Disaster Risk Reduction Architecture in Southern Africa: lessons learned from 10 years of adaptive architecture for practitioners, decision-makers and field workers in disaster-prone countries of southern Africa and south-west Indian Ocean*. It offers practical examples of adaptive construction practices for several hazards, as well as specific lessons learned for both practitioners and decision-makers willing to understand what works and what does not, and what is worth reproducing. The study and its technical annexes are available at www.seadrr.org or on request from UN-Habitat Mozambique,Malawi and Madagascar.

Jan Meeuwissen
UN-Habitat
Risk Reduction and Recovery Branch Coordinator

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Acronyms and Abbreviations

CBO	community-based organization
DIPECHO	Disaster Preparedness ECHO
DFID	Department for International Development (United Kingdom)
DoDMA	Department of Disaster Management Affairs
DRR	disaster risk reduction
ECHO	European Commission Humanitarian Aid and Civil Protection Office
GEF/UNEP	Global Environment Facility/United Nations Environment Programme
INGC	Instituto Nacional de Gestão de Calamidades
km	kilometre
m	metre
MICOA-DINAPOT	Ministério para a Coordenação da Acção Ambiental (Mozambique)
MLHUD	Ministry of Land, Housing and Urban Development
MOPH	Ministério das Obras Públicas e Habitação
NGO	non-governmental organization
TEVETA	Technical, Entrepreneurial, Vocational, Education and Training Authority
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organisation
US$	United States Dollar

1. Adaptive Architecture for Disaster Risk Reduction in Southern Africa

The southern African and South-West Indian Ocean region is at risk

The southern African region is highly exposed to natural hazards, i.e. cyclones, floods, droughts and earthquakes. For instance, countries such as Mozambique (nine international rivers; 2 700 km of coast; the Great Rift Valley; semi-arid areas); Madagascar (island in the cyclone-prolific south-western Indian Ocean; semi-arid areas); and Malawi (large river basins on the edge of the Rift Valley; semi-arid areas) share an extreme natural hazard profile.

Cyclones and floods, in particular, have recurrent, immensely destructive effects on the built environment: each year, hundreds

Figure 1 (left): Damaged food items following the 2013 floods in Chokwe, Mozambique.

Figure 2 (right): Floods after Cyclone Hubert in Manakara, Madagascar.

of houses, school buildings and basic community infrastructures are destroyed, with lives lost and enormous impacts on the economy. These events result in lives being lost, often due to a lack of shelter during the peak of the events, as well as loss of assets, including dwelling units, bridges, roads, railways, the uprooting of transmission towers and, importantly, key basic infrastructure, such as schools. The effort to reconstruct and recover from the loss of property and assets is so demanding that sustainable development is at stake each year. Furthermore, it is now a fact that meteorological events are becoming more severe as a result of the changing climate, especially in coastal cities of Mozambique, Madagascar and Namibia (rise in sea-level; stronger cyclones and winds; and food insecurity as a consequence of lower supply from rural areas).

Fortunately, there is a growing consensus on the need to conceptualize, design and build human settlements in a way that takes into account the risk profile of the countries. There are hundreds of examples of adaptive architecture in southern Africa, using both local and conventional materials and techniques.

This brief showcases a number of adaptive architecture cases that are replicable and can be transformed into normal community and national practices. The objective is to offer an overview of the wealth of experiences so as to take stock and transform experience into capitalized practices, normal disaster-resistant constructive behaviour and, ultimately, enforceable policies.

Figure 3: Damaged school following Cyclone Funso in Pebane, Mozambique.

2. Capitalizing on DRR Architecture Practices

From pilots to policies…

The richness of examples in the field has not yet been compiled and analysed in all its potential at country or regional level. Sometimes, examples are replicated spontaneously by the communities and by the local authorities; however, more often than not, they remain isolated cases, with limited room for large-scale replication. There is a need to take stock of these experiences to mainstream the approach to the built environment in all communities, and rural, peri-urban and rural settlements. All cost-benefit analyses (a list of complete references and background is offered in the bibliography) agree that with an increase of 5 to 10 percent in the construction of buildings, communities and conventional builders – including the state – can save up to 30 to 40 percent of funds otherwise used for emergency and reconstruction – not to mention avoiding the setbacks experienced by communities which recurrently lose their schools, houses and assets. In line with the priorities of the Hyogo Framework for Action and the Making Cities Resilient Campaign, there is room to 'learn how to live with the hazards' in the built environment, to adopt adaptive policies as a

Figure 4 (left): Flood-resistant elevated school in Maniquenique

Figure 5 (right): On-the-job training with local builders in Manica for earthquake-resistant houses normal practice in communities, to develop and approve disaster-resilient norms and building codes, and to develop the capacity to enforce them as a priority.

In other terms, the examples developed in southern Africa by communities, national governments, the local authorities, non-governmental organizations (NGOs) and international technical cooperation agencies should be recognized and, when relevant, capitalized into practices and policies. To do this, increasingly aware national and local institutions demand that sound, evidence-based good practices in the area of disaster-resistant basic housing, shelter and community infrastructure construction and reconstruction are analysed and lessons learned. In effect, there are hundreds of practices in the subregion, both in local and conventional material, including community shelters, housing, schools, crèches and health clinics.

Figure 6: Elevated latrines in community shelter in Madagascar

…through evidence!

This brief is an abstract of the comprehensive stocktaking document *Taking Stock of Disaster Risk Reduction Architecture in Southern Africa: Lessons learned from 10 years of adaptive architecture for practitioners, decision-makers and field-workers in disaster-prone countries of Southern Africa and South-West Indian Ocean*, produced by UN-Habitat through Disaster Preparedness ECHO (DIPECHO) III in 2013 in three countries in southern Africa (Madagascar, Malawi and Mozambique) in an attempt to address the lack of evidence. The three countries have been chosen as a sample because – although disaster impacts vary among them – they offer a complete array of natural hazards: recurrent cyclones and floods, and even earthquakes, which are highly destructive (although not frequently of high intensity). In addition, these countries experience frequent drought; although this hazard does not have an impact on infrastructure, its impacts can be mitigated to an extent with simple, inexpensive water harvesting measures taken by households and in schools or public posts.

This brief is conceived as an introduction for institutions, practitioners and donors, to analyse what has been done up to now and what is the potential and benefit of scaling up adaptive architecture measures into practices, policies and programmes.

3. How Adaptive Architecture Can Reduce Risks

Why adaptive architecture?

To a large extent, the risks of disasters and their impact on the built environment can be mitigated through a disaster-sensitive approach to construction, planning of settlements, maintenance and reconstruction (the Building Back Better approach). This is known as DRR Architecture and Planning, the Disaster-Resistant Approach to the Built Environment or, simply Adaptive Architecture.

Figure 7: Cyclone-resistant community shelter built by CARE in Fenerive, Madagascar.

What's new, it may be asked? Communities in southern Africa and the south-west Indian Ocean have traditionally adapted to the environment. In Madagascar, for instance, in several areas of the country there are traditional builders with a profound knowledge of the hazards and how to adapt to them. Nonetheless, the recurring nature and strength of the hazards, coupled with unplanned growth in settlements, exceeds communities' capacities to construct appropriately. This also concerns the more formal built environment that, in the haste of building rapidly and cheaply, often disregards the very concepts of adaptation to the environment.

There is the need to reintroduce basic concepts of adaptation on the one hand, and to disseminate economically viable solutions on the other. In the last decade, southern Africa was a laboratory of examples of resistant housing, shelter and basic infrastructure both in local and conventional materials. Some of these cases are showcased here, and a more complete assessment is available in the bibliography. In effect, also through DIPECHO I to III, national and local authorities, communities, NGOs and the United Nations have constructed a number of architectural solutions for disaster risk reduction in the subregion during the past decade. The purpose of this action, overall, was to demonstrate that adaptive architectural solutions contribute to:

- Directly protecting lives through the provision of safer houses, for example, in the case of non-engineered dwellings;
- Directly protecting lives during and in the aftermath of an emergency, through transforming basic infrastructure (schools, kindergartens) into safe havens;
- Directly saving economic and physical assets from the effects of disasters;
- Indirectly saving economic assets through Building Back Better after disasters, so as to mitigate the risk of occurrence in the future; and
- Indirectly sustaining the effort of sustainable development, by avoiding disruption of social, economic, cultural and educational activities of societies.

Figure 8: Local builders applied disaster-resistant construction techniques in Angoche.

Learning to live with hazards

The concept of adaptive architecture is part of "learning how to live with hazards", which includes: 1) understanding risks and vulnerabilities; 2) planning settlements in a participatory and resilient manner; 3) adopting resilient basic service provision in terms of drainage, solid waste management and water management; 4) building safely; 5) rebuilding improved structures after disasters; and 6) learning preparedness and preventive measures in schools, community exchanges and families.

In general, poverty inhibits the use of better materials or skills. Spontaneous constructions, regardless of regulations, with little support from more skilled technicians and authorities, also contribute to vulnerability. Notwithstanding this, it is a common misconception that local non-engineered constructions are necessarily more vulnerable than those constructed with conventional materials. Evidence suggests that formal constructions, including public constructions (such as formal schools), may also be vulnerable to hazards. Non-resistant constructions are often the tangible result of a series of factors. These include lack of land ownership or tenancy rights; poor physical planning that disregards natural hazards; insufficient or unenforced building regulations; weak technical know-how in construction or not valorizing local traditional knowledge; and lack of preparedness, among other factors.

Applied local solutions

Architecture is adaptive when it is able to adjust its structure, behaviour and resources to local climatic and geologic conditions; i.e. a robust structure is able to sustain the impact of severe natural hazards or contribute to easing the life of communities, is adjusted to the local context, and is therefore sustainable. The combination of robustness and sustainability results in increased community resilience, and is defined in this sector as the capability of a system: 1) to maintain acceptable levels of functionality during and after disruptive events; 2) to recover full functionality within a specified period of time after the event; and 3) to provide communities with additional tools to face adverse climates. In simpler terms, adaptive architecture must learn from the local context, i.e. from traditional construction or commonly used public building specifications to provide affordable and appropriate solutions. Within this approach, there are a number of areas for action:

- Increasing awareness through simple, user-friendly materials.
- Creating understanding to foster an appreciation of safe versus unsafe buildings in the context of the disaster related to additional forces, loads and effects.
- Facilitating application by creating an enabling environment for application of the appropriate norms to ensure structural safety. In effect, even when communities are aware, they often lack training and capacities within the community, which needs to be addressed through on-the-job training.

Figure 9: Simple technique using local material to improve resistance to cyclones.

Given the breadth of experiences in southern Africa, stock can be taken of promising practices studied to influence constructive behaviour. The challenge, given the immense diversity and richness of cultures in the subregion, is to find a common ground for extracting lessons. Understanding the potential or proven impact of a given solution is a good filter for lessons, i.e. How many people are safer thanks to the intervention in the long run?

Figure 10: The River Game is an advocacy and awareness tool developed by UN-Habitat and partners which is used in communities to demonstrate the various threats and hazards related to river flooding.

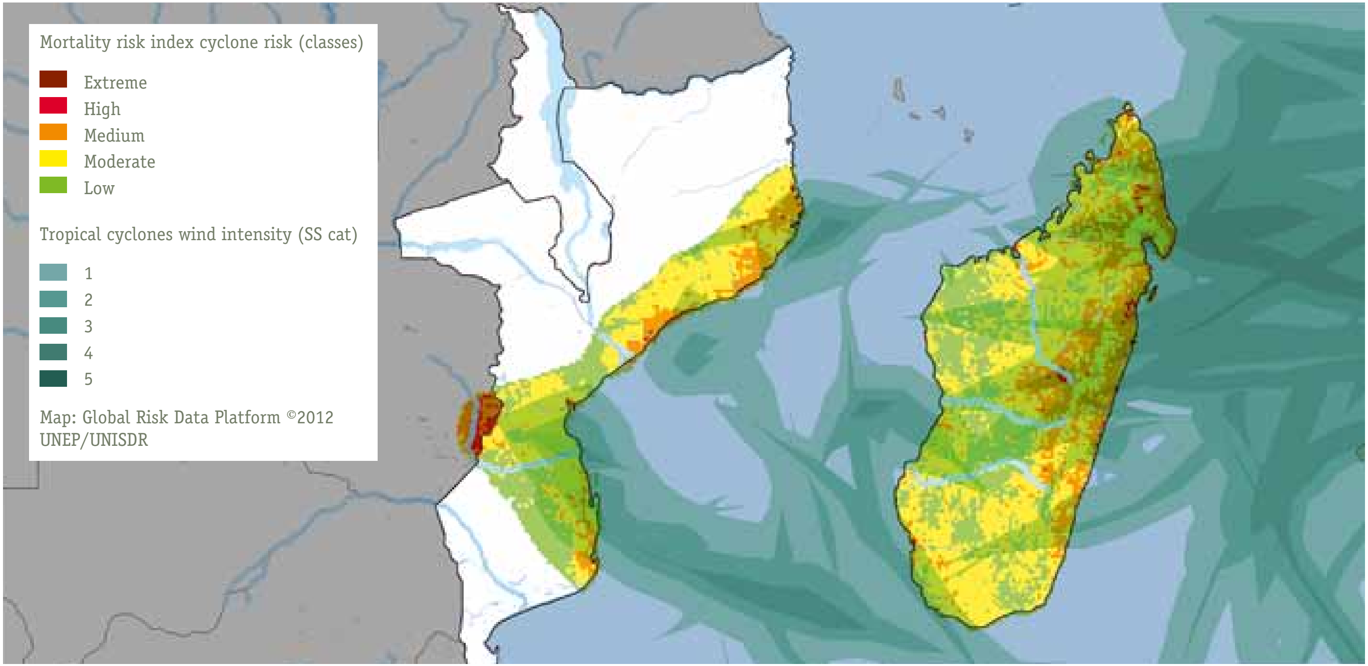
How much can be saved? Also, understanding the degree of replicability is a key parameter: interventions are best practices when their potential is exploited through replication.

In the next section, a selection of solutions resistant to cyclones, floods and earthquakes are described. They include both local and conventional materials and technologies, and involve a range of local and formal builders, communities, local institutions, national institutions, NGOs, UN agencies and other entities. Samples have been studied through: 1) data collection forms; 2) focus groups between UN-Habitat, local NGOs, national and local institutions in the different countries (Mozambique, Malawi, Madagascar) on activities since 2002; 3) data review and field visits; and 4) interviews with key team members and relevant government counterparts, in particular IINGC/MOPH/MICOA (Instituto Nacional de Gestão de Calamidades[1]/ Ministério das Obras Públicas e Habitação[2]/Ministério para a Coordenação da Acção Ambiental,[3] (Mozambique), DODMA MLHUD (Department of Disaster Management Affairs/Ministry of Land, Housing and Urban Development, Malawi), partners (NGOs) and community beneficiaries.

1 The National Institute for Disaster Management
2 The Ministry of Public Works and Housing
3 Ministry of Environmental Affairs

Cyclone and strong-wind-resistant examples

The coastline of south-east Africa is affected by cyclones and tropical storms coming from the Indian Ocean – one of the most prolific cyclonic areas in the world. Madagascar is the most vulnerable country in the subregion, with winds up to 350 kms per hour, followed by Mozambique. The cyclone season normally occurs from November to April, peaking in January and/or February.



Typically, 12 cyclones occur annually in the south-western Indian Ocean, involving heavy rainfall and storm surges that cause the ocean level to rise by as much as 10 m. Over the past 20 years, 7.1 million people are believed to have been affected and losses of US$1.6 billion were experienced in both countries as a result of cyclones. Cyclones have devastating impacts on housing and public facilities, especially affecting roofing structures, and also have damaging effects on infrastructure. Storms and strong winds below cyclone strength also cause significant damage. To resist cyclones, a number of architectural solutions have been devised and implemented in Madagascar and Mozambique, using both local and conventional materials. This concerns housing and safe havens.

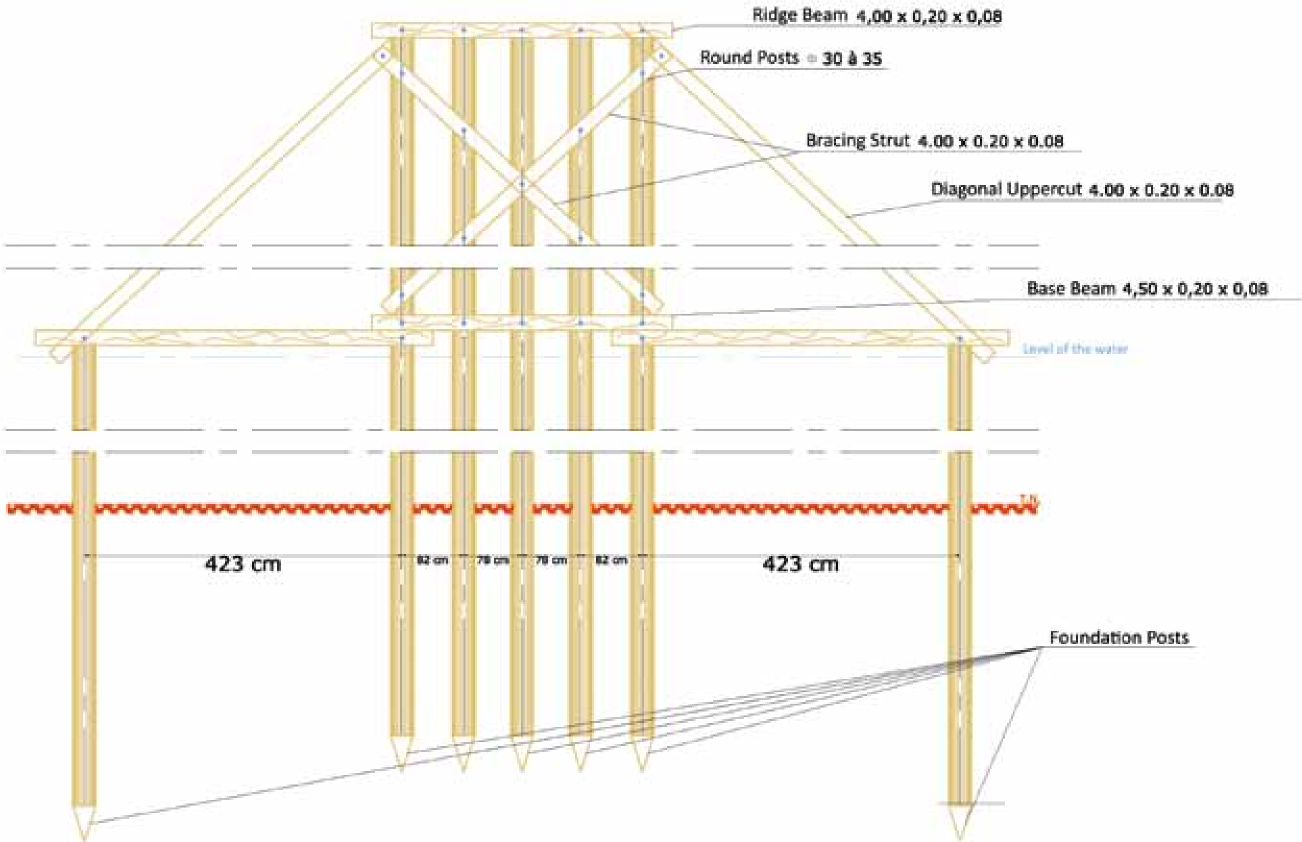
Figure 11: Poor construction or limited consideration of the risk exposure can lead to significant structural damage, as seen here in Mozambique.

Case 1: Individual house – Maroantsetra, Analanjirofo, Madagascar

- Within the framework of the TSARAKOBABY project, Medair, in partnership with local authorities, implemented low-cost anti-cyclonic individual houses with local materials. The project involved seven vulnerable communities in the Maroantsetra District.
- Implementing agency: Medair
- Donor: DIPECHO

Why is this architecture adaptive? The house integrates in its design and implementation many simple architectural solutions which do not necessarily imply additional costs. The walls are made of stems of ravenala assembled using bamboo to facilitate replication by villagers. The structure must be tight and secure to prevent wind penetration at the interstices. The anchoring of the structure's columns in the soil allows the stabilization of the house while protecting the wood from termite attacks. The house is raised on braced poles. The adding of diagonals allows for unloading the horizontal wind load on the ground, and the house is more cohesive.

Why is it replicable? The cost of local-material design interventions is limited, which makes replicability possible. Importantly, this house was constructed using improved local know-how, which makes techniques easier to master and integrate. Authorities could use these examples and showcase them to other communities through on-the-job training and mainstreaming of capacities, from local peer builders to others.



Ridge Beam 4,00 x 0,20 x 0,08
Round Posts ⌀ 30 à 35
Bracing Strut 4.00 x 0.20 x 0.08
Diagonal Uppercut 4.00 x 0.20 x 0.08
Base Beam 4,50 x 0,20 x 0,08
Level of the water
423 cm
82 cm
78 cm
78 cm
82 cm
423 cm
Foundation Posts

Case 2: Kindergarten – Vilankulos, Inhambane Province, Mozambique

- The kindergarten can be used as shelter in case of a cyclone. The school has a 200 m^2 plan, divided into a multipurpose room, cafeteria, office, kitchen and female/male toilets. The project came about as a result of the impact of the prototype testing workshop that UN-Habitat implemented with the Municipality of Vilankulos: one year later the municipality decided to spontaneously replicate a cyclone-resistant intervention, funded by an international organization, and asked UN-Habitat for technical assistance.
- When: 2010–2011 (six months)
- Donors: Associaçao Moçambique Alemanha
- Partners: Vilanculos Municipal Council and UN-Habitat

Why is this architecture adaptive? The applied principle is that a building's reaction to cyclone winds is related to its shape and its weight or its technological characteristics. In particular, the cyclone-resistant buildings featured have roofs using prefabricated wire mesh concrete vaults whose shape, slope and weight ensure excellent resistance to cyclones. In the kindergarten's case, the prefabricated vaults that compose the roof structures are of large dimensions, each covering three bays for a total length of 9 m. The section is not a true semicircle, but rather a flattened arch. The vault formwork technology was developed by the Institute of Cooperation and the United Nations Educational, Scientific and Cultural Organization Chair for Basic Habitability and the Technical University of Madrid, and adapted by UN-Habitat in Mozambique.

Why is it replicable? According to the results of the prototype construction testing, the ferrocement prefabricated technique proved appropriate but required skilled construction companies, rather than local builders. Nonetheless, private citizens in Vilankulos, using the same techniques, are currently building a number of private houses. This proves that good tangible examples can go a long way in influencing constructive behaviour.

Figure 12 (opposite): Cyclone-resistant kindergarten in Vilankulos, Mozambique.

Case 3: Shelter house – Maroantsetra, Analanjirofo, Madagascar

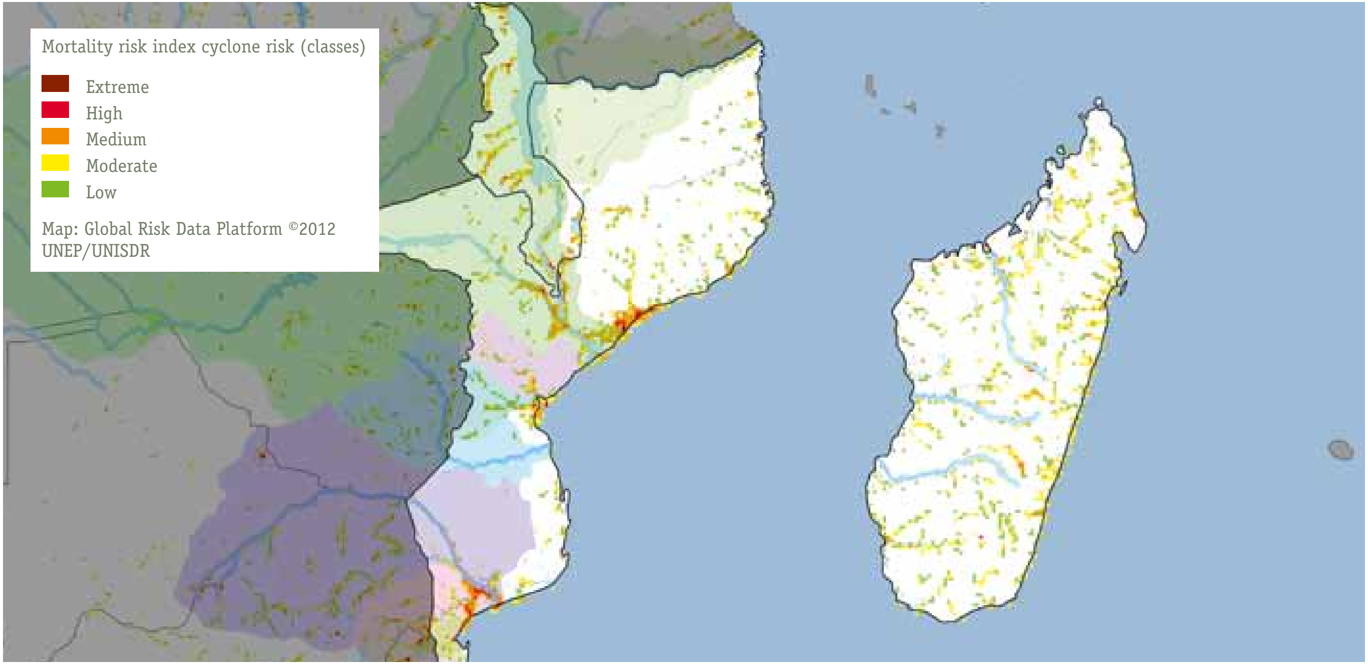
- This 'shelter house' was built by Medair, through DIPECHO, to serve as a safe haven during emergency periods. During the non-cyclonic season, the house can be rented to finance its maintenance or, if possible, to support the local community.
- Where: Maroantsetra Municipality, Maroantsetra District, Analanjirofo Region
- Partners: Medair, local authorities and communities
- Donors: DIPECHO

Why is this architecture adaptive? The rectangular shape offers an even resistance to the wind loads experienced in a cyclone-prone area, thus proving that mitigation through adaptive architecture aims first at building more resistant structures without the use of additional resources. Also, foundations, which have been well treated against termites, elevate the safe haven to prevent floods associated with the strong winds and rains of a cyclone. The wall structure is a wooden frame filled with wood, and the roof structure is made of sheet-metal. It should be mentioned that often the use of mixed materials, in addition to infrastructural considerations, provides a good balance between the use of local material and a more conventional appearance. This may help institutions in adopting models and promoting their replication.

Why is it replicable? Safe havens such as this promote double-purpose construction. Within an adequate territorial strategy (i.e. building safe havens in strategic areas) they may have a large catchment population. Their replicability, however, also depends on the capacity to generate income (or at least funds for maintenance), the relevance to the community's daily life.

Flood-resistant examples

Abnormally high rainfall (e.g. due to tropical cyclones) is the primary cause of flooding in southern Africa. It occurs along the ten international river basins and 7 300 km of coastlines of the subregion, affecting more than 7.5 million people in the last 20 years. Many human-induced contributory causes interact to increase communities' vulnerability to floods, including land degradation;



deforestation of catchment areas; increased population density along riverbanks; poor land-use planning, zoning and control of flood plain development; inadequate drainage, particularly in cities; and inadequate management of discharge from river reservoirs.

A number of flood-resistant schools, safe havens, platforms and houses have been piloted in the subregion. These involve both local and conventional materials. Adaptive architecture can extensively mitigate the impact of floods through the adaptation of flood-prone settlements.

Case 1: Elevated school – Maniquenique village, Chibuto District, Gaza Province, Mozambique

- UN-Habitat, in partnership with national institutions, facilitated participatory planning sessions with identified communities, with the construction of a new school as the priority. Maniquenique (6 km from Chibuto, where the district administration is located) is a village located in a flood-prone area, and was totally flooded in 2000 by water averaging 1 m deep.
- Partners: Government of Mozambique, MICOA-DINAPOT, UN-Habitat, community-based organizations (CBOs)
- Donors: Global Environment Facility/United Nations Environmental Programme (GEF/UNEP)
- Cost (including labour): 200 m^2 – approximately US$30 000
- When: 2007–2008

Why is this architecture adaptive? The elevated primary school built in Maniquenique has a dual function: as a school in normal times, and as a safe haven during floods. The floor was built higher than the 1-m flood waters experienced in 2000. In addition, the roof structure was reinforced so that it can be used as a refuge platform. The school includes a rainwater harvesting system, as drinkable water is one of the major concerns during floods, and improved, elevated sanitation facilities which can be used both during a flood and in normal times. The design of the school took maximum advantage of local knowledge, building materials and manpower. Results include one primary school/safe haven built, 300 children provided with education space, 150 to 200 community members provided with flood emergency shelter, builders trained and awareness raised.

Why is it replicable? During the floods of 2013 (Limpopo River basin, January–February 2013) communities used the school's elevated platform for shelter. In addition to benefiting the host community, the school serves to increase awareness among local and national stakeholders. Costs are absorbed over the mid to long term (in case of floods, the return period seems to be changing in some areas) and compared with the lack of negative impacts as a result of the floods. Although more costly than local material solutions, such schools could be replicated strategically in large flood plain areas. The community also constructed an additional classroom on a compacted landfill, entirely in local materials.

Figure 13: Different construction phases of the flood-resistant elevated school in Maniquenique, Mozambique.

Case 2: Safe haven and housing – Chikwawa District, Malawi

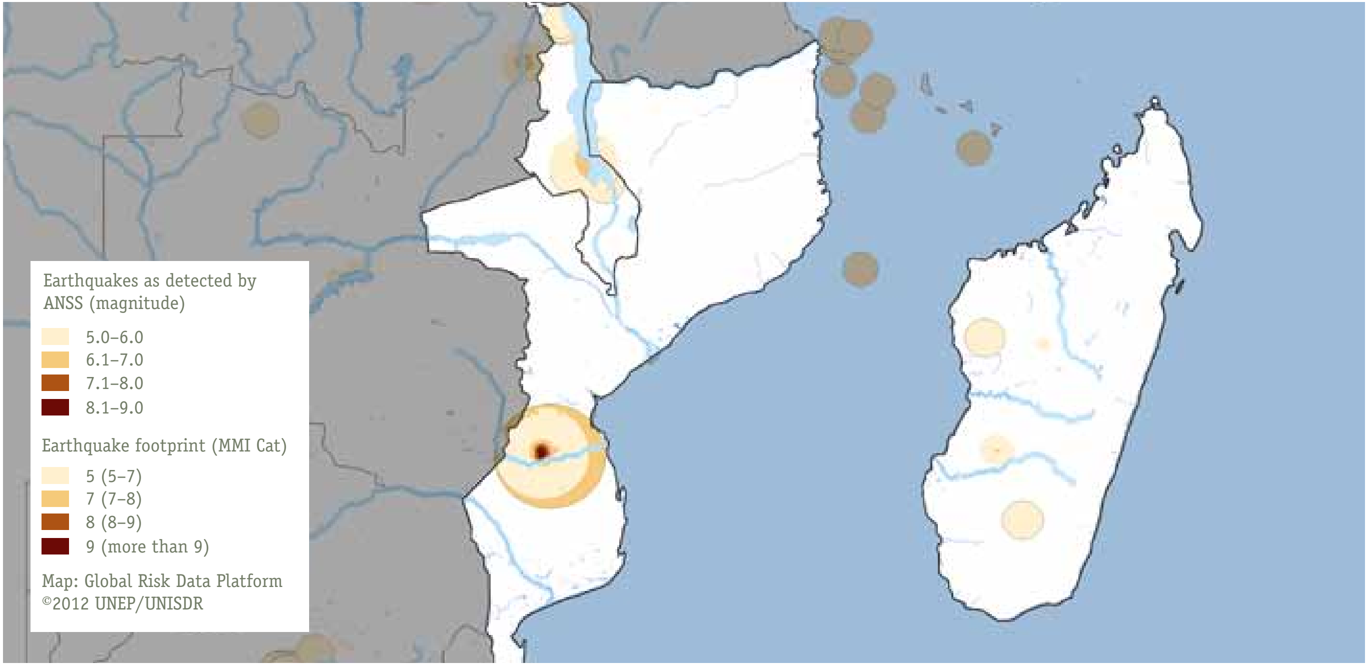
- In one of Malawi's most flood-prone regions, Chikwawa District, UN-Habitat has tested the Living with Floods approach. Under the coordination and monitoring of DoDMA (Department of Disaster Management Affairs) and MLHUD at national level, and the active involvement of Chikwawa District Council, the project was implemented with the local communities who contributed actively in site selection and materials for the construction to reduce vulnerability to floods living in low lands, prone to low and moderate flooding through small-scale shelter mitigation interventions.
- Where: T.A. Makhwira in Chikwawa District
- When: 2010–2012 (20 months)
- Donors: DIPECHO with the participation of ONE-UN Fund
- Partners: UN-Habitat, Habitat for Humanity, Chikwawa District, DoDMA, MLHUD, CBOs
- Cost (including labour): house approximately US$3 500; safe haven approximately US$28 000

Why is this architecture adaptive? The safe haven design includes two large rooms to accommodate 500 people, toilets and an external covered space for cooking. It is designed for normal community use during the rainy season. The site selection followed a participatory process and integrated local knowledge of the hazards. An elevated plinth raises the building 750 mm from the ground and a raised walkway to the kitchen and toilets enables safe and dry access to these facilities, even in flood conditions. The roof is designed to resist strong winds. The construction of the safe haven was used as on-the-job training for local builders, which provides sustainable awareness-raising and possible replication at individual housing level.

Why is it replicable? The beneficiaries concurred on the need to replicate the experience. The safe haven structure provided refuge to hundreds of flood-displaced people in 2013. After the floods, the facility has been used as an early childhood development centre and for other community development activities. Community members indicated the need for a lighting system and a fence to guarantee safety of goods and people at night, as well as for a rainwater catchment system to provide potable water in times of floods. As with the cyclone shelters, the safe haven can be replicated to the extent that it has a functional double purpose (meeting centre, community centre, school, functions) that either generate small incomes for its maintenance (renting) or is constructed by national authorities in flood-prone areas within the framework of DRR school construction programmes.

Earthquake-resistant examples

Malawi and Mozambique span the south of the Eastern African Rift, the boundary between two plates in separation, thus creating an active fault zone. Devastating earthquakes with magnitudes greater than 6.0 occur almost annually in the East African Rift. In 2006, an earthquake measuring 7.0 on the Richter scale affected eastern Mozambique and was felt across the country, as well as in



parts of Zimbabwe, South Africa, Swaziland, Botswana and Zambia. In 2009 an earthquake of 5.8 magnitude hit the district of Karonga in Malawi, followed by a 6.2 magnitude earthquake, destroying houses and public buildings. As this is an infrequent hazard in the region, the affected population and concerned institutions were largely unprepared and unable to respond.

Earthquakes have the potential to be highly destructive to housing and infrastructure, and are a potential cause of lost lives. Earthquake-resistant measures are not optional features in public buildings, especially schools. In the subregion, however, not many earthquake-resistant local material houses or basic infrastructures have been tested. Guidelines for non-engineered constructions, however, are available in Malawi and Mozambique and awareness is increasing.

Figure 14 (far right): On-the-job training for earthquake-resistant construction in Manica, Mozambique.

Figure 15 (right): An example of a flood- and earthquake-resistant building in Chikwawa, Malawi.

Case 1: Housing reconstruction and retrofitting, Karonga, Northern Region, Malawi

- In the immediate aftermath of the 2009 earthquake, the Malawi Red Cross Society (MRCS) provided emergency shelter to 6 000 displaced families. In order to reduce the vulnerability of the affected households in the long term the Department for International Development of the United Kingdom (DFID) provided financial support for a project that provided materials, cash grants and training to build and repair houses and sanitation facilities for households and schools; and disseminated better building practices, through training of hygiene promoters, training of artisans and beneficiary dissemination workshops. One of the guiding principles for the project was that households, communities, and government were responsible for providing safe and adequate housing. Every beneficiary was given a range of designs to choose from and both householders and artisans were trained to ensure that important construction details and methods were implemented.
- When: 2010–2012
- Donor: DFID
- Partners: Malawi Red Cross Society, Karonga District Council, MLHUD, UN-Habitat, TEVETA (Technical, Entrepreneurial, Vocational, Education and Training Authority), CBOs
- Cost (including labour): reconstruction approximately US$4 000; retrofitting US$350

Why is this architecture adaptive? Among other technical specifications, this example underscores the importance of building design; the shape is a major factor in the disaster-resistant design, disproving the common belief that disaster-resistant measures necessarily imply much higher costs. In this case, the house is square and compact, and unsupported wall spans are less than 5 m long; the plinth is raised from the ground, and walls, made in fired bricks as in the local custom, are reinforced. The openings do not exceed 50 percent of overall wall area, and a minimum distance of is kept between window and door openings and the corners of the buildings.

Why is it replicable? The techniques used are easy to grasp, local materials were used, and costs were limited, making it accessible to communities. While integrating earthquake (and strong-wind) resistant measures, the house remains affordable, and capitalizes on local techniques and capacities.

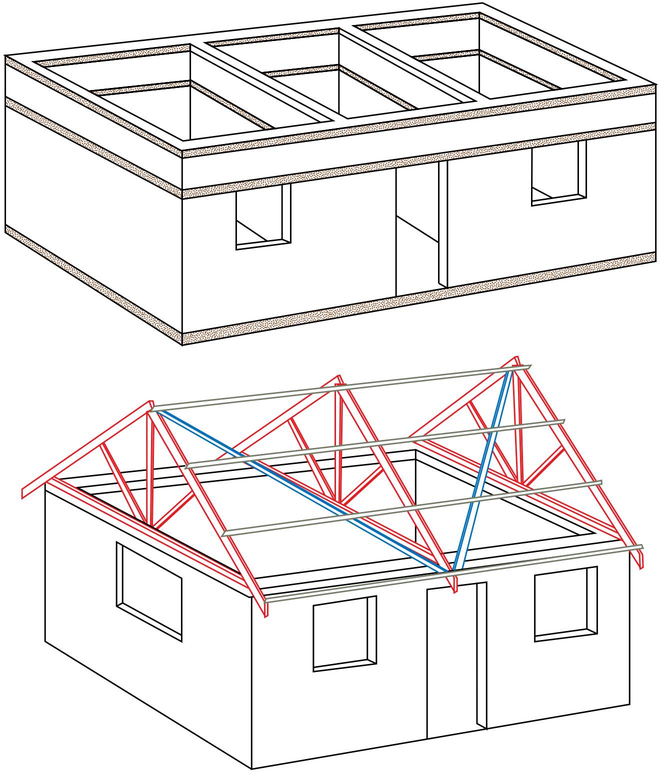
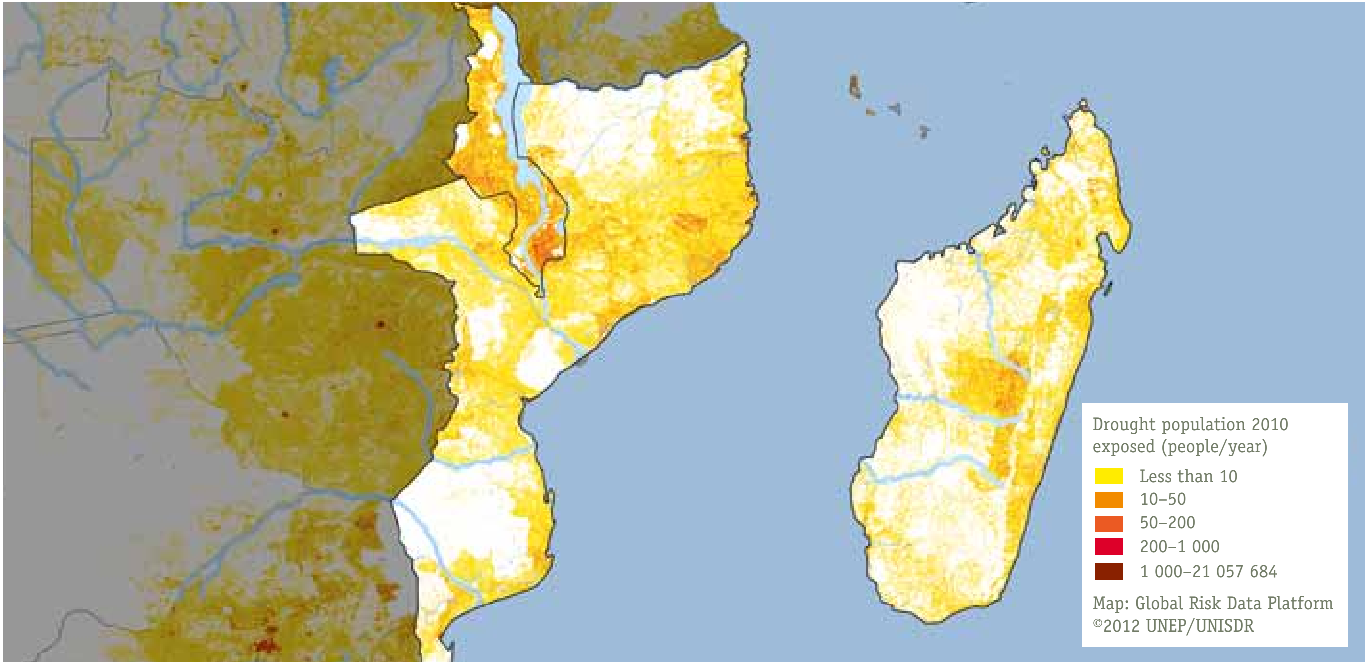


Figure 16 (above): Technical drawings for earthquake-resistant houses in Karonga, Malawi.

Drought-resistant examples

Drought is a major chronic natural hazard in southern Africa, which has the potential for dire consequences on affected populations. With a very short recurrence period of three to four years, droughts increase the vulnerability of poor populations which do not have sufficient time to recover from the economic and social impacts provoked by droughts from one cycle to the next.



Although droughts do not have a direct impact on building infrastructures, adaptive architecture can mitigate the impacts through different techniques and mechanisms, most of which are accessible to communities and have high potential in areas with low precipitation and difficult access to water.

Figure 17 (right): Improving water access through water harvesting tanks in Chicualcuala, Mozambique.

Case 1: Multi-purpose community centre, Chicalacuala, Gaza Province, Mozambique

- Chicualacuala District, Gaza Province, is affected by chronic droughts. The project raised awareness among local communities by introducing innovative rainwater harvesting techniques. The main building area includes housing, offices, meeting rooms, kitchens, toilets, porches, recreational and playground spaces and public parks.
- When: 2008–2013
- Donors: Spanish Government, United Nations Development Programme (UNDP) Millennium Development Goal Fund
- Partners: Food and Agriculture Organization (FAO), UNEP, UN-Habitat; United Nations Industrial Development Organisation (UNIDO), UNDP, World Food Programme (WFP), INGC, MICOA
- Cost of the intervention (including labour): approximately US$4 000 for the big water tank; and US$700 for the small water tank (excluding the large building)

Why is this architecture adaptive? The rectangular main building is made of concrete columns and beams and stabilized interlocking masonry blocks. The single-pitched roof slope has been designed for the collection of rainwater with the use of gutters and downpipes connected to a water-harvesting system that ends in three underground tanks with a total capacity of 40 000 litres. The most interesting feature of the project is the rainwater harvesting system, using roofs that are similar to canopies situated above the cultivated fields. The geometrical form allows the roof harvesting system to interact with renewable energies, such as sunlight, creating a new type of sustainable agriculture. The roof slopes converge in collection holes which are used to channel water into large tanks, so that collected rainwater can be used to irrigate crops in the fields. Community rainwater tanks, although technically challenging, are a measure to be further studied and replicated.

Why is it replicable? Apart from the larger building, there are a number of very simple water-harvesting systems that can be introduced in all public buildings – especially schools – that involve simple piping and water collection tanks. These are generally inexpensive, go a long way in mitigating the impact of droughts on the life of communities, and can be operated with basic technical capacities. Nonetheless, consideration of water contamination should always be taken into account and proper awareness must be central in the dissemination of these practices.

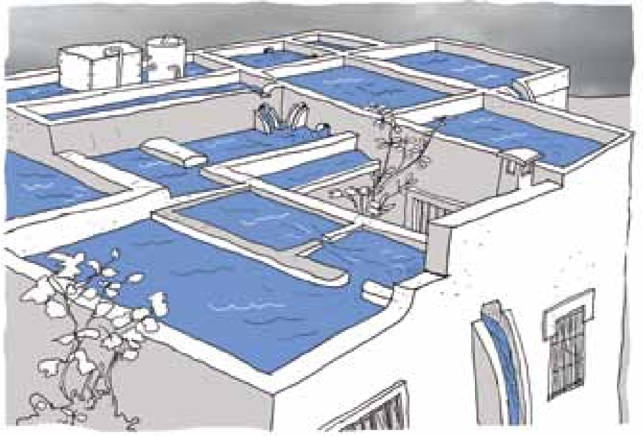


Figure 18 (left): Large water harvesting tank being built in Mozambique.

4. Lessons Learned and Recommendations

General recommendations for adaptive architecture interventions in the subregion

The samples showcased in the previous section represent an overview of relevant interventions in adaptive architecture, which have been proven to be sustainable, appropriate and affordable (within a given context) and, importantly, replicable. Extracting lessons for across southern Africa and the south-west Indian Ocean remains, however, a challenge. Architectural behaviour is the composite result of the interplay between cultural values, technological awareness and technical abilities, economic capacities and an overall legal, institutional environment. The same prototype implemented in different environmental contexts, by different communities and through the cooperation of a different institutional framework, produced varied results. Using the filter of replicability and potential impact, and including the suggestions

from all stakeholders interviewed, this provided the opportunity to extract a range of lessons and recommendations for future replication.

In general, there is consensus on the following:

- Coordination provides a wider impact and further replication possibilities for best practices in construction;
- Community mobilization and participation should be gender-balanced and inclusive of vulnerable groups from the design stage; this is crucial for the project's success;
- To ensure technical viability, communities need small, simple, labour intensive, economically and socially viable projects, which can be maintained and operated by the communities themselves in a sustainable way;
- Existing knowledge/practices should be the basis for all intervention;
- Hardware (construction) must go hand in hand with software (awareness, training) activities for maximum, sustainable impact;
- Partnership among communities, governments and other organizations (UN/NGOs) is a critical success factor and enables better access to the affected communities;
- User-friendly materials should be disseminated for training of builders;
- Prototypes, if used as premises for local committees, also increase their visibility;
- Isolated practices of pilot construction, which do not build on lessons learned and are not part of a wider strategy of awareness and stock-taking with local and national institutions, should be discontinued; and
- Local materials are low-cost and easy to reproduce; however, institutions in some countries sometimes disregard them. Advocacy on their relevance should be promoted consistently.

Cost-effectiveness and cost-benefit

In short, building 'adaptive' is cheaper than reconstructing. Recurrent destruction of houses and other public infrastructures documented in each natural disaster in the subregion simply demonstrates that a portion of the financial resources invested by or within every country is lost annually in the recovery of the infrastructures. Considering the risk/vulnerability profile of most of southern African countries, investment in hazard-resistant measures translates into medium- to long-term savings and a maintained focus on achieving national development and poverty reduction objectives. This is even more relevant in the context of climate change, which assumes that these events will recur more frequently and with greater impacts – a hypothesis increasingly supported by data. To calculate the economic benefits derived from applying resistant measures from the start, the cost of these measures can be subtracted from the cost of potential impact, for example:

Table 1: Cost-benefit analysis of DRR architecture

Cost-benefit example	
Initial cost to build a classroom (IC)	Sample country in 2012, including toilets and administrative block = US$24 500
Reconstruction of 500 classrooms US$5 500 per classroom (field visits, contract management, implementation)	US$5 500 x 500 classrooms = US$2.75 million
Cost of lost items and assets	US$300 per classroom x 500 classrooms (books, furniture) = US$150 000
Cost of emergency response (CE)	US$200 per classroom x 500 classrooms = US$100 000
Projected costs to reconstruct 500 classrooms	US$3 million
Application of resistant measures into original project equal to 8% –15% of the initial cost: (IC) = US$2 940 per classroom	US$2 940 per classroom x 500 classrooms = US$1.47 million
Estimated savings US$3 million – US$1.47 million = x	x = US$1.53 million (!)

More resistant construction costs less in the long term (or in the medium term, given the recurrence of cyclones) than a school that has to be rebuilt every time a severe natural event occurs. This example does not include the estimated costs of recurrent disruption of educational services over the long term. Considering the expected economic and social benefit, the following can be recommended:

- The progressive adoption of improved reconstruction (Building Back Better) techniques, where a dwelling or a public infrastructure is affected by a natural event, by including it in the contingency budget of reconstruction projects.
- Launch national and regional campaigns to raise awareness and evaluate the level of vulnerability of the building assets.
- Carry out actions to maintain and retrofit building assets, in order to reduce the vulnerability of existing buildings.

Prototype-specific recommendations

Although implemented in different geographical contexts, a number of recommendations are extracted per prototype, effective for the entire subregion.

Cyclone-resistant shelters and housing in traditional materials

These prototypes are present on the northern coast of Mozambique and Madagascar. Although double-purpose buildings are not yet commonly acknowledged by communities, when these show tangible results, spontaneous replication has been observed. This replication and further upscaling is facilitated in most cases by the use of local material for construction.

In many cases, however, local materials are not easily accepted and reproduced by institutions which sometimes disregard their cost-effectiveness. In this regard, practitioners should spare no effort in the promotion of local technologies, techniques and materials.

Recommendations

- Where possible, adaptive public infrastructures should always have a double purpose, i.e. they should have another function in the communities aside from that of an emergency shelter. They will be used always, maintained more effectively and improve awareness.
- Double-purpose buildings can be used for simulation and training with the local communities and children on preparedness and response.
- Along with on-the-job training in construction, the very presence of a resistant public building improves the behaviour of local builders, who will copy the often only example of resistant infrastructure in the community.
- Always include training on hygiene, water and sanitation together with on-the-job training in construction, as cultural behaviors on these issues may hinder the effectiveness of shelters during emergencies.

Cyclone-resistant shelters and housing: conventional materials

These prototypes are present on the central coast of Mozambique and northern coast of Madagascar. In general, in all experiences surveyed, the design did not include the possibility for expansion

Figure 19 (left): A cyclone-resistant shelter built with traditional materials.

Figure 20 (right): A cyclone-resistant shelter built with conventional materials.

and modification of the buildings and houses, according to the local tradition. Also, where some components of the building are made in ferrocement (e.g. roofing vaults), its cost prevents an upscale of the prototype, even though it is cheaper than concrete. However, in the case of Vilankulos (Mozambique) a number of houses of private citizens have started to be constructed with the same measures, proving that a tangible example of cost-effectiveness over the mid term might overcome considerations in the short term. Nonetheless, where ferrocement is involved, the implementation technique was more easily replicable by small construction companies than by individual local builders.

Recommendations

- Develop where possible 'incremental building design' (e.g. the possibility for the building to be increased in size for a growing family) as a guiding principle in the original design of every prototype.
- To facilitate spontaneous replication, it is advisable to carry out on-the-job training sessions with small construction companies or artisans, who can train individual field-based builders once trained on the technology.
- Small-scale investments in the industrialization process of ferrocement construction can help to reduce the implementation cost in the long term.

Elevated double-purpose platforms: conventional materials

These prototypes are present in the southern Malawi and across Mozambique, along international rivers. Sometimes, replicability has been reduced because of the very size of the intervention, especially in remote areas. Most importantly though, some of these interventions were isolated and lacked a territorial strategy for their use, which should prevent the overcrowding experienced during recurring floods. This overcrowding demonstrated both the relevance of the structures and their limitations when conceived outside an overall territorial demographic strategy and contingency planning.

Figure 21: A building with an elevated double-purpose platform built with conventional materials.

Recommendations

- The platforms should be built with techniques familiar to builders.
- The wooden roofing structures could also be substituted with metal trusses, which can bear the weight of people finding shelter on the roof of the building.
- Each structure should be accompanied by a rainwater catchment system.
- The elevated platform could be adapted to be used not only as a school, but also as a clinic or other public infrastructure.
- Isolated interventions should be included in a wider strategy for vulnerability reduction and sustainable development in zones prone to flooding.

Quake-resistant housing: conventional materials

Prototypes are present in northern Malawi and central Mozambique along the East African Rift, a fault line that identifies the seismic area of the subregion. The key to resilience to this hazard is to increase risk awareness, develop sound and enforceable building regulations, and to promote, use and upscale simple but effective solutions, at least for simple ground-level buildings.

Figure 22: A quake-resistant house built with conventional materials.

Recommendations

- Bamboo is widespread in earthquake prone areas of Mozambique and it is cheap. It can be used to create an interlaced framework to reinforce wall courses, lintels and corners. Builders in the area already know how to interlace bamboo slats.
- Earthquake-sound building layout for non-engineered houses and schools needs to be tested and applied all over the seismic-prone area.
- Malawian experience of cash transfers for reconstruction through mobile networks to beneficiaries affected by the earthquake has been successful and could be repeated.

Water harvesting systems: conventional materials

These prototypes have been surveyed in central Mozambique, but are also present in several other southern African countries. Although they do not pose a threat to infrastructure, droughts are among the hazards that result in the highest loss of life in the subregion. Knowing the hazard areas, all schools should be provided with basic water harvesting systems; likewise, many simple solutions can be devised for housing.

Recommendations

- Water harvesting is an effective, mostly inexpensive approach that can be introduced in practices and policies without significant cost implications.
- To ensure sustainability, the implementation has to be accompanied by awareness-raising initiatives and training activities with local committees; this is particularly true concerning hygiene and water contamination.
- The application of water harvesting systems to education infrastructures accompanied by awareness-raising campaigns targeting students has been successful.

Figure 23: Water harvesting system.

5. Conclusions

There are a number of interesting, sustainable and replicable experiences to be taken stock of in southern Africa and the south-west Indian Ocean. The selection of experiences presented here is only a fraction of the possible alternatives which are limited only by knowledge of the local context, the requirements of the communities and creativity. A more complete compendium can be accessed on the website of UN-Habitat and the DRR Portal (www.seadrr.org).

Introducing more resistant measures in the construction of public buildings is not optional, considering the risk profile of the subregion. The benefits, both in terms of safety and investment, are too great not to be transformed into national practices. On the other hand, the experiences of local material construction attest that, through local knowledge and know-how, different solutions can be devised and replicated to scale thanks to the low cost, simplicity of execution and potential to raise awareness. Finally, Building Back Better practices should be adopted in all countries. Madagascar is pioneering work to make public schools resistant to cyclones, and Mozambique is also undertaking a process to integrate disaster-resistant measures into this important sector. Malawi is increasingly promoting the Living with Floods approach, and adopting hazard-sensitive practices and regulations. These are extremely important examples to be mainstreamed within these same countries, from which lessons can be extracted and applied for the whole subregion and compared to other experiences in neighbouring countries.

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