Government Office for Science

Foresight

The Challenges of Climate Change and Exposure Growth for Disaster Risk Management in Developing Countries

Commissioned Review

Foresight, Government Office for Science

The Challenges of Climate Change and Exposure Growth for Disaster Risk Management in Developing Countries

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27 November 2012

Report produced for the Government Office of Science, Foresight project ‘Reducing Risks of Future Disasters: Priorities for Decision Makers’

CONTENTS

EXECUTIVE SUMMARY

Since the early 1980s, total economic losses from all natural perils have more than tripled in real terms. Evidence suggests that the main driver of past trends has been the increasing accumulation of people and assets in hazard-prone areas, such as coastal cities. Globally and in many regions, investments in disaster risk management (DRM) have failed to keep pace with the increase in exposure to natural perils. The economic and social impacts have been particularly great in developing countries, where unless the impacts of natural perils can be reduced, past development gains will be at risk and human security will be increasingly threatened.

Without strong and progressive interventions, the economic and human costs of disasters will continue to rise. At a global level, exposure growth could remain the main driver of risk in the short-term, but beyond about 2030, climate change could begin to play a more significant role. Trends are expected to be greatest in low and lower-middle income countries, with hot spots of risk in urban centres, particularly small to medium size cities. We also expect a shift toward more 'intensive risks'; that is, a larger fraction of losses coming from 'mega-disaster' events, which could have increasingly global implications. Tackling these trends will bring new and additional challenges for DRM in developing countries.

The influences of climate change and the rapid accumulation of people and assets in hazard-prone areas strengthens the need for a more forward-looking and long-term approach to disaster risk management, with a greater focus on reducing risk before a disaster strikes. We conclude that:

- **Investing in risk reduction now can bring effective, tangible and immediate benefits.** Today, in many developing countries, there is a far greater emphasis on responding to disasters ex-post, through humanitarian assistance and reconstruction, than on reducing risks before a disaster strikes. But as risks increase, this approach will become progressively less effective and more costly, in both monetary and human terms. Where risk is rising and uncertain, there is an even stronger case for reducing risks and building resilience to disasters before they occur.
- **There is an urgent need to take action now to reduce or better manage the underlying drivers of the trends in risk; a failure to act now will commit societies to a more vulnerable development path.** The world is committed to further climate

change, but there is an opportunity to curb other trends in risk, such as urban development in hazard-prone coastal areas, subsidence related to groundwater extraction and environmental degradation.

- **Not accounting for long-term risks now, will reduce the lifetime and value for money of our long-lived investments.** For long-lived decisions, like infrastructure, it is often cheaper and easier to incorporate long-term risks upfront in decision now, rather than retrofit later.
- **Insurance has significant benefits, but should support DRR rather than replace it.** Insurance (and risk transfer more widely) can be an effective and flexible tool for managing risk. But, where risk is increasing, it must be designed to reinforce efforts to reduce risk before a disaster strikes.

The scale of the emerging risks and uncertainties calls for a more robust, flexible and progressive approach to risk management. Climate change and exposure growth will lead to more rapid, larger and more unpredictable changes in risk than have been experienced in the past. Consequently, strategies should aim to reduce risk incrementally over time, bringing tangible immediate benefits, while being flexible enough to adjust as more is learnt about future risks.

Institutions already struggle to manage present-day risks and this emerging risk environment could create new challenges. The goals and priorities laid out in the Hyogo Framework for Action (HFA) provide the right foundation for addressing many of the practical challenges identified in this paper. However, we argue that to tackle the emerging risks will require a scaled up and more urgent implementation of the HFA's Priorities for Action. We also suggest that in some areas, the HFA should be strengthened or extended to tackle these emerging risks.

Emerging science and technology, while not a panacea, can improve our ability to prepare for and respond to the emerging risks. To improve the application of new science and technology, key priorities may include, for example: (i) international research and collaboration to apply the emerging science and technology in closing the gaps in our understanding of current vulnerability, exposure and hazards and the drivers of risk; (ii) building the capacity to interpret risk information and integrate it appropriately within decision making structures; and (iii) building the knowledge and capacity to implement progressive and flexible risk management frameworks, which are able to learn and respond to changing information.

I. INTRODUCTION

Key Messages

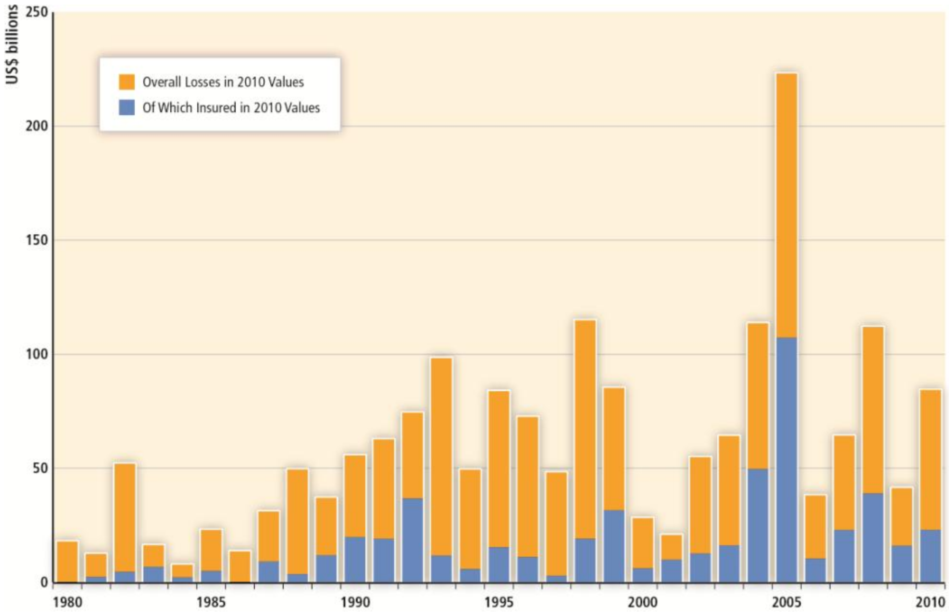
Since the early 1980s, total economic losses from all natural perils have more than a tripled in real terms. The economic and social impacts have been particularly great in developing countries. Unless the impacts of natural perils can be reduced, past development gains will be at risk and human security will be increasingly threatened.

Over the coming decade, climate change and exposure growth could push losses to even higher levels. In this paper, we argue that tackling these trends will bring new and additional challenges for disaster risk management (DRM) in developing countries. We consider if and how policies and programmes may need to change to reduce risks and build resilience in a world where risk is changing, and where future risk is deeply uncertain, and also the practical implications for institutions involved in DRM today.

The economic and human costs of disasters are rising. Since the early 1980s, total economic losses from all natural perils globally have increased by $34 billion per decade (in real terms, Neumayer and Barthel, 2011) (Fig. 1). This is more than a tripling of losses over a 30-year period. Increasing damages have been observed in most countries, but the greatest impacts, in terms of lives lost and long-run impacts on human development have fallen on developing countries (UNISDR, 2009a).

While the incidence of natural catastrophes is similar in developed and developing countries, 90 per cent of deaths from these events occur in developing countries (Hoeppe and Gurenko, 2006). Through destroying lives, assets, savings and livelihoods, disasters can force families into poverty and set back development by many years (O'Brien *et al.* 2012). Unless the impacts of natural disasters can be systematically reduced, past development gains will be at risk (World Bank 2010a) and long-run human security will be increasingly threatened (O'Brien *et al*. 2012).

Fig 1: The overall losses and insured losses from weather- and climate-related disasters worldwide (in 2010 US$)1. Reproduced from Handmer *et al*. 2012, data from Munich Re, 2011



The need to build resilience to disasters in developing countries has been highlighted by several high-profile reports (IPCC 2012; Dfid 2011; UNISDR 2011; World Bank 2010, 2011). But, there are major challenges to be overcome, not least financial constraints, a deficit of information, capacity and skills, and importantly, weak institutional structures and risk governance (UNISDR, 2011).

Over the coming decade, climate change and exposure growth could push losses to even higher levels. But, it is impossible to know exactly how risk will evolve; we expect non-linear and unforeseeable changes in risk, particularly at the local level.

In this paper, we argue that tackling these trends and the uncertainties therein will bring new and additional challenges for disaster risk management (DRM). We consider if and how policies and programmes may need to change to reduce risks and build resilience in a world where risk is changing and the practical implications for institutions involved in implementation. We consider the particular challenge of making decisions with long-term implications where

[1] These data include major weather- and climate-related events, defined (by Munich Re) as where one or more of the following criteria are true: the number of fatalities exceeds 500, the overall loss exceeds US$ 650 million (in 2010 values), the number of homeless exceeds 200,000, the country's GDP is severely hit, and/or the country is dependent on international aid.

there is high uncertainty about future risk and discuss approaches to tackle these within decision making today.

We argue that while risk has never been constant, the influences of climate change and the very rapid accumulation of people and assets in hazard-prone urban centres strengthens the need for a new flexible, forward-looking and more progressive approach to disaster risk management, with a much greater focus on ex-ante action – that is, reducing risk before a disaster strikes.

The paper focusses on developing countries and considers only hydrometeorological perils, such as floods, droughts, storms and heat waves[2]. These perils account for a large proportion of total losses: since 1980, weather-related catastrophes have caused almost 1,200,000 fatalities and led to direct damages amounting to US$610 billion in low and lower middle income countries[3] (Munich Re, 2011).

The following section summarises the current evidence on how risk is likely to evolve over the next two decades, outlining the changing risk environment within which DRM will need to operate. Section III then discusses the consequences of these changes for the design of DRM policies, strategies and measures. Section IV explores approaches to deal with the long-term uncertainty in risk. The final section of the paper considers the practical challenges of the conclusions of Sections IV and V, particularly for institutions. The paper concludes by identifying research gaps in the area and by suggesting priority areas for policy makers today.

[2] Throughout this paper the terminology of the UNISDR is used (UNISDR, 2009b).
[3] Those countries with a gross national income per capita of less than $11,905 US in 2010

II. THE CHANGING RISK ENVIRONMENT

Key Messages:

Evidence suggests that the main driver of past trends in losses from natural perils is the increasing accumulation of people and assets in hazard-prone areas, such as coastal cities. In many regions, disaster risk management has failed to keep pace with this rapid increase and concentration of exposure.

Given our understanding of the drivers of trends in risk, it is likely that without strong and progressive interventions, the observed increase in the economic and human costs of disasters will continue.

Globally, we expect to see a shift toward more 'intensive risks' – that is, a larger fraction of losses coming from 'mega-disaster' events, which in a more interconnected world, could have increasingly global implications.

Trends are expected to be greatest in low and lower-middle income countries. The evidence points toward growing hot spots of risk in urban centres, particularly small to medium size cities where governance capacities are lower.

At a global level, exposure growth could remain the dominant driver of risk for some decades, but beyond around 2030, climate change could begin to play a more significant role in determining the landscape of risk.

Risk is characterised by three components. The *hazard* describes the physical characteristics of the peril (such as its frequency and severity). The *vulnerability* is determined by the circumstances of a community, system or asset that make it susceptible to the damaging effects of a peril[4]. Finally, the *exposure* is defined by the people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses. Hazard, vulnerability and exposure are changing constantly. The recorded increase in losses from natural perils (Fig. 1) is the result of the combined effects of changes in each of these components.

The 2012 Special Report of the Intergovernmental Panel on Climate Change (IPCC) concluded that there is strong evidence that *exposure* is the major driver of the global trend in losses (Handmer *et al*., 2012)[5]. Since 1980, global population has increased by more than 50 per cent (UN, 2011) and the world gross domestic product (GDP) has increased almost six-fold (in current prices) (IMF, 2012).

In a much richer, more populous world, it may be little wonder that losses are rising (Hallegatte, 2011). However, in many regions, losses are rising more quickly than wealth (GDP) and despite increases in investment in DRM (UNISDR, 2009). This suggests that the global trend is hiding a much more complex local reality and that DRM is failing to keep pace with environmental, social and economic changes.

In this section, we explore the evidence for the drivers and scale of changes in each of the three components of risk separately. We then discuss the combined effects of these changes.

II.a. Growth and concentration of exposure

Over the next few decades, population growth and economic development will continue to increase the exposure to natural perils in many regions. The resulting increase in risk is aggravated by the fact that most of this growth will occur in urban centres, which tend to be located in hazard-prone areas, close to coasts and major rivers (UNISDR, 2011). Hanson *et al.* (2011) concluded that these combined influences alone would lead to more than a doubling of the number of people exposed and an eight-fold increase in the value of economic assets exposed to storm surges in the world's largest cities by the 2070s.

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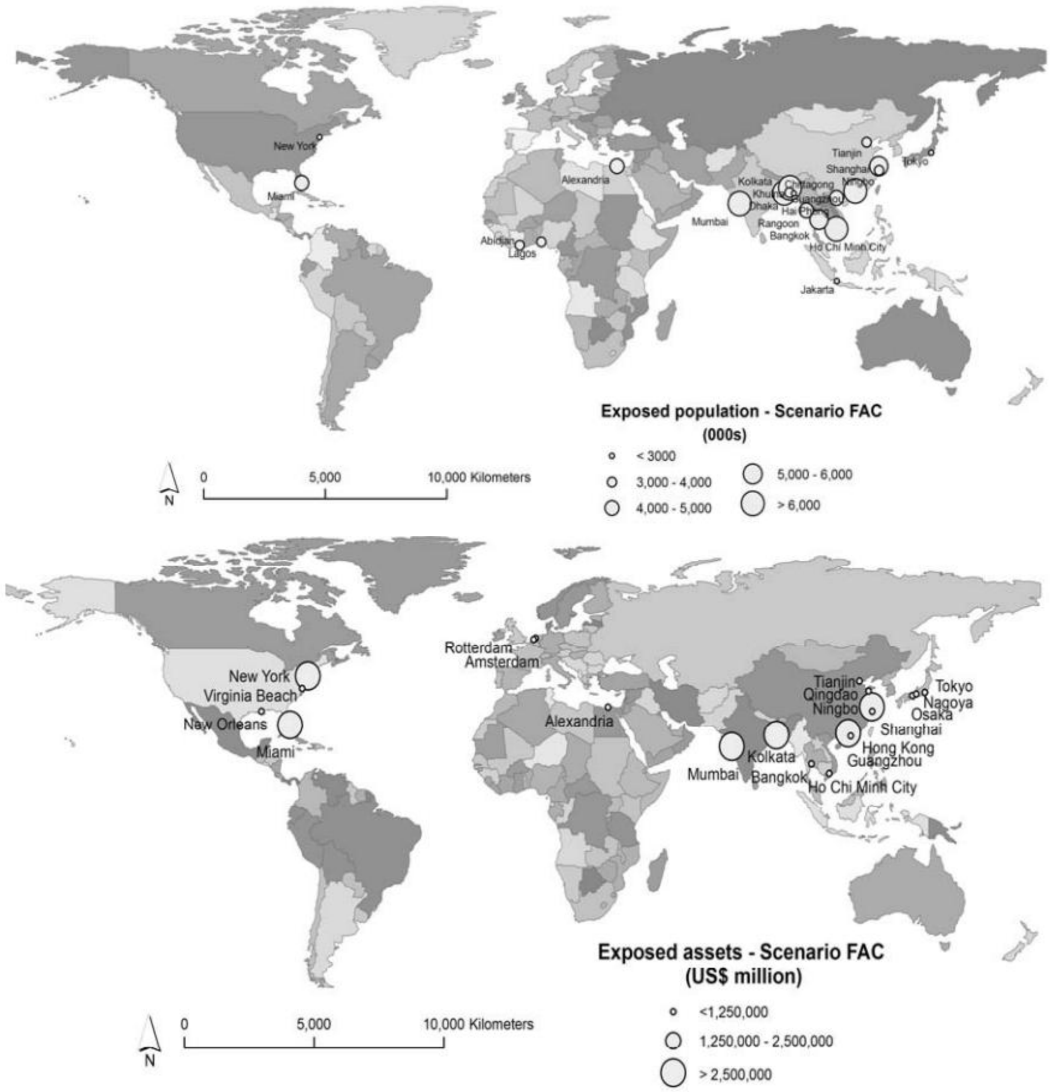
[4] Vulnerability has both physical (such as the quality of housing and protective infrastructure) and social and institutional aspects (such as low levels of health care, lack of access to early warnings and a lack of vehicles for evacuation). The term also incorporates resilience, the capacity to recover from events when they occur.

[5] It is difficult to quantify the roles of climatic changes and vulnerability in these trends as a result of the sparse and short data records in these areas.

The number of people living and working in hazard-prone areas is expected to rise most rapidly in developing countries, particularly the Asian megacities (Fig. 2). Conversely, the total value of economic activity and assets, including buildings, infrastructure and businesses, in hazard-prone areas is likely to continue to increase most rapidly in the developed and emerging economies. These increases in exposure do not necessarily translate into increases in risk if there is adequate protection. Increases in risk are expected to be greatest in lower income countries and second-tier cities where growth is less likely to be matched by increased investments in protective infrastructure (UNISDR, 2009).

Fig 2. Top 20 cities in terms of exposed assets (top) and population (bottom) in the 2070s, assuming climate change, subsidence, population and economic growth and urbanisation (Nicholls *et al.* 2007).



II.b. Changing characteristics of natural perils

A growing body of evidence suggests that manmade climate change is already adjusting the frequency and severity of hydrometeorological perils in many parts of the world (Seneviratne *et al.* 2012). In the future, scientists expect to see clearer and more widespread changes in the characteristics of extreme weather events globally. Table 1 summarises the findings of the IPCC's 2012 Special Report. Globally, on average, this suggests a shift toward more severe weather events. But these global trends hide significant variation between regions and high uncertainty at the local level. Some regions could see reductions in one type of risk but increases in another, while others could become susceptible to perils rarely experienced.

Table 1: Examples of conclusions of the 2012 IPCC Special Report (Seneviratne *et al.* 2012)

Natural Peril	Projected changes (up to 2100) with respect to the late 20th century
Temperature extremes	*Virtually certain*[6] decrease in the frequency and magnitude of unusually cold days *Very likely* increase in length, frequency and/or intensity of warm spells and heatwaves over most land areas.
Heavy Rainfall and Flooding	*Likely* increase in frequency of heavy rainfall events over most land areas and *medium confidence* that this will contribute to rain-generated local flooding (but *low confidence* in projections of future flood risk due to insufficient evidence).
Tropical Storms	*Likely* decrease or no change in frequency of tropical cyclones *Likely* increase in mean maximum wind speed, but possibly not in all basins

[6] The likelihood and confidence statements in Table 1 are expert judgements by the IPCC on the robustness of conclusions given current knowledge. For example, *virtually certain* indicates a >99% probability, *very likely,* a >90% probability and *likely,* a >66% probability, based on expert judgement of the available evidence. A confidence statement indicates the type, amount, quality, and consistency of evidence; for example, a low confidence suggests little available research or little consistency between findings at present. Note that a likelihood statement implies high confidence.

Natural Peril	Projected changes (up to 2100) with respect to the late 20th century
	Likely increase in heavy rainfall associated with tropical cyclones
Extratropical Storms	*Likely* impacts on regional activity (low confidence in detailed projections) *Medium confidence* in a reduction in the numbers of mid-latitude storms *Medium confidence* in projected poleward shift of mid-latitude storm tracks
Droughts	*Medium confidence* in projected increase in duration and intensity of droughts in some regions
Extreme water levels	*Very likely* that mean sea level rise will contribute to upward trends in extreme coastal water (surge) levels.

Natural climate variability also has significant implications for hazard severity and frequency. For example, the El Nino Southern Oscillation (ENSO) has a major influence on the likelihood and intensity of drought, flooding and tropical storms around the tropics (Holland, 2009). Indeed, the severe drought in East Africa in 2011 is thought to be partly linked with the 2010/11 La Niña (Wolff *et al.* 2011).

There is evidence that for some types of events, the magnitude of natural climate variability may remain larger than the manmade trend for some decades. However, the combination of climate change and natural variability could lead to much higher (or lower) levels of risk in the short-term (Ranger and Niehoerster, 2012). For example, Stott *et al.* (2004) concluded that the likelihood of a European Heatwave as seen in 2003 has already doubled[7]. Beyond 2030,

[7] Single events cannot be attributed directly to climate change; there is always a possibility that an event would have occurred naturally. However, for some types of event, it is possible to estimate using climate modelling or statistical analyses the change in likelihood of occurrence due to climate change.

climate change could begin to play a more significant role in determining the landscape of risk (Parry *et al.* 2007).

At a local level, a broader range of manmade drivers are also important. For example, environmental degradation and land-use change (including urbanisation) are also causing increased hazards in some areas. The 2005 Millennium Ecosystem Assessment reported that many ecosystems that regulate natural perils, such as forests, mangroves, wetlands and coral reefs, are in decline (Hassan *et al.* 2005). In many developing countries, groundwater extraction is causing subsidence, creating major problems for many rapidly developing cities. Hanson *et al.* (2011) estimated that human-induced subsidence alone could increase the global population exposed to storm surges by 14 per cent by the 2070s, with the largest increases expected in Asian mega-cities, such as Guangzhou, Kolkata, Shanghai and Bangkok.

Natural geological processes can also influence risk. For example, in the UK, Glacial Isostatic Adjustment[8] is causing the land mass in the north of the UK to uplift, while the south is subsiding, which reduces or aggravates (respectively) the impacts of manmade sea level rise.

II.c. Vulnerability hot spots

There is evidence that the number of people killed (as a proportion of the population) in natural disasters is falling. Experts believe that this is one sign that vulnerability to natural perils maybe, on average, decreasing in some regions (UNISDR, 2009). Declining vulnerability, and increasing resilience to disasters, is associated with progress in DRM, poverty alleviation and development (UNISDR, 2011).

These regional trends hide the increasing vulnerability of some communities. The urban poor (particularly those living in informal settlements) are more vulnerable to perils, due to their living conditions, the lack of investment in infrastructure and poor urban governance (Satterthwaite, 2007). Almost 1 billion people now live in informal settlements around the world's fastest growing cities and this is increasing at a rate of 25 million per year (UNISDR, 2009). This results in urban hot spots of vulnerability. But, in both rural and urban areas, conflict, political instability, environmental degradation and ecosystem decline, vulnerable rural livelihoods,

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[8] Glacial Isostatic Adjustment is the vertical movement of land masses (upward or downward) caused by the rebound of areas that were depressed by the huge weight of ice sheets during the last glacial period.

poverty and disasters themselves can also increase vulnerability and reduce the capacity to manage long-term risks (UNISDR, 2011).

In the long-term, climate change itself may increase the vulnerability to natural perils, through its direct impact on people, livelihoods, economic growth and human security and by diverting resources away from development and DRM (O'Brien *et al.* 2012; Lavell *et al.* 2007). Rising hazard levels may also render current DRM and resource management practices, such as water supply systems, increasingly inadequate.

A rising frequency of disaster losses, resulting from climate change or exposure growth and other factors, could challenge the capacity of international disaster response, increasing vulnerability at a global and local level.

It is difficult to anticipate how the increasing complexity and interdependency of global systems, including finance, transport, water, food and energy, will influence vulnerability to disaster risk (UNISDR, 2011a). Interconnectedness brings benefits but also risks. In general, the interconnectedness of the global economy means that disasters in one region can create a global shock. For example, the floods in Thailand in 2011 caused major disruption to supply chains of electronics across the world[9]. But, there are many factors at play. For example, for developing countries, access to global food markets can increase resilience to local droughts; yet, there are many examples of where rising food prices at the global level (due to climate and other shocks elsewhere in the world) have negatively impacted local communities (WEF 2012). At the same time, the increasingly globalised insurance market increases the financial resilience to local catastrophic losses[10].

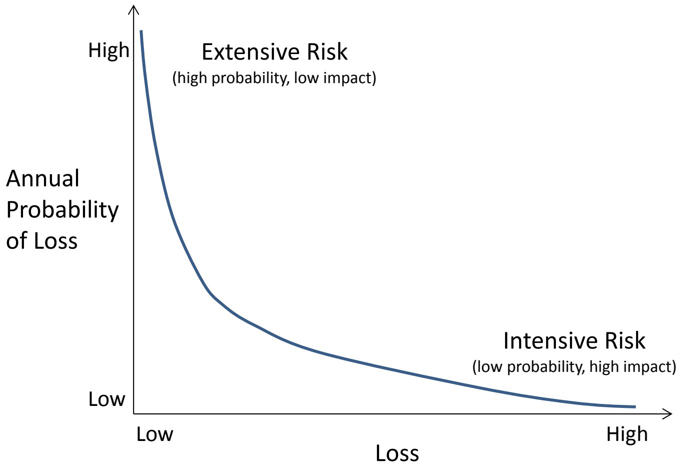
II.d. Combined effects on risk

When combined, the expected trends in exposure, hazard and vulnerability could suggest a general shift toward more *intensive risk*[11] in the future, that is, a greater fraction of losses coming from more catastrophic events. While *extensive risk*, associated with more frequent but lower intensity events, could decline in many regions as a result of reductions in vulnerability and increasing disaster resilience. In other words, we expect the probability-loss curve (Fig. 3) to become more 'fat-tailed'. Already mortality and direct losses are highly concentrated

[9] For example, Financial Times "Computer makers caught in wake of Thai floods" 28th October 2011.
[10] The most vulnerable communities rarely have access to this market (Warner *et al*. 2009).
[11] For definitions of intensive and extensive risk, see UNISDR (2009b).

geographically and in a small number of '*mega-disaster*' events. For example, between 1975 and 2008, almost 80 per cent of deaths (1.8 million people) were caused by only 0.25 per cent (a quarter of one per cent) of recorded disasters (UNISDR 2009).

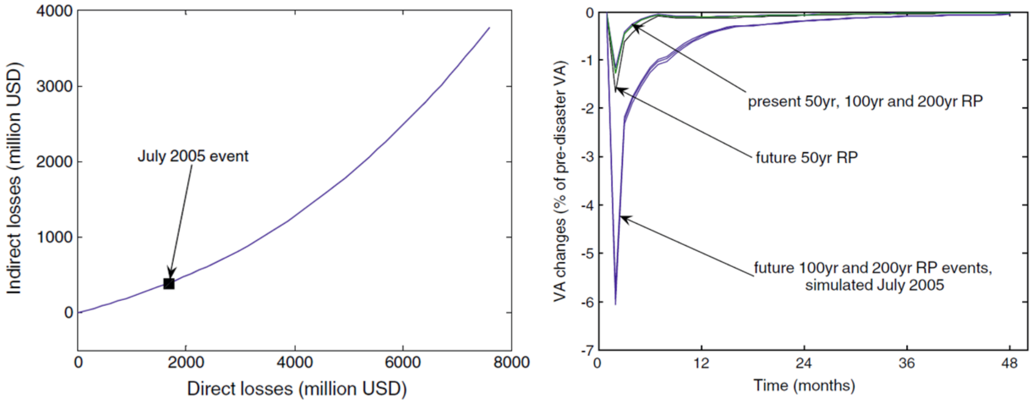
Fig. 3: Diagram illustrating a classic probability-loss curve, showing the extensive risk (high probability, low impact) and intensive risk (low probability, high impact).



As the magnitude of the direct losses from natural perils grows, we expect to see non-linear increases in the indirect effects[12] of these events (Fig. 4) and more long-lived effects on employment, consumption and economic growth (Lindell and Prater 2003; Hallegatte *et al.* 2007). Empirical studies and theoretical modelling demonstrate that the long-run impacts are greater and more negative in lower-income countries, as a result of the higher vulnerability and lower resilience to disasters, and for larger direct losses (UNISDR 2009a; Ranger *et al*. 2011). Together, this means that, without interventions, total impacts on the most vulnerable could be much higher, with longer-lived implications for growth and development.

[12] The direct effects of disasters can be amplified through (1) spatial or sectoral diffusion of direct costs into the wider economic system over the short-term (e.g. through disruptions of lifeline services, such as communication and transportation networks) and over the longer term (e.g. sectoral inflation due to demand surge, energy costs, company bankruptcy, job losses, larger public deficit, or housing prices); (2) social responses to the shock (e.g. loss of confidence, change in expectations, indirect consequences of inequality deepening); (3) financial constraints impairing reconstruction (e.g. low-income families cannot finance rapidly the reconstruction of their home); and (4) technical constraints slowing down reconstruction (e.g. availability of skilled workers, difficulties in equipment and material transportation, difficulties in accommodating workers). These additional losses are described as indirect economic costs (Ranger *et al.* 2011).

Fig. 4. An illustration of the indirect effects of a disaster (in a developing country[13]) based on a theoretical model for Mumbai flood risk (Ranger *et al.* 2011). (Left) The non-linear relationship between direct and indirect losses from an event (the estimated values for the 2005 floods in Mumbai are marked). (Right) The time evolution of the economic impact of an event, measured in terms of changes to the total value added of all sectors, for events of three magnitudes (expressed in terms of the return period today and in the 2080s).



Risk is expected to increase most strongly in the rapidly growing low and lower-middle income countries, where reductions in vulnerability have in the past failed to keep pace with the very strong increases in exposure to natural perils (UNISDR, 2009a). Within these countries, the evidence points toward growing hot spots of risk in urban centres, particularly those of small to medium size where governance capacities are lower (UNISDR, 2011a).

In conclusion, without strong and progressive interventions, that tackle the underlying causes of trends in risk and keep pace with changing risk levels, the damages from hydrometeorological perils will continue to grow (Ranger and Garbett-Shiels, 2012).

[13] In a developed country, where resilience is higher, the time evolution of total damages can appear very different. Typically, there is a small (or no) immediate negative shock followed by a rebound in value added, driven by the increased productivity of the construction sector (Hallegatte *et al.* 2007).

III. IMPLICATIONS FOR DISASTER RESILIENCE STRATEGIES

Key Messages

While risk has never been constant, the influences of climate change and the rapid accumulation of people and assets in hazard-prone areas strengthens the need for a more forward-looking approach to disaster risk management, with greater focus on reducing risk before a disaster strikes. We conclude that:

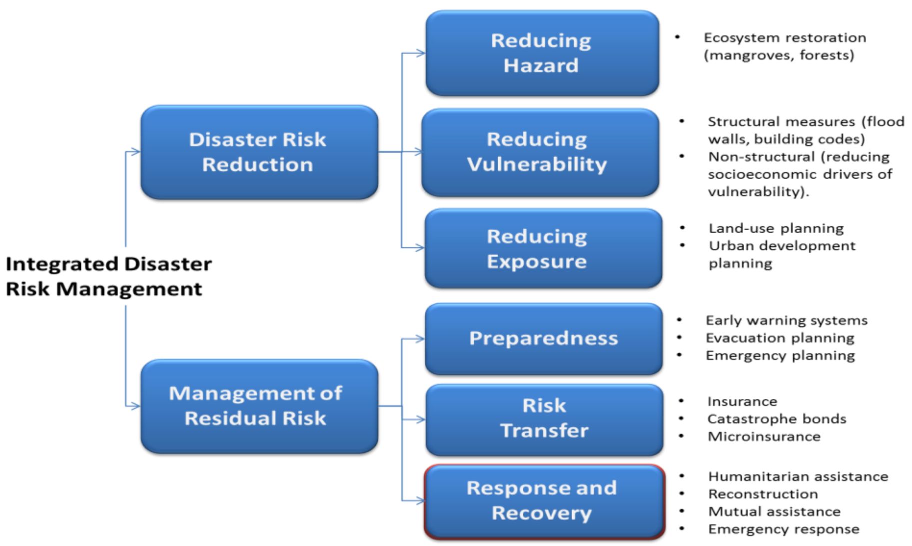
- Where risk is rising, the benefits of investments in ex-ante risk reduction, relative to the costs, are greater. In addition, a continued reliance on ex-post response will become progressively less effective and more costly, in both monetary and human terms. Together, this means that there is an even stronger case for reducing risks and building resilience to disasters before they occur. Investing in risk reduction now can bring effective, tangible and immediate benefits.
- There is an urgent need to take action now to reduce or better manage the underlying drivers of the trends in risk, such as the development of hazard-prone areas, environmental degradation and the unsustainable use of natural resources. A failure to act now will commit societies to a more vulnerable development path.
- There are benefits to considering long-term risks upfront in policies and programmes today. For example, for long-lived decisions, like infrastructure, it can be more costly and difficult to retrofit investments to cope with changing risks later on. Not accounting for long-term risks now, will reduce the lifetime and value for money of our long-lived investments today.
- Finally, insurance (and risk transfer more widely) can be an effective and flexible tool for managing risk, but should support DRR rather than replace it. Where risk is increasing, insurance must be designed to reinforce efforts to reduce risk before a disaster strikes.

An integrated disaster risk management strategy calls for a wide range of policies and measures (Fig. 5). Here, we group these into two types:

- *Disaster risk reduction* (DRR), which aims to reduce the direct impacts of natural perils before an event occurs through reducing levels of hazard, vulnerability and exposure. This can include structural measures, such as flood protection and restoring mangroves, and non-structural measures, such as land-use planning, diversified livelihoods and improved risk awareness.
- *Management of residual risk,* which aims to reduce the impacts of natural perils when they occur. This includes preparedness (including early warning systems and emergency planning), risk transfer (such as insurance and social safety nets) and response and recovery.

With the exception of response and recovery, all of these policies and measures can be classified as *ex-ante*, that is, they are all implemented in advance of an event. Response and recovery occurs *ex-post*. A comprehensive strategy requires both ex-post and ex-ante measures. For example, ex-post measures, such as disaster management (including relief and humanitarian assistance), post-disaster financing, reconstruction and rehabilitation, are crucial for a speedy recovery and for reducing the indirect impacts of disasters, such as further fatalities from injury and disease and the long-run effects on growth and development (World Bank, 2010a).

Fig. 5: Schematic illustrating the components of an integrated disaster risk management strategy and examples of specific measures. Ex-post measures are circled in red.



In this section, we explore how the changing risk environment alters our understanding of which mix of measures and policies will deliver the best outcome both economically and socially. While all of these measures and policies are important and can have considerable benefits, we argue that as risk increases, there is a greater need for taking action to reduce risk ex-ante.

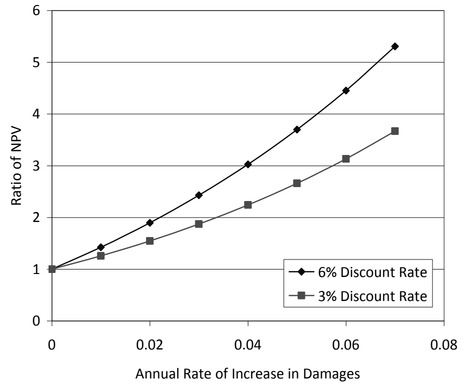
III.a. Rationale for a greater focus on ex-ante action

To-date, the main focus of DRM in developing countries has been ex-post response. Yet, international organisations have long highlighted the significant financial and societal benefits of a greater emphasis on acting ahead of time, to reduce risk and build resilience before events occur (UNISDR, 2007). Indeed, ex-ante action has been shown to be several times more cost-effective than ex-post (UNDP, 2007; World Bank 2010c; Michel-Kerjan *et al. in press).*

The 2012 Special Report of the IPCC concluded that the observed and expected trends in risk strengthen the case for such *ex-ante* action (Cutter *et al.*, 2012). On purely monetary grounds, the benefits of DRR, relative to the costs, are greater where risk is increasing. This is illustrated in Fig. 6, which shows the relationship between the net present value (NPV) of an investment in DRR and the annual rate of increase in damages. The faster the increase in risk, the higher the NPV of the investment; in practical terms, this means that where risk is rising, there is a greater justification for an upfront investment in DRR[14].

[14] This does not mean that all DRR investments become cost-beneficial, but instead that benefits rise.

Fig.6: A simple cost-benefit analysis[15] showing the relationship between the annual rate of increase in damages and the net present value (NPV) of an investment in DRR (expressed relative to the case where risk is unchanging) for two discount rates (6% and 3%).



There are also a broader set of arguments for ex-ante action. Firstly, ex-ante risk reduction is the only approach that can limit the immediate, direct fatalities and damage from natural perils. Ex-post responses cannot prevent these immediate fatalities and damages, but rather reduce the indirect and long-term impacts. Without proactive risk reduction, direct losses and fatalities will continue to grow.

Secondly, in practice disaster relief can be insufficient and slow and puts considerable strain on national governments and local communities16, diverting resources away development and poverty alleviation. In 2007, humanitarian aid totalled more than $120 billion USD and estimates suggest that international assistance covers only 10% of the real costs (UNISDR, 2009).

Thirdly, as risks increase, an overreliance on ex-post responses will become progressively less effective and more costly, in both monetary and human terms

Finally, there is evidence that an overreliance on post-disaster assistance can actually discourage risk reduction, putting more lives at risk (Kunreuther, 2006).

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[15] The actual ratios of NPV also depend on the size of the costs and benefits. Here, the cost-benefit analysis assumes an upfront cost of $100,000 and annual benefits accrued at a rate of $10,000 per year. The annual benefits of DRR grow at the same rate as the annual average damages. The decision maker is assumed to be risk neutral.

[16] The first, and in many cases, most significant assistance comes from members of the affected community. The majority of coordinated emergency assistance and disaster relief comes from regional and national government to local communities. Reconstruction funding may take up to 12 months or more to put into action, even if it is allocated effectively (UNISDR, 2009).

III.b. Tackling the underlying drivers of risk trends

Economic growth and development can be effective forms of DRR, through reducing socioeconomic vulnerability and increase adaptive capacity[17] (World Bank, 2010a). But, they do not always lead to a net reduction in risk, as described in Section II. As economies grow, exposure tends to increase faster than vulnerability can decrease, leading to higher risk (Hallegatte 2011; UNISDR, 2009). Economic growth is also sometimes associated with the increased degradation of the natural environment and the overexploitation of other natural resources, such as water, forests and soils, which can result in a greater long-term vulnerability to natural perils.

Tackling such underlying drivers of increasing risk can be one of the most robust and effective approaches to curbing long-term risks (Ranger *et al.* 2010; Cutter *et al.* 2012). We emphasize that here we refer to measures to prevent, or slow, the accumulation of additional risk, rather than reduce current risk. These types of policies and measures are urgent because decisions are made every day that may increase the risk to current and future natural perils. In some cases, particularly in areas related to infrastructure, the environment and planning, these decisions can be slow and costly, or impossible to reverse, and so effectively 'lock-in' future risk.

In addition, DRR measures cannot always fully compensate for rising risk. For example, structural measures, such as levees, dams and building codes, cannot eliminate risk created by increasing exposure. Indeed, as observed in New Orleans prior to Katrina, structural measures can create a false sense of safety, which can lead to increased property development in hazard-prone areas (the '*levee effect'*, Montz and Tobin 2008; Burby 2006, Wilbanks and Kates, 2010). The net result is an increase in *intensive* risks; that is, damages are experienced less often due to DRR, but when they do occur they are much larger (Section II, Hallegatte, 2011).

The fourth priority action of the Hyogo Framework for Action (HFA)[18] highlights a number of key activities that aim to tackle the underlying drivers of risk trends:

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[17] Adaptive capacity refers to the capacity of a system or actor to adapt if the environment is changing

[18] The HFA outlines five priorities for action and offers guiding principles and practical means for achieving disaster resilience, with the goal of substantially reducing disaster losses by 2015. It was adopted by 168 Member States of the United Nations in 2005 at the World Disaster Reduction Conference.

- Environmental and natural resource management, including the sustainable use and management of natural resources and ecosystems (e.g. avoiding the loss of systems that mitigate hazards, such as mangroves and coral reefs).
- Social and economic development practices, including promoting food security and ensuring the resilience of new infrastructure (e.g. hospitals and energy systems).
- Land-use planning, including:
    - incorporating risk assessment into rural and urban planning;
    - mainstreaming disaster risk considerations into planning procedures for major infrastructure;
    - upgrading and encouraging the use of guidelines and monitoring tools for the reduction of disaster risk in the context of land-use planning and policy;
    - encouraging the development/revision of new building codes
    - adjusting post-disaster rehabilitation and reconstruction practices to ensure rebuilding in ways that increase resilience to natural perils.

Climate change is an example of a risk driver that cannot be mitigated over the next few decades. Lags in the climate system mean that the world is already committed to further warming and climate changes as a result of past greenhouse gas emissions. Based on current projections, it is likely that the world will continue to warm for several decades even under the most ambitious mitigation scenarios (IPCC, 2007). The commitment to climate change increases the need for a greater emphasis on tackling other drivers of rising risk, as outlined above.

III.c. Forward-looking and long-term risk management

Better management of today's natural perils is an important foundation to managing long-term risks (Smit and Wandel, 2006; Pielke *et al.* 2007). But, the changing and uncertain nature of risks also calls for a more forward-looking and long-term approach to risk management. There are often benefits to considering long-term trends in risks upfront in programmes and policies today. For example, for long-lived investments with high-sunk costs, such as infrastructure (communications, transport, energy, water, flood protection), it is often cheaper and easier to take account of trends upfront, rather than making costly retrofits later (Fankhauser *et al.* 1999). A failure to take account of long-term risks today could mean that the useful lifetime and value for money of investments will decrease.

In addition, the speed and scale of the expected changes in risk could limit the ability to manage risks reactively (i.e. once new levels of hazards or exposure have been reached). It will take time to build capacity and to implement new risk management programmes and therefore, it is important to act ahead of time. In addition, in some cases, significant changes in risk could require *transformational* risk management, such as the relocation of vulnerable populations, introduction of new institutions, or changing social norms, which have long lead-times to plan and implement.

Finally, if long-term trends are not considered upfront in decisions, this could make societies more vulnerable in the future. For example, if a rural development strategy incentivised greater investment in water-intensive agricultural practices, but then rainfall levels decreased due to climate change, that policy could put rural populations at greater risk, as well as wasting resources. Similarly, as discussed in Section III.b, policies that encourage building in areas that could see increasing hazards in the future (such as the low-lying coasts) could commit societies to a more vulnerable development path.

In some cases, long-term framing of risk management, to enhance long-term welfare and development, can have trade-offs for people in the short-term (O'Brien *et al.* 2012). For example, relocating the most vulnerable communities may be essential in the long-term but may threaten their livelihoods and social capital today. Section V discusses the practical challenges of balancing such trade-offs.

III.d. The role of insurance in a changing risk environment

By sharing risks across individuals, regions and countries, insurance, and risk transfer[19] more widely, can increase the financial resilience to natural perils, speeding recovery and reducing the long-run (indirect) impacts of disasters. Well-designed risk transfer markets can play a positive role by helping to manage those risks that cannot be cost-effectively reduced[20]. Indeed, in an environment of more *intensive* risk, risk transfer could become a more important tool as the capacity to absorb losses may be reduced (Cutter *et al*. 2012).

[19] Risk transfer is a mechanism whereby an individual or organisation (the insured) transfers part of their risk to an insurer in return for a payment (the premium). If the insured experiences a loss, the insurer pays out a previously agreed amount.

[20] The advantage of risk transfer over post-disaster assistance is that it can be relatively fast to respond, efficient, reliable and the pay outs are certain (UNISDR, 2009).

The availability and use of risk transfer instruments has so far been limited in low income countries. In industrialised countries, around 40 per cent of reconstruction following a disaster is funded by insurance, compared with only a few percent in developing countries (Hoeppe and Gurenko, 2006). There are a number of barriers to extending the use of insurance in developing countries, including affordability and a lack of local capacity and distribution networks (Warner *et al.* 2009). However, recent innovations in risk transfer, such as micro-insurance, sovereign catastrophe bonds and regional risk pooling, attempt to increase the accessibility of risk transfer for lower-income countries and are now evolving from the initial pilot phase.

However, risk transfer is not a silver bullet solution. Firstly, it does not reduce the direct impacts of disasters, including monetary losses and fatalities. This means that without measures to reduce risk, impacts will continue to increase and risk transfer will become more expensive and ultimately unsustainable. Secondly, poorly designed risk transfer initiatives decrease incentives for risk reduction or create moral hazard. For example, in many regions, even those with free-market insurance systems, risk is underpriced and this reduces the incentive to invest in risk reduction measures (Kunreuther 2006).

Conversely, well designed risk transfer can promote DRR and so could play an important role in an environment where risk is rising. A number of pilot projects have trialled innovative approaches to promoting risk reduction through the design of risk transfer, such as the Wind Hazard Mitigation programme in Florida, which offers insurance discounts for homeowners that invest in verified risk reduction measures, and the Harita micro-insurance scheme in Ethiopia, which enables the insured to pay premiums through work on risk reduction projects (Warner *et al.* 2009).

But, the insurance industry itself is vulnerable to rising risk, and particularly rising *intensive* risk (Herweijer *et al.* 2009). In developed markets, increasingly catastrophic losses have led private insurers to withdraw insurance from some markets, for example, in the USA, UK and Germany (Priest *et al.* 2005, Botzen and van den Bergh, 2008). This has resulted in insurance becoming unavailable to many households, reducing their resilience. It is not known how the private markets would react to rising risk levels in the future, particularly in developing countries, and how this interacts with local factors, such as regulation. Certainly, effective DRR will be crucial in maintaining the availability and affordability of insurance where risk is rising (Herweijer *et al.* 2009). In addition, risk-adequate pricing is an important foundation of developing risk transfer markets that are robust to changing risk[21] (Herweijer *et al.* 2009). If risk is underpriced, then the accumulation of capital may be inadequate to cover losses and the solvency of insurers is threatened.

[21] There are several challenges to risk pricing in a dynamic risk environment (Herweijer *et al*. 2009).

IV. DESIGNING ROBUST STRATEGIES FOR DISASTER RISK MANAGEMENT

Key Messages

There are considerable, irreducible uncertainties in projections of future risk. In particular, the non-linearity of impacts, global and local multiplier effects and physical, social and ecological 'tipping points', could lead to significant changes in vulnerability and risk that are difficult to predict ahead of time.

It is unlikely that these uncertainties will be meaningfully reduced on the timescale that most DRM decisions need to be made. But, uncertainty cannot and need not delay action.

We argue that the level of uncertainty, combined with the urgency of DRM, necessitates a new approach to risk management today, which is more robust to the long-term uncertainties in risk, including:

- Firstly, the nature of the risks and uncertainties may justify a greater focus on acting ahead of time to manage the long-term drivers of risk.
- Secondly, rather than being a one-off decision, risk management must be long-term and progressive.
- Thirdly, strategies should aim to reduce risk incrementally over time, bringing tangible immediate benefits, while avoiding foreclosing options to manage long-term risks.
- Lastly, for decisions with long-term implications, such as development planning and infrastructure, there are benefits to adopting an approach that is flexible enough to respond as more is learnt about future risks.

Understanding risk is a crucial foundation of designing risk management strategies and of evaluating their effectiveness. Yet, there are major issues in assessing even present day risk, particularly at sub-national scale (UNISDR 2009)[22]. The *non-stationarity* of risk adds to this challenge. While experts can identify the major trends in risk and provide estimates of their scale, it is not possible to know exactly how risks will evolve in the future.

In this Section, we first discuss the source and nature of the uncertainties and then explore approaches to design risk management policies and programmes that deliver tangible benefits today whilst being robust to the long-term uncertainties in risk.

IV.a. Why is long-term risk so uncertain?

The high level of uncertainty in climate change projections from climate models is well documented (e.g. Ranger and Niehoerster 2012; Stainforth *et al.* 2007). Indeed, due to their relatively small spatial scale, uncertainties are particularly great for long-term projections of the frequency and severity of natural perils. However, Lavell *et al.* (2012) highlights that estimating the impacts of future extreme events is at least as challenging, involving predicting future vulnerability and behaviour of complex systems under stressed and novel conditions. Future socioeconomic trends, such as population and economic growth, are also highly uncertain (O'Brien *et al.* 2012).

In addition, interconnected drivers (including resource scarcity and rising demand for food, water and energy), multiplier effects and physical, social and ecological 'tipping points' (such as the collapse of ecosystems, changes in the monsoon circulations and human migration) could have significant impacts on disaster risk that are almost impossible to predict ahead of time (O'Brien *et al.* 2012; UNISDR, 2009). The uncertainties increase non-linearly in scale as we look further out in time.

Uncertainty itself is not necessarily a problem as decisions are made under uncertainty every day. For example, engineers routinely make decisions about the design of infrastructure to cope with local weather conditions, which by their nature are uncertain. However, in the case of future risks from natural perils, the uncertainties are such that science is not yet able to give robust estimates of the likelihood (i.e. probabilities) of different scenarios. We refer to this situation as deep uncertainty (Fig. 7). An overreliance on deeply uncertain projections in

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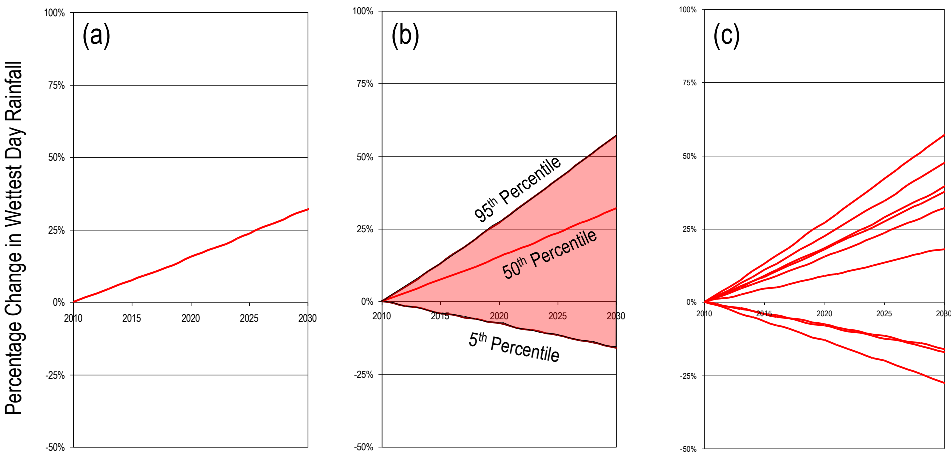
[22] Climate change adds to this challenge. For example, where dealing with rare events, it is difficult to separate the influences of climate change from natural variability and this makes it impossible to accurately determine the baseline characteristics of hazards (Herweijer *et al.* 2009). The result is that decision makers can no longer rely on historical observations as a guide to current risk levels.

decisions today can lead us to make poorer choices, for example, taking too much, not enough or the wrong types of risk management measures, leading to greater risks and costs. Under such conditions, common tools used in planning and engineering, like expected value analyses, can break down (Morgan *et al.* 2009).

Fig 3: Illustration of the levels of uncertainty: (a) is an example of a deterministic forecast (i.e. no uncertainty); (b) is an example of a probabilistic forecast, where there is well characterised and quantifiable uncertainty; (c) is an example of a forecast with deep uncertainty – there are multiple forecasts and not robust information on their relative likelihood. Many experts have argued that despite efforts to better characterise uncertainties, probabilistic information remains model dependent and so the true level of uncertainty in climate projections is closer to (c) (e.g. Stainforth *et al.* 2007).



Some experts have stressed the importance of investing in developing more accurate risk projections as necessary to inform risk management decisions (Lavell *et al*. 2012). However, this argument has been criticized on the grounds that such projections are likely to remain deeply uncertain, for the reasons outlined above. Here, we focus on the implications of the uncertainties for disaster resilience strategies today and approaches to deal with this in decisions.

IV.b. Dealing with uncertainty in decisions today

Importantly, uncertainty does not mean that risk reduction cannot take place or should be delayed until better information is available (Dessai *et al.* 2009). Indeed, where there is deep uncertainty over long-term risks, there may be an even greater rationale for acting ahead of time to curb those risks, through for example, investments in DRR and in tackling the underlying drivers of risk. It does however mean that a new approach is needed that is more robust[23] to uncertainty.

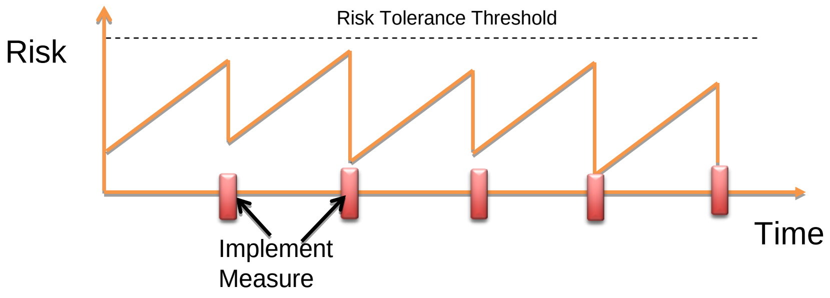
Many risk reduction measures are robust to uncertainty; that is, they are effective in reducing risk whatever the future brings. These so-called ‘low-regret’ measures include, for example, poverty alleviation, improving urban governance, diversifying rural livelihoods, improving health and education, restoring ecosystems and building human and institutional capacity to manage risks. Each of these measures can provide tangible and cost-effective benefits both today and in the future (Cutter *et al.* 2012; World Bank 2010b; UNISDR, 2009; Willows and Connell 2003).

However, depending on the circumstances, there may be some difficult choices and trade-offs. For example, a decision over whether to increase investments in water infrastructure to maintain existing agricultural production, or to take the chance of shifting to less water intensive crops (O’Brien *et al.* 2012). Decisions over long-lived buildings and infrastructure also tend to be more sensitive to the uncertainties in future risk. For example, it can be much more expensive to build a much larger flood wall just-in-case a worse-case scenario of future sea level rise is realised.

To design robust strategies, recent literature and practice recommend that rather than making one-off decisions now, there are benefits to taking a more flexible and progressive approach to risk management, which reduces risk incrementally and cost-effectively over time (Fig. 8), while avoiding foreclosing future options (WRI 2011; World Bank 2010b; UKCIP 2010; HMT and Defra 2009; Dessai *et al.* 2009; Morgan *et al*. 2009; Ranger *et al*. 2010; Willows and Connell 2003).

[23] A robust strategy is usually defined as one that performs well for a wide range of conditions.

Fig 8. Illustration of the evolution of risk within an adaptive risk management approach



Practically, a more flexible approach may involve strategies and measures that have wider safety margins or that can be adjusted over time in response to changing circumstances (Fankhauser *et al.* 1999). For example, the Thames Barrier that protects London can be over-rotated to cope with greater than anticipated sea level rise (Reeder and Ranger, 2011). A suite of tools are available to help inform decisions in such circumstances[24].

Such approaches are not necessarily more expensive. They do require a more forward-looking and long-term risk management processes that are supported by governance structures that enable regular monitoring and reviews of progress, as well as facilitating learning and responses to new information.

[24] A range of tools, such as Robust Decision Making and Real Options Analysis, can help a decision maker to evaluate the desirability of the trade-off between the costs and benefits of strategies under deep uncertainty (see review by Ranger *et al*. 2010). Several of these methods have been applied in practice; including to flood management in London (Haigh and Fisher, 2010) and water supply management in California (Groves *et al*. 2008).

V. PRACTICAL CHALLENGES FOR RISK GOVERNANCE

Key Messages

The changing and uncertain nature of risk brings several new challenges for the institutions involved in disaster risk management; institutions that already struggle to manage current risks:

- Firstly, there are existing barriers to the implementation of DRR, particularly for measures related to managing the underlying drivers of risk, such as urban development. Where risk is rising and uncertain, the challenges may be greater, as decisions could be more urgent and higher-stakes, but the benefits are more long-term and uncertain.
- Secondly, there will be additional technical challenges for institutions, requiring new skills and data. There are also existing barriers to the integration of risk information within decision making that must be tackled and may be aggravated by the presence of deep uncertainty.
- Thirdly, the ability of institutions to implement progressive, flexible risk management programmes is unclear, but there are indications of a number of gaps in current capacity, particularly related to learning.

The goals and priorities of the Hyogo Framework for Action (HFA) provide the right foundation for addressing many of these challenges. But, we argue that to tackle the emerging risks will require a scaled up and more urgent implementation of its Priorities for Action. Also, in some areas, the HFA should be strengthened or extended to tackle these emerging risks, for example:

- Stronger focus and guidance on approaches to manage the underlying drivers of trends in risk, including encouraging high-level leadership and the exploration of innovative policies and partnerships.
- Greater recognition of the need to understand and deal with changing and uncertain risks within HFA Priorities 2 (on risk assessment and

early warning) and 3 (on using knowledge to build resilience).

- A new strategic goal that emphasises DRM as a progressive, flexible, learning process, rather than a one-off investment.

The institutions involved in DRM in many least developed countries already struggle to manage current disaster risks (World Bank 2008). While there is evidence of progress in some areas[25] (UNISDR, 2011), many barriers to implementation remain (O'Brien *et al.* 2012; UNISDR, 2009). In this Section, we consider the *additional* challenges brought about by the changing and uncertain landscape of risk described in Section II and the approaches outlined in Sections III and IV.

While in practice a broad range of actors must be involved in DRM, we focus on institutions for two reasons. Firstly, the evidence suggests that quality of a country's governance of risk will have a significant influence on the evolution of risk and its underlying drivers over the coming decades (UNISDR, 2011a). Secondly, Sections III and IV recommend emphasis on forward-looking and long-term risk reduction, which may involve a greater role for national and regional government[26] (Burton *et al.* 2003), both in delivering public goods (such as public infrastructure and information) and in building the legislative and regulatory frameworks, incentives and partnerships to stimulate and support effective, efficient and equitable action by other actors.

We identify four broad areas where barriers may arise, which are discussed in turn below. We find that the evidence on approaches to overcome these barriers is largely consistent with the Hyogo Framework for Action, though there are some new areas which require attention, particularly those related to dealing with uncertainty.

We recognise that the changing and uncertain nature of the risks will also have implications for other actors, with many parallels to the points raised below. However, a full discussion of these implications is beyond the scope of this paper.

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[25] Progress is reported particularly in developing policy, legislative and institutional frameworks, along with risk assessment capacity, for disaster risk reduction.

[26] Burton *et al*. (2003) suggests that local levels actions are typically reactive and short-term; whereas national and regional government tend to have a greater capacity for anticipatory actions.

V.a. A greater focus on ex-ante risk reduction

Institutions involved in DRM in developing countries have in the past devoted far less resources to ex-ante disaster risk reduction, compared with ex-post response (Lal *et al*. 2012; FAO 2008; Dfid, 2011). Ex-post response, which brings tangible and immediate benefits, is often more politically appealing and broadly supported than investments in risk reduction, which can entail greater upfront costs but less immediate, certain and visible benefits (O'Brien *et al.* 2012; Seck, 2007).

This existing challenge may create a significant barrier to dealing effectively with the challenges of climate change and exposure growth, which as Section II suggests, call for a greater emphasis on ex-ante risk reduction. Action may come up against additional barriers particularly where the uncertainties and stakes are high, options are disputed and decisions are urgent (O'Brien *et al.* 2012). Also, long-term risks are often seen as requiring less immediate attention than pressing issues such as economic growth, health and education (O'Brien *et al.* 2012).

Reducing disaster risk and building resilience are recognised as key strategic goals within the Hyogo Framework for Action. To help overcome the barriers identified above, it stresses the need to strengthen institutional structures and to integrate DRR within other policy agendas, such as urban planning (UNIDSR 2011b). It lays out a number of priorities for action in this regard; in particular:

- *Priority 1: Ensure that DRR is a national and a local priority with a strong institutional basis for implementation*. Key activities include making DRR a part of development policies and planning, building appropriate legislative frameworks, fostering political commitments, decentralising responsibilities and resources for DRR and encouraging participation of civil society.
- *Priority 3*: *Use knowledge, innovation and education to build a culture of safety and resilience at all levels.* This includes information sharing and cooperation, networks across disciplines and public awareness.

The emerging challenges of a changing and uncertain risk environment further underline the importance of the activities laid out by the Hyogo Framework for Action.

One example of a programme that is implementing these recommendations is the Asian Cities Climate Change Resilience Network (ACCCRN) [27]. This programme places emphasis on peer-to-peer networking and continued interactions between local planners, climate and disaster experts, in order to build political will and encourage local ownership of DRR within cities, as well as to capture local knowledge, learning and build capacity.

V.b. Managing the underlying drivers of risks

Sections III and IV also called for more emphasis on tackling the underlying drivers of risk trends, such as exposure growth and environmental degradation. Yet, the 2011 assessment of progress against the Hyogo Framework for Action highlighted the lack of progress in this area in many developing countries (UNISDR, 2011b). The evidence points to several (interlinked) barriers to action:

- At the national level, responsibility for DRM is often held within the Civil Defence and Ministries of the Interior, or a National Disaster Management Authority (Sperling and Schezely 2005; Thomalla *et al*. 2006). Typically these institutions will not have the mandate to address the most important drivers of risk, such as development planning (World Bank 2008; UNIDSR 2011). They also tend to lack power to influence the Ministries or Departments that hold such a mandate. This prevents the integration of DRM into development planning and investment decisions.
- Managing the underlying drivers of rising risk often involves complex policy challenges. For example, reducing migration into hazard-prone informal urban settlements requires addressing underlying issues, such as rural employment, changing livelihoods and wealth inequalities (Cutter *et al.* 2007).
- Some activities that increase risk, such as development in hazard-prone coastal areas, can sometimes have significant economic benefits (Hallegatte, 2011). For example, industrial areas on the coast tend to have a higher economic productivity than those inland (associated with transport networks and cheaper access to markets) and so attract further development.

[27] Funded by the Rockefeller Foundation, the ACCCRN network was started in 2009 and works in 10 second-tier cities in India, Vietnam, Thailand and Indonesia. It will run until 2013. www.acccrn.org

- Efforts can be constrained by competing political and economic pressures for development and poverty alleviation, a lack of incentives, social norms or a lack of capacity for enforcement (Mitchell *et al.* 2012; Cutter *et al.* 2007).

The goals and priorities for action set out by the Hyogo Framework for Action are still highly relevant here. Indeed, the urgency of avoiding locking societies into vulnerable development paths strengthens the need to make progress in this area. In addition, there is evidence that progress could be made through:

1. *Seizing opportunities to reduce long-term risks when they come about naturally, for example during reconstruction following a disaster or during urban redevelopment.* This strategy has proved successful (but not the norm) in Mumbai, Delhi and New Orleans (O'Brien *et al.* 2012).
2. *Strong, participatory risk management that facilitates partnerships between the national and local scales.* Managing risk drivers will require both a strong national enabling framework and effective local decision making, with the participation of a range of stakeholders from civil society. For example, urban partnerships between local government, NGOs, and communities in Pakistan and Columbia have been successful in lowering risks to informal settlements, through a combination of improved infrastructure, better services for the urban poor and innovative methods to secure land tenure (UNISDR, 2009).
3. *Taking an integrated and local approach to development needs and DRR.* In Vietnam, the restoration of mangroves plays a key role in the production of exports such as shrimps and crabs as well as protecting the community's homes, agricultural lands, livestock from storm surges (UNISDR, 2007; 2009).
4. *High-level leadership and champions.* The Kiribati Adaptation Program (KAP) is guided within the Office of the President, ensuring high-level champions and leadership. With this support, on the basis of extensive consultation, the KAP is successfully integrated across national development strategies and sectoral plans, and tied directly into all priorities and activities identified by the government planning documents (Mitchell *et al.* 2012).
5. *Ensuring attractive alternatives to unsustainable practices.* For example, incentivising urban development away from hazard-prone coastal areas by providing businesses with safe development zones that are connected to ports by efficient transport networks and

by providing cheap, rapid public transport from job centres to safe residential areas that can be developed (Hallegatte, 2011).

V.c. Challenges to technical capacity and decision making

The complexity and uncertain nature of long-term risk may bring several additional challenges to the institutions involved in DRM. For example:

- The lack of technical capacity and risk information can already create a barrier to DRM (WB 2008; Prabhakar *et al*. 2009). To tackle these new challenges, additional skills and data may be required. There is progress in developing these capacities, for example for climate change adaptation, but the institutions involved in DRM are often not integrated with these institutions (UNIDSR 2011; Prabhakar *et al*. 2009; Schipper and Pelling 2006).
- The nature of risks and uncertainties may raise fundamental psychological barriers to action. For example, individuals often underestimate the likelihood of rare but catastrophic events[28], and can misjudge external drivers of risk and overestimate their own response capacity (O'Brien *et al.* 2012; Hertwig *et al.* 2004). Responding rationally to slow-onset long-term drivers, such as climate change, can also be inhibited by difficulties in making trade-offs across time and between options with uncertain benefits (Cutter *et al*. 2012; O'Brien *et al*. 2012). These barriers may adversely affect judgements about the allocation of efforts to address risks (Cutter *et al*. 2012).

There are also a number of existing barriers to be overcome; risk assessments and decision analyses are important, but have little value if they are not integrated appropriately within institutional decision making structures. Lal *et al*. (2012) found limited evidence that national systems and associated measures are explicitly integrating knowledge of projected future changes in risk.

This evidence provides some insights into the potential barriers to action, but there are significant gaps in our understanding of how institutions will respond in an environment of changing and deeply uncertain risk. For example, little is known about how DRM institutions are making decisions under current conditions of uncertainty, and how, if at all, this will change under deep uncertainty (Lal *et al.*, 2012). It is also unclear how uncertainties are managed across scales from international frameworks to national DRM organisations, local

[28] Conversely, when disasters occur, people's estimates of their future risk are temporarily inflated (Weber *et al.* 2004).

implementation and community responses, and which scale is appropriate to manage uncertainties (Prabhakar *et al*. 2009). This is pertinent given the shift towards decentralisation of DRM (Scott and Tarazona 2011).

The Hyogo Framework for Action stresses the need to identify, assess and monitor disaster risks (including climate modelling) (Priority 2), as well as activities to enhance the use of knowledge, such as information sharing networks, training at multiple levels, public awareness and developing research capacity (Priority 3). These activities must be implemented in a way that explicitly recognises the need to deal effectively with changing and uncertain risks. For example, training programmes should aim to build an understanding of approaches to deal with uncertainty in decision making. In addition, we suggest there is a need for:

1. *Building institutional frameworks to better exchange knowledge and capacity across policies and programmes relevant to DRR.* For example, the Bangladesh Comprehensive Disaster Management Programme (CDMP) has a disaster management information centre and a climate change cell (Luxbacher and Goodland 2010). This arrangement allows for easy transfer of scientific information and capacity, as well as a concrete institutional link between current disaster risk and future risks.
2. *Using participatory approaches to decision making that build a shared understanding of the nature of the risks, uncertainties and options.* Participatory approaches facilitate the engagement of a wide range of stakeholders and can help to build support for DRM strategies (O'Brien *et al.* 2012). Practice suggests that qualitative approaches, such as building scenarios and narrative storylines, can be effective communication tools where uncertainties are high (Lempert *et al.* 2003).

V.d. Implementing flexible, progressive decision making processes

Responding to a changing and uncertain risk environment may require more flexible and adaptive institutions that are able to monitor and learn from disasters, and broader impacts, and innovate for the future (Pahl-Wostl 2009; Berkhout *et al.* 2006). Yet, there is little evidence on how this can be achieved in practice (Lal *et al.*, 2012) and how such an approach would fit within current institutional frameworks.

There is evidence of barriers to learning in some areas; for example, a survey of Sub-Saharan African countries suggested that few would review, update and improve their DRM plans over time (WB 2008). There is also evidence of a lack of information and knowledge management within DRM organisations, which has constrained the ability of the organisations to learn from changing circumstances (FAO 2008; WB 2008). Better understanding this capacity is an important area of future research.

The goals and priorities of the Hyogo Framework for Action can support action in this area, but importantly, they do not emphasise DRM as a progressive, flexible and learning process. There is a need for more work in this area to develop a set of recommendations that could inform future action. A high level review of the literature suggests some initial recommendations, for example:

1. *(a) Implementing processes to regularly review the effectiveness of DRM and (b) building appropriate governance structures that integrate this knowledge progressively into decision making at multiple-levels, from local to national.* For example, the Cayman Islands have a National Hurricane Committee that assesses the response to hurricanes at multiple levels and identifies successes and failures. This is incorporated into the National Hurricane Plan which ensures that findings are institutionalised (Tompkins 2005). This regular learning process should help to ensure that the Committee is able to react quickly to changing risks or vulnerabilities.

Structuring risk management programmes (and associated institutional frameworks) with long-term mandates, which allow flexibility in plans, and a clear mandate for monitoring, review and updates. For example, the Yangtze River project in China addresses flooding issues in the basin through a 30 year master plan with regular 5 year updates (Pittock and Xu 2010). The long-term mandate allows the officials to plan ahead for future risks as well as re-evaluate every five years for new threats.

VI. IMPLICATIONS FOR SCIENCE AND TECHNOLOGY

Key Messages

Science and technology, though not a panacea for DRM, can improve our ability to prepare for and respond to the emerging risks. To improve the application of new science and technology, key priorities may include:

- International research and collaboration to apply the emerging science and technology in closing the gaps in our understanding of current vulnerability, exposure and hazards and the drivers of risk.
- Understanding and building the capacity to interpret risk information and integrate it appropriately within decision making structures.
- Building knowledge and capacity to implement progressive and flexible risk management frameworks, which are able to learn and respond to changing information.

In the process of this research, we have identified a number of gaps in current scientific knowledge that may constrain the capacity to cope with the challenges of a changing and uncertain risk environment. Most fundamental of these are the gaps in our knowledge of current vulnerability, exposure and hazards, and the drivers therein. Improved risk information will provide a stronger basis for DRM.

Yet, risk information can only be beneficial where there is the capacity to use it effectively and integrate it within decision making structures. There are important local capacity gaps that must be resolved before new science can have tangible benefits (UNISDR, 2011). Programmes that aim to build this capacity will have tangible benefits today and should be a priority for research and action.

Some scientists have stressed the importance of developing more accurate climate projections as part of this. While continued investment in climate science and modelling is crucial, we argue that investments in other areas may have greater benefits: firstly, research is unlikely to yield significant reductions in uncertainties in the near-term (Dessai *et al.* 2009); and secondly, it has been shown that uncertainty need not paralyse action today and there is now a library of guidance on the design of robust strategies (Section IV.b). Consequently, we suggest that there is greater value in focusing investments and further research in developing the capacities, knowledge and skills to use the currently available information more effectively.

There are also gaps in our understanding of how to achieve the necessary flexible and progressive risk governance frameworks to manage long-term and uncertain risks in practice (Section V.d). There is an urgent need to build the knowledge base in this area through empirical research and pilot studies.

There is much work already on-going in many of these areas. One example is the international research programme, Integrated Research on Disaster Risk (IRDR). It has three main objectives: (i) the characterisation of hazards, vulnerability and risk; (ii) understanding decision-making in complex and changing risk contexts; and (iii) reducing risk and curbing losses through knowledge-based actions. These types of programmes should be ramped up to address the challenges ahead, but, to the extent practicable, must be participatory and focussed to ensure that the knowledge generated has tangible benefits in terms of building national and local capacity.

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