LLOYD'S

Innovation Report 2018

Understanding Risk

Innovative finance for resilient infrastructure

In association with

CENTRE FOR GLOBAL DISASTER PROTECTION

UKaid from the British people

RMS

: vivideconomics

re:FOCUS PARTNERS

Disclaimer

This report has been co-produced by Lloyd's and the Centre for Global Disaster Protection ("the Centre") for general information purposes only. This does not reflect the views of the UK Department for International Development or the World Bank Group and additionally does not necessarily reflect the views of any of our partners. While care has been taken in gathering the data and preparing the report and the information herein, Lloyd's, the Centre and RMS do not make any representations or warranties as to its accuracy or completeness and expressly excludes to the maximum extent permitted by law all those that might otherwise be implied. Lloyd's, the Centre, DFID, RMS and the World Bank Group accept no responsibility or liability for any loss or damage of any nature occasioned to any person as a result of acting or refraining from acting as a result of, or in reliance on, any statement, fact, figure or expression of opinion or belief contained in this report. This report does not constitute advice of any kind. RMS results are included in this report for general information purposes only and none of the content is intended to constitute risk management advice or a recommendation to make (or refrain from making) any kind of risk management decision and may not be relied on as such. Any results of RMS' contained in this report are RMS' proprietary and confidential information and may not be used by any recipient of this report without RMS' prior written consent.

About Lloyd's

Lloyd's is the world's specialist insurance and reinsurance market. Under our globally trusted name, we act as the market's custodian. Backed by diverse global capital and excellent financial ratings, Lloyd's works with a global network to grow the insured world – building resilience of local communities and strengthening global economic growth.

With expertise earned over centuries, Lloyd's is the foundation of the insurance industry and the future of it. Led by expert underwriters and brokers who cover more than 200 territories, the Lloyd's market develops the essential, complex and critical insurance needed to underwrite human progress.

About the Centre for Global Disaster Protection

The Centre for Global Disaster Protection was launched by UK Prime Minister Theresa May in July 2017 with the goal of working with governments to strengthen pre-disaster planning, catalyse innovative finance for resilience and use risk financing tools like insurance to protect people and speed response and recovery. The Centre brings together partners including the UK Government, the World Bank, civil society and the private sector with the shared goal of enhancing the financial resilience of developing countries to climate and disasters. The Centre is funded by the UK Department for International Development (DfID).

About Risk Management Solutions

For almost 30 years, RMS' mission has remained constant: to make communities and economies more resilient to disasters through a deeper understanding of catastrophes. Today, RMS is a leading provider of products and services that help governments, public agencies, corporations, financial institutions and their clients to evaluate and manage catastrophe risks throughout the world. Operating from twelve offices across the Americas, Europe and Asia, RMS serves hundreds of clients around the world, collaborating with them to help them build the capacity required to manage their risk.

About Vivid Economics

Vivid Economics is a leading strategy economics consultancy with global reach. We strive to create lasting value for our clients, both in government and the private sector, and for society at large.

Vivid Economics is a premier consultant in the policy-commerce interface and resource and environment-intensive sectors, where we advise on the most critical and complex policy and commercial questions facing clients around the world.

The success it brings to its clients reflects a strong partnership culture, solid foundation of skills and analytical assets, and close cooperation with a large network of contacts across key organisations.

Key contacts

Trevor Maynard
Head of Innovation
innovation@lloyds.com

For general enquiries about this report and Lloyd's work on emerging risks, please contact innovation@lloyds.com

RMS project team
- Daniel Stander, Global Managing Director
- Charlotte Acton, Director
- Conor Meenan, Senior Consultant
- Jed Scanlon, Analyst

Vivid Economics project team
- John Ward, Managing Director
- Irena Sekulska, Engagement Manager
- Luke Kemp, Senior Economist
- David Ren, Economist

Lloyd's project team
- Dr Trevor Maynard, Head of Innovation
- Lucy Stanbrough, Innovation Associate
- Rebekah Clement, Speech and Studies
- Flemmich Webb, Speech and Studies

DFID project team
- Mark Povey, Infrastructure Adviser
- Dr Nicola Ranger, Senior Adviser on Disaster Risk Financing and Insurance
- Daniel Clarke, Actuary
- Peter Bentley, Adviser, Private Sector Department
- Harvey Naylor, Policy Adviser
- Dr Harriette Stone, Financial Sector Team

Acknowledgements

The following people were interviewed, took part in workshops or roundtables, or commented on earlier drafts of the report; we would like to thank them all for their contributions:

Innovation lab workshop and consultation
- Gilbert Harrap, MS Amlin
- Adam Beatty, Nephila
- Brendan Plessis, XL Catlin
- Emma Radcliffe, XL Catlin
- Benjamin Baltesar, Hiscox
- Ian Branagan, Ren Re
- Emma Whiteacre, Beazley
- Andreas Prystav, Swiss Re
- Benjamin Antwi-Boasiako, Allianz
- Michael Roth, Munich Re
- Tony Stubbs, Parhelion
- Nigel Brook, Clyde &Co
- Jo da Silva, Arup
- Ian Callaghan, Ian Callaghan Associates
- Simon Young, GeoSY
- Madeleine Rawlins, Mott Macdonald
- Espen Nordhus, Securis Investments
- Peter Buettner, First River Partners
- Gavin Newton, Willis Towers Watson
- Jacqueline Wharton, Willis Towers Watson
- Carlos Sanchez, Willis Towers Watson
- David Simmons, Willis Towers Watson
- Emily Wilkinson, ODI
- Jane Newman, Social Finance UK
- Jun Rentschler, World Bank
- Rashmin Gunasekera, World Bank
- Theodore Purnendu Talbot, Global Partnership
- Judith Amar, START Network
- Claire Souch, AWHA Consulting
- Kerstin Pfliegner, The Nature Conservancy
- Federico Berna, European Commission
- Nick Lane, PwC
- Tom Strickland, PwC
- Miroslav Petkov, S&P Global
- Peter Datin, RMS
- Robert Muir-Wood, RMS
- Tony Lloyd-Jones, Westminster University
- Jamie Rhodes, re:focus
- Shalini Vajjhala, re:focus
- Ruth Hughes, NERC
- Piran White, York University
- Swenja Surminski, LSE
- Paul Bispham, Actuarial Regulatory & Tax Advisors Limited
- Harvey Duckers, Actuarial Regulatory & Tax Advisors Limited
- Ian Rogers, GAD

Further thanks go to the authors of the 'Financial Instruments for Resilient Infrastructure' report

RMS project team
- Charlotte Acton, Director
- Conor Meenan, Senior Consultant
- Jed Scanlon, Analyst

Vivid Economics project team
- John Ward, Managing Director
- Irena Sekulska, Engagement Manager
- Luke Kemp, Senior Economist
- David Ren, Economist

DFID project team
- Mark Povey, Infrastructure Adviser
- Dr Nicola Ranger, Senior Adviser on Disaster Risk Financing and Insurance
- Daniel Clarke, Actuary
- Peter Bentley, Adviser, Private Sector Department
- Harvey Naylor, Policy Adviser
- Dr Harriette Stone, Financial Sector Team

re:focus project team
- Shalini Vajjhala, Founder & CEO
- Jamie Rhodes, Director

All icons have been sourced and licencensed from the Noun project.

Date of publication: October 2018

Contents

Executive summary

This report, published by Lloyd's in association with the UK's Centre for Global Disaster Protection, identifies and provides an outline design of four financial instruments that could be used to incentivise and deliver greater investment in resilience.

The instruments were developed through the Centre's first 'Innovation Lab', which brought together experts from a range of sectors, including finance, insurance, engineering, humanitarian and development. Together they created initial 'strawman solutions', identified the main challenges to implementation and discussed ways to overcome these challenges.

The Lab built upon a detailed literature review of the state of infrastructure finance and analysis of existing financial instruments, directly and indirectly related to resilience. Experts worked on hypothetical case studies based on real-world settings, using background informationand modelled examples of the resilience benefits for each case.

Background

Global economic losses from disasters are substantial and growing. They will continue to increase, driven by greater wealth, hazard exposure and, for some events, climate change. Developing countries are affected disproportionately by these events and their losses are often compounded by poorly designed and constructed infrastructure, inadequate maintenance, a lack of insurance and delayed recovery.

However, the severity of impact can be reduced by investing in greater resilience, creating a so–called "resilience dividend". This dividend is the sum of the benefits of greater resilience, which include both reduced asset damage and faster economic recovery post disaster.

Greater resilience also gives confidence to businesses by lowering risk, thereby stimulating innovation and economic growth. There are strong and proven arguments in favour of investing in greater resilience – some studies show that the benefits of such investment exceed its costs by a ratio of four to one.

Despite the evidence, many countries do not invest as much as they need to realise these benefits, mainly due to higher up–front costs, misaligned incentives and a lack of information. This is particularly the case in developing economies where the benefits of improved resilience are often perceived as intangible or only likely to materialise in the distant future.

This lack of investment in resilience has a substantial economic and human cost, and in many cases acts as a drag on the economic growth of developing nations, particularly those that are prone to frequent disasters. For example, last year's hurricane season left Dominica – a small island state with a GDP per capita eight times lower than the US – suffering losses of 224% of GDP.

Encouraging greater investment in resilience

One cost–effective way of improving resilience is through financial instruments, including insurance products. Well–designed insurance products can incentivise pre–disaster response planning, so that when disruptive events take place agencies take quick decisions and distribute resources effectively and fairly.

As a result, insurance can be an effective part of a layered risk management strategy to deliver post–disaster finance. Research also shows while uninsured losses often lead to a drop in economic growth, growth is protected if these losses are insured.

Another benefit is that with careful design, insurance and investments in resilience can be mutually reinforcing. Greater resilience reduces risk, which is then reflected in lower insurance premiums[a], providing a strong financial incentive to make suitable investments.

As well as providing insurance cover, insurers often play a valuable role in helping governments and other stakeholders understand and "price" their risk exposure

[a] As an alternative, insurance provision can be made conditional on undertaking resilience investments.

before events take place. Disasters represent a significant contingent liability for governments. This liability is not clearly defined by law, so governments often find themselves acting as insurers of last resort, in some cases without knowing exactly what their disaster risk exposures are (*The World Bank & Swiss Confederation, 2011*). By working with insurers, governments can better assess, understand and manage these risks.

Four financial tools to improve resilience

This report examines four innovative financial mechanisms that help monetise the resilience dividend for investors, thereby providing a strong economic case and financial incentive for investing in greater resilience. Two were chosen for cash flow modelling – the insurance–linked loan package and the resilience impact bond – to help illustrate the viability of promoting resilience as well as the role that insurance can play in enhancing it. The four mechanisms are:

- Insurance–linked loan package: an infrastructure loan, which has a built–in insurance component. Insurance premium savings based on the subsequent risk reduction derived from the insurance cover are used to offset the loan's interest repayments.

  The product may be well–suited to large infrastructure projects in high–risk regions, ideally involving a portfolio of multiple assets. It can be easily modified to include donors keen to reduce interest costs on loans for critical resilient infrastructure. This mechanism requires only small changes from existing practices to make it applicable to building greater resilience.

- Resilience impact bond: a pay–for–performance contract between a donor, funding greater resilience and social goals, and a group of investors. The donor makes payments to the investors depending on their success in delivering physical, operational and financial resilience measures, incentivising investors to be as efficient as possible by transferring the delivery of the resilience dividend to the investor.

  This product is particularly well–suited to cases where the benefits of resilience are spread widely across a community, such as services provided by schools, social care bodies and hospitals The requirement to take out insurance to cover losses associated with disasters would be specified as one of the measures of resilience against which the donor would make a payment.

  In addition, the impact investor may also choose to take out insurance to ensure it has sufficient resources to implement disaster response and contingency plans needed to meet the criteria for payment. The investor may also seek insurance to protect against the risk of receiving a smaller pay–out from the donor, on account of not meeting all of the resilience metrics.

- Resilience bond: an innovative risk–linked financing mechanism that builds on the existing catastrophe bond model to take account of the positive impact of resilience measures. Under this structure, when resilience measures are implemented, coupon payments on the bond are reduced. The reduction in coupon payments can be securitised, thereby providing a way of funding investment in greater resilience.

  This product is well–suited to cases where several different stakeholders have a common interest in enhancing the resilience of services provided by a critical asset, such as a coastal road or port.

- Resilience service company (ReSCo): this product/business model involves an agent who pays upfront for an insured asset, in return for a share of future insurance premium savings. The approach was inspired by the innovative financing mechanisms employed by Energy Service Companies (ESCOs).

  It may be best suited to situations where there are many diffuse but similar assets, such as residential or commercial property assets, that are all subject to frequent disaster events.

Conclusions

Investment in greater resilience can be a cost–effective way of mitigating the risks posed by disasters and reduces the costs of recovery from them.

Resilience measures that demonstrably reduce risk can result in realised cash savings through reductions in insurance premiums. In other words, where insurance is already in place, insurance provides a vehicle for monetising the resilience dividend. Public (donor) funding provides a complementary means of allowing investors to realise a financial return from resilience measures. The insurance–linked loan package and resilience impact bond transfer these cashflows to a structure or party who is able and willing to receive them over a longer timeframe.

Further work is required to make the four products analysed in this report applicable for real–world use. In the case of insurance–linked loan packages and resilience impact bonds, further development and design could be undertaken by convening a group of interested stakeholders to pilot the products in a specific context. This would generate useful information that can be added to the significant practical experience that already exists. In the case of resilience bonds and resilience service companies, more research is needed to demonstrate proof of concept in a developing economies context, using similar analysis to that deployed in this report.

Further work can also be done to explore the broader societal and economic benefits of greater resilience beyond the reduction in expected damage and losses caused by disasters. These benefits have not been included in the risk and cash flow modelling for the financial mechanisms in this report. Quantification of these benefits could allow future financial structures to monetise these benefits more directly. This would increase the incentive for using these sorts of instruments.

Policymakers have a critical role to play in driving forward the development of these and similar products, tailoring their design and sponsoring pilots. The significant public benefits from investment in resilience justify the public funding these products often require to be successful. This work should form part of a broader effort by policymakers to invest in risk data gathering and monitoring, disaster preparation and planning in key sectors, and implementing systems and tools to improve resilience. Donors are likely to have a particularly important role in environments with high discount rates and in less developed insurance markets.

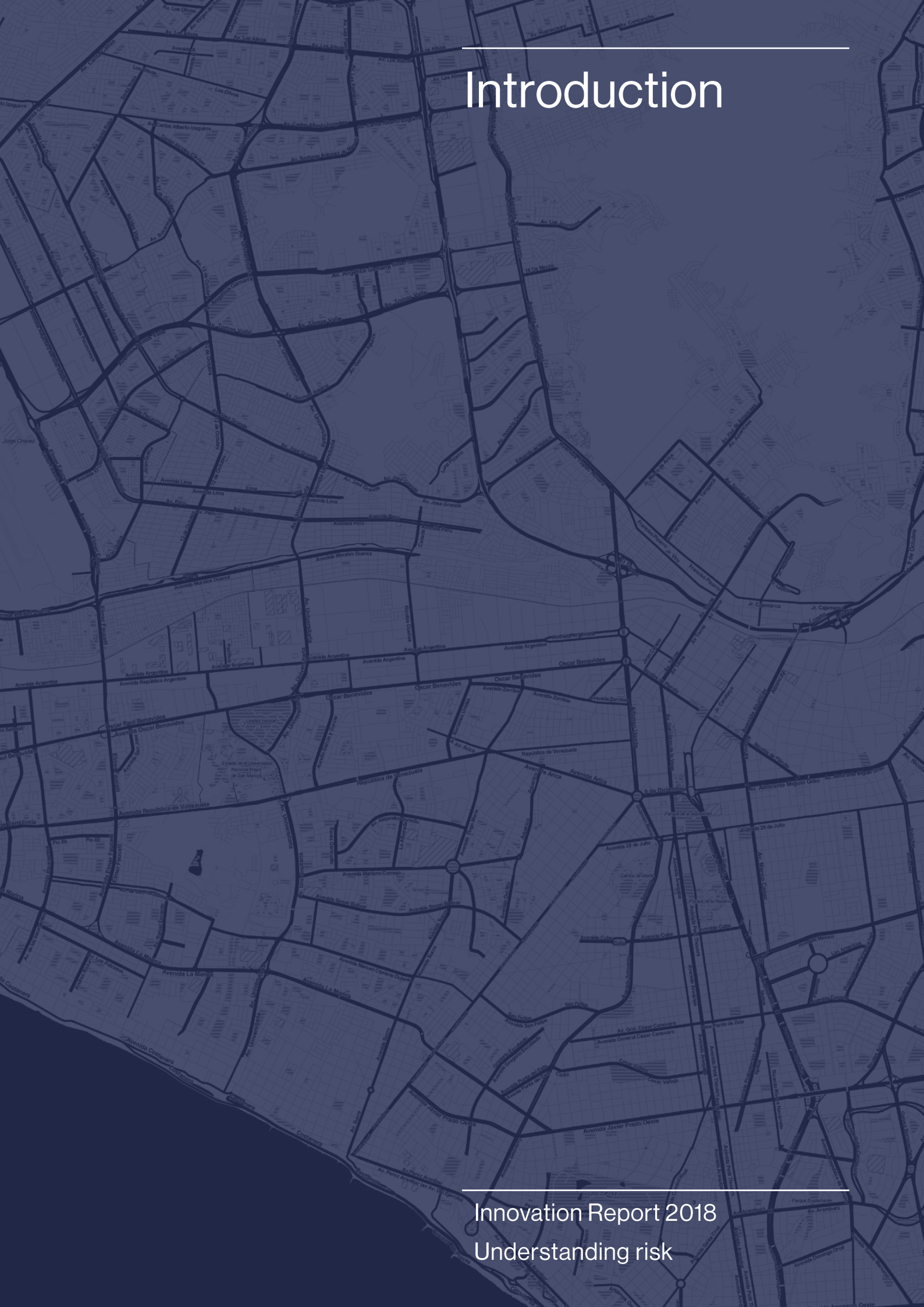
Risk-based pricing within insurance policies will help policymakers. The financial mechanisms analysed in this report, with the exception of the resilience impact bond, rely on the reduction of risk to physical assets that investment in greater resilience brings and access to insurance pricing which fully reflects this risk reduction.

Reasonable certainty that investment in resilience will result in reduced insurance premiums is required to stimulate innovation in this area and insurers must continue to reflect ongoing improvements to their understanding of the underlying risk in their pricing. Insurers could also help policymakers by providing risk modelling and assessment advice, guidance on risk financing tools, and support to help push resilience up the political agenda.

Next steps

- Test the four financial mechanisms with developing countries, the private sector and donors to gauge interest and real–world potential.
- Develop criteria to determine in what situation each product is useful, e.g. for infrastructure such as schools.
- Investigate how these financial mechanisms could be brought to market and what the role of DFID and other donors should be[b].

[b] For further details please refer to 'Financial Instruments for Resilient Infrastructure' (RMS, 2018a).



Introduction

Innovation Report 2018

Understanding risk

1. Introduction

This study explores how innovative financial mechanisms, which combine funding and incentives for resilience with insurance, can play a critical role in reducing the worst impacts of disasters. The mechanisms do this both by building resilience before a disaster strikes and by driving a quick and coordinated recovery afterwards.

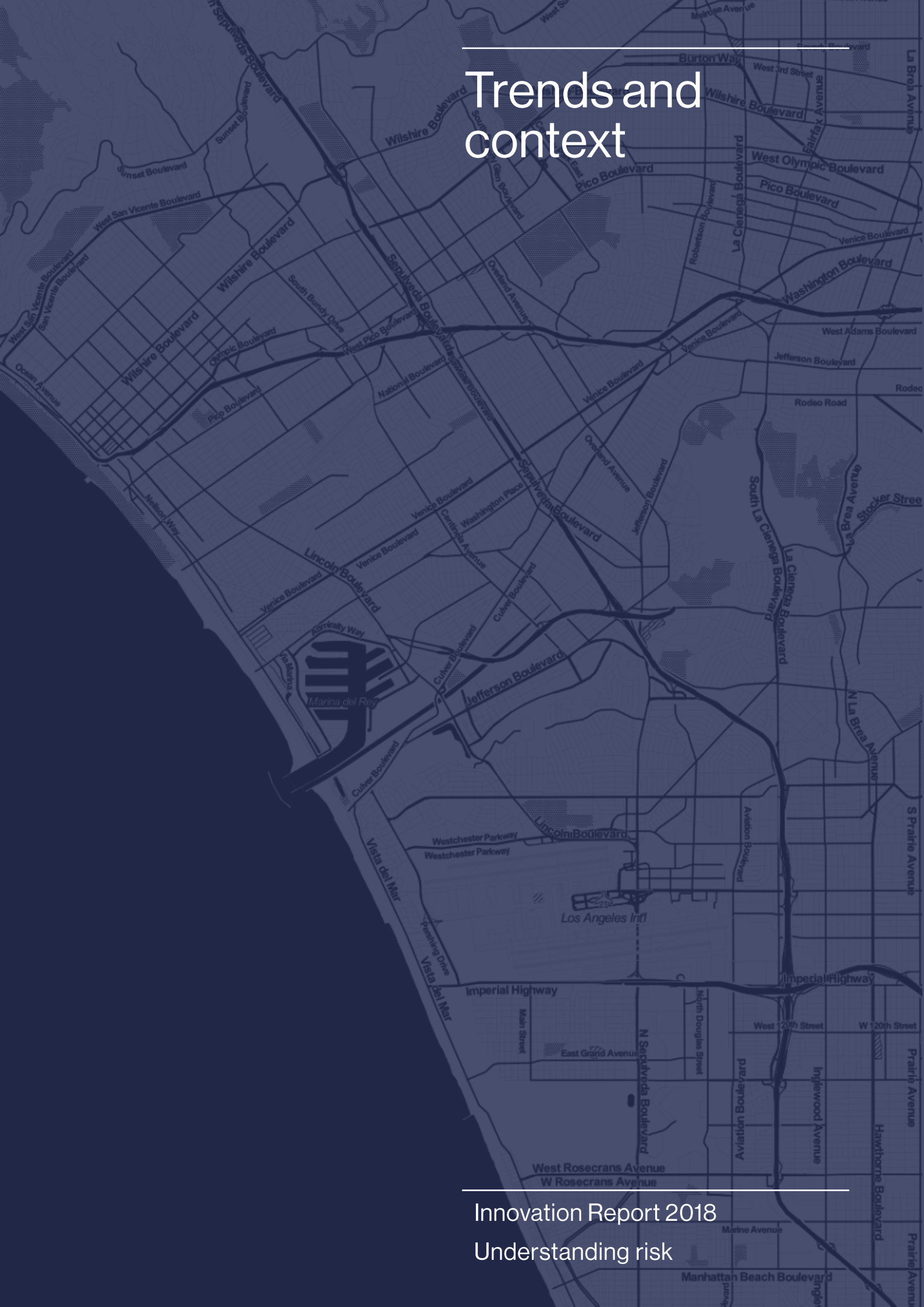
The products emerged from an Innovation Lab run by The Centre for Global Disaster Protection[c], in partnership with Lloyd's. This convened experts from across the financial services, development, humanitarian and engineering communities to catalyse new thinking on how innovative financial instruments can help respond to the global resilience challenge.

Lloyd's continues to support this topic and sees the Lab and the products as a pathway to building developing countries' understanding of and access to the insurance products, in alignment with the InsuResilience and Insurance Development Forum goals. As part of these efforts a group of businesses at Lloyd's have launched a Disaster Risk Facility, which pools $445m capacity along with the expertise to develop reinsurance solutions for natural catastrophe risks in emerging economies.

The report is structured as follows:

- Section 2 provides the critical context for the study, highlighting the growing damage caused by disasters, and how these damages are exacerbated by underinvestment in resilience, underinsurance, and delays in recovery and reconstruction.
- Section 3.1 explores the concept and importance of resilience measures in more detail and some of the key barriers that need to be overcome to deliver and maintain resilient infrastructure.
- Sections 3.2 and 3.3 discuss the complementary role that risk transfer options can play in building resilience and ensuring that communities and society can bounce back better and faster after disasters strike.
- Section 4 outlines four instruments that combine incentives for constructing and maintaining resilient infrastructure with risk transfer solutions. Their aim is to allow people to build better – and build back better.

[c] The Centre for Global Disaster Protection is a partnership between the UK Government and World Bank and works with governments and humanitarian agencies to strengthen pre-disaster planning, catalyse innovative finance for resilience and use risk financing tools like insurance to protect people and speed up response and recovery times.



Trends and context

Innovation Report 2018

Understanding risk

2. Trends and context

Global economic losses from disasters are substantial and growing. They will continue to increase in the absence of action, driven by greater wealth, hazard exposure and, for some events, climate change. Developing countries are affected disproportionately by these sorts of disruptive events and their losses are often compounded by poor infrastructure, inadequate maintenance, a lack of insurance and delayed recovery.

2.1 Disaster trends

The global economic and human losses from disasters are enormous. The 2017 hurricane season, aside from the record–breaking losses, generated losses of large magnitude in several different classes of insurance and from different types of loss events from Harvey, Irma and Maria (HIM). Insured industry losses for Harvey are likely to represent a relatively small proportion of total economic losses, with a suggested range of $25–35bn (*RMS, 2018*) with Lloyd's net losses being $1.6bn in 2017 financial results[d].

The 2017 hurricane season was the costliest on record with losses of $215bn *(Munich Re, 2018)*. As shown in Figure 1 *(overleaf)*, modelled losses from Hurricane Maria were in the region of $1.8–2.2bn and those for Hurricane Irma in the region of $18.4–19.3bn. These events helped contribute to the costliest hurricane season on record *(Munich Re, 2018)*.

By the end of 2017 it was recorded that more than 11,000 lost their lives as a result of all disasters *(Swiss Re, 2018)* and preliminary estimates suggest total economic losses range from $300–330bn, 40–60% of which were not insured *(Munich Re, 2018; Swiss Re, 2018)*.

Global losses due to disasters are rising. 2017 is unlikely to be an outlier. The average annual cost of damages has increased by almost 10 times between the 1970s and this decade, driven by increased wealth, hazard exposure and, for some events, climate change *(Ranger and Surminski, 2013)*. Swiss Re *(2018)* data suggests annual average losses since 2010 ($203bn) have been around 50% higher than in the previous decade, and almost twice the average losses in the 1990s. RMS analysis suggests that in terms of U.S. and Caribbean industry insured wind, storm surge and flood losses, the 2017 hurricane season corresponds to a return period of between 15 and 30 years *(RMS, 2018)*.

Future climate change will exacerbate these trends. In 2017, weather related disasters were responsible for more than 95% of the losses from disasters (*Swiss Re, 2017*). Climate change will make many of these extreme events more frequent and severe, resulting in unprecedented, destructive events *(IPCC, 2014; IPPC, 2012)*.

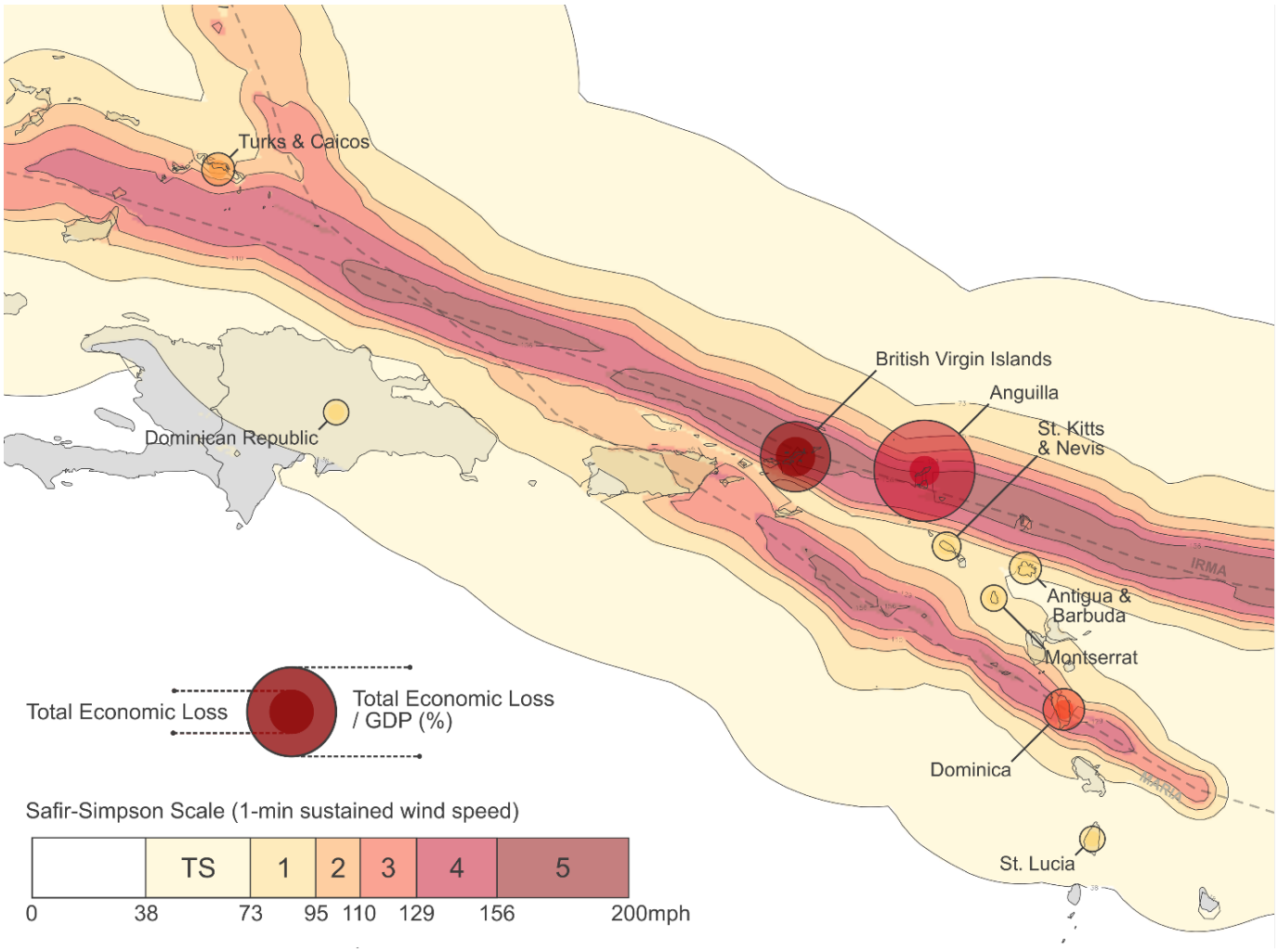
Disasters hit developing and vulnerable countries disproportionately harder. Last year's hurricane season left Dominica – a small island state with a GDP per capita eight times lower than the US – suffering losses of 224% of GDP. Direct economic losses[e] from disasters are 14 times higher in low–income countries than high–income countries *(Ranger and Surminski, 2013)*, while low– and low–middle income countries account for 81% of fatalities from disasters *(UNDP, 2014)*. Low–income, high–exposed countries such as Bangladesh can suffer losses of approximately 3–5% of GDP every 5–10 years from recurring disasters *(OECD, 2015)*.

Many of these losses, especially in developing countries are not insured. 40–60% of losses from disasters in 2017 were not insured. While the proportion of losses not insured has been steadily decreasing over time, yet insurance still regularly covers under half of total losses. Underinsurance is highest in developing countries. Today, nearly 90% of economic losses from disasters in low–income nations remain uninsured. Recent catastrophes demonstrate both the insurance gap, and the difference in coverage between developing and

[d] Lloyd's 2017 Annual Results, Analyst Presentation, 21 March 2018.

[e] As a % of GDP

Figure 1: Hurricanes Irma and Maria, modelled direct economic loss estimates, and loss as a function of GDP, for a subset of Caribbean islands



Map shows RMS HWind 1–min sustained wind speed footprints, with relative modelled impact shown for a subset of Caribbean countries affected by the hurricanes. Modelled economic loss estimates reflect expected direct damage and loss to residential, commercial and industrial type structures within the islands. Results are derived from RMS's best understanding of modelled loss to the region which sits within a range of plausible losses that are defined by uncertainties that still exist in wind speeds, vulnerability, and post–event loss amplification, including non–modelled effects such as prolonged power outages in Puerto Rico.

Source: RMS in *(Centre for Global Disaster Protection, Department for International Development and Lloyd's, 2018)*

developed countries. In Ecuador, the Government requested $3.3bn for recovery from an earthquake struck in April 2016. It was only capable of covering $2.3bn (67%) of the costs *(Pestano, 2016)*. In contrast, of New Zealand's estimated $30bn economic losses (direct and indirect) in 2010 and 2011 *(Deloitte, 2015)*, following the destructive earthquakes in Christchurch, 75% were picked up by international insurers with payouts totalling over $20bn *(ICNZ, 2018)*.

Loss estimates are often even higher than suggested by headline statistics. Most estimates do not consider the impacts of disasters on the informal sector[f], or the knock–on impacts from a disaster on, for example, the fiscal position of the country *(United Nations, 2015)*. These neglected areas can comprise a significant part of the costs of disasters. Losses from disasters might be 50% higher once impacts on informal businesses[g] and low–income households are included *(UNDP, 2014)*.

Disaster losses are exacerbated by both poor infrastructure and delays in recovery. While disasters cannot be avoided, the economic costs and human impacts are often aggravated by two factors:

1. Poorly constructed and badly maintained infrastructure, and
2. Delayed response post disaster, as explored further in the following section.

2.2 Underinvestment in resilience

Under investment in resilience is not cost–effective in the long run. Infrastructure lasts a long time and risk levels are changing all the time due to ongoing global megatrends. This makes it crucial to implement building codes that are robust in the light of both current and future risks. Implementing risk assessment and resilience can also be particularly challenging in developing countries where interventions may be less financially viable, or in places with moderate or low–frequency hazard profiles, where there can be greater complacency.

RMS analysis clearly outlines this by suggesting that Caribbean damage costs from hurricanes Irma and Maria could have been of the order of $16.5bn less had impacted buildings across all islands been constructed according to 2018 design codes (Centre for Global Disaster Protection and Lloyd's, 2018). Proportionate savings would likely be significantly higher for less extreme events with a more frequent return period.

There are numerous examples in the literature. For example, Arup (*2014*) found that a $3bn upgrade of the electrical grid of New York would save more than $3bn in terms of lower maintenance and disaster repairs, and generate a further $4bn of economic benefits including avoided disruptions to business.

Inadequate maintenance further undermines infrastructure resilience. The challenges are not restricted to ensuring that infrastructure construction is of a high standard; maintenance is often not performed, or done poorly, leaving infrastructure more vulnerable to disasters. In Puerto Rico, high government indebtedness impacted spending on maintenance, significantly worsening the impact of Hurricane Maria and helping to explain why 7% of utility customers were still without power six months after Maria struck *(Irfan, 2018)*.

After the 2004 tsunami, southern Sri Lankan regions recovered much more quickly than northern regions, a pattern that can be largely explained by the better maintained infrastructure in the south, as well as its stronger institutional capacity and political stability *(Palliyaguru, et al., 2007)*.

To better manage risk and recover quickly from future disasters infrastructure owners and operators must move beyond asset–by–asset risk management to build resilience within, and between, infrastructure systems. This requires consideration of how infrastructure performance might change when shock or stress events occur.

Ongoing maintenance of infrastructure assets[h] can be considered from the earliest stages of business case analysis to ensure sustainable funding models are in place, along with contract structures which incentivise maintenance (such as Public Private Partnerships or Private Finance Initiatives) *(Arup and Lloyds, 2017)*. "Low maintenance design" can be particularly beneficial in harsh environmental conditions, or where funding is scarce. "Designing for maintenance" ensures infrastructure design supports access and maintenance. "Effective maintenance" requires properly trained human resources and systems for accountability *(Arup and Lloyds, 2017)*.

[f] The informal sector refers to those without registration or social security, *(Benjamin, Beegle, Recanatini and Santin, 2014)*. This might include, for instance, domestic workers and casual day labourers.

[h] Refer to ISO 55000.

2.3 Delay has a high price

The costs of disasters are compounded by slow recovery resulting from a lack of readily available finance. Recovering infrastructure quickly can save lives, minimise economic and social losses, and prevent a domino–effect of other connected infrastructure systems failing (*Lloyd's, 2017*). More can be done before an event to build resilience and reduce the impacts on people.

Donor countries and development banks have traditionally responded post–disaster. The United Nations closed 2017 asking for a record $24bn to tackle crises in more than 30 countries. International donors covered only 52% of these funding needs *(UNOCHA, 2018)*. The gap between humanitarian requirements and available funding has been growing since 2004 *(UNOCHA, 2018)*.

This means that humanitarian relief and recovery funds are uncertain, typically taking anywhere between one to nine months to be dispersed *(World Bank, 2017)*. A recent example of how a lack of pre–established responses and agreed finance can escalate costs comes from the World Health Organisation (WHO). WHO research estimated the outbreak of Ebola in West Africa would have cost $5m to contain when it was first detected in Guinea in 2014. This figure increased exponentially to $1bn eight months later *(Woo, 2015)*.

In other cases, the challenge is not a lack of finance but instead problems of preparedness, regulatory and contractual issues, or capacity constraints. In Nepal, many citizens continued to live in improvised shelters more than 18 months after the 2015 earthquakes *(Kumar 2016)*. Poor management of the recovery from the 1972 Nicaraguan earthquake meant that it took some impacted by the event up to four decades to receive replacement housing *(Rogers, 2011)*.

The longer it takes for countries to build back after a disaster, the greater the impact on social, human and economic development. Hampered recovery can prolong transport disruptions and have ripple effects throughout the economy, including on retail, production and trade (*UNDP, 2014*). Delayed assistance can also trap poor people into vicious cycles of poverty as households sell–off productive assets or take on debt with unfavourable conditions to recover *(IIASA, 2015)*.

2.4 Responding to the challenge

Responding to these trends, the Centre for Global Disaster Protection's first Innovation Lab, held in partnership with Lloyd's, focused on developing new financial instruments that combine incentives for resilience with risk transfer to broaden the evidence base and provide a framework for products that could be taken forwards.

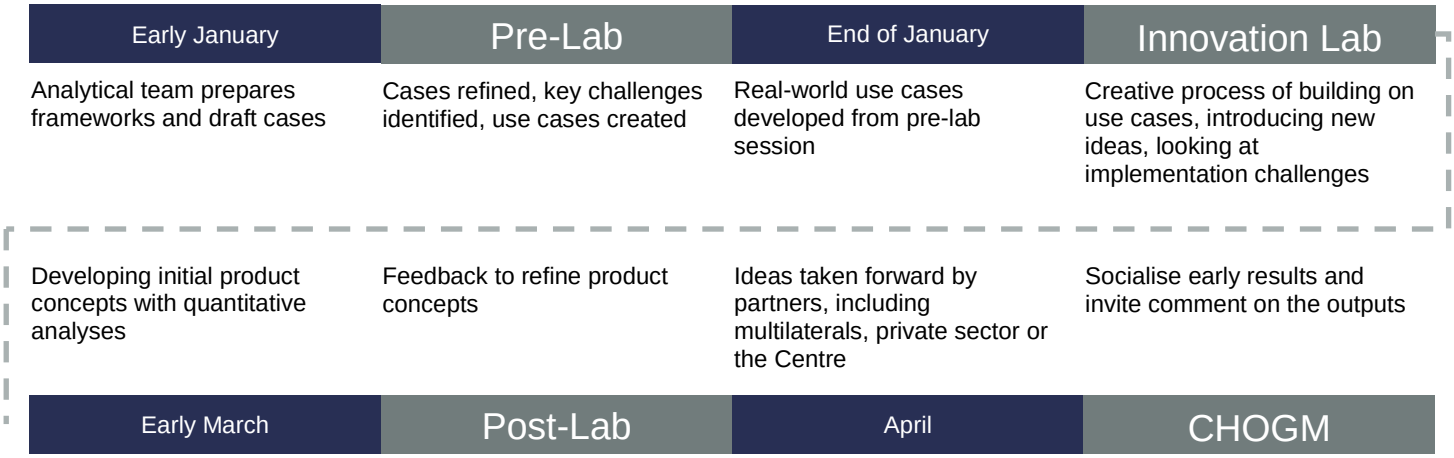
Box 1: The Innovation Lab

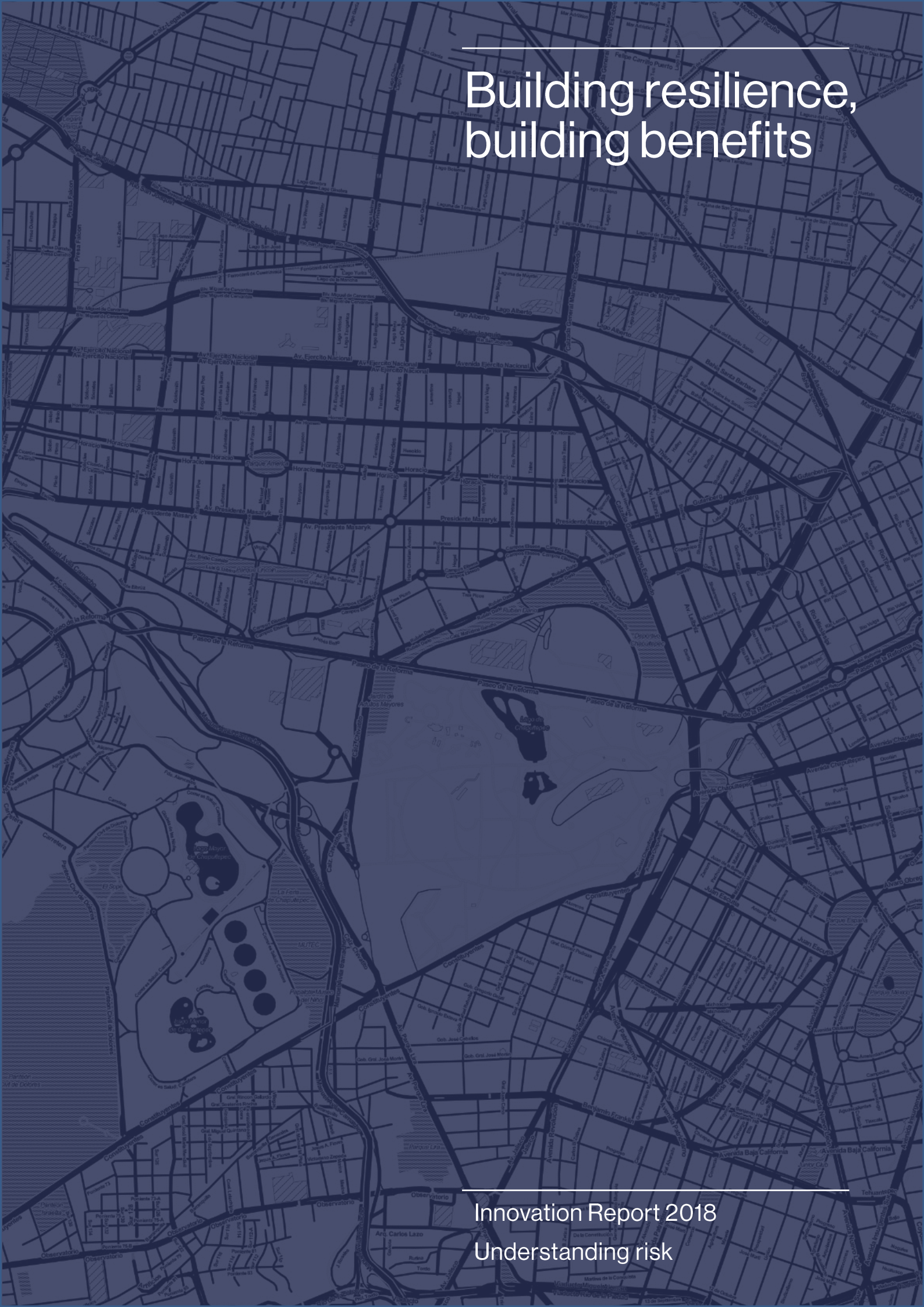
The Centre for Global Disaster Protection's (the 'Centre') is a partnership between the UK Government and World Bank, and works with governments and humanitarian agencies to strengthen pre-disaster planning, catalyse innovative finance for resilience and use risk financing tools such as insurance to protect people, and speed-up response and recovery.

The Innovation Lab brought together experts from the public and private sector, in an open format, to generate and incubate new solutions to meet identified problems. The Centre's first Lab was held in January 2018 to investigate financial products and structures that incentivise risk reduction and resilient rebuilding by bringing together elements of project financing and risk transfer.

The Lab was a dynamic working session with more than 50 participants working together from across the insurance, investor, engineering, humanitarian and development communities. Participants worked from real-world use cases prepared in a pre-Lab session, identifying, developing and stress-testing possible solutions. It was supported by a team of experts from Risk Management Solutions (RMS), Vivid Economics and re:focus partners, providing technical analyses. The innovation lab process is described in Figure 2 *(overleaf)*.

Figure 2: the Innovation Lab process





Building resilience, building benefits

Innovation Report 2018

Understanding risk

3. Building resilience, building benefits

The role for resilience measures in addressing the rising impact of disasters is largely untapped, especially in developing countries. Resilient infrastructure can save lives and money. It offers a proven way to reduce the increasing economic impacts of disasters. Despite this promise, much infrastructure is characterised by its vulnerability rather than its resilience.

Building resilience for all stakeholders means finding new ways to break down silos within and between government, the private sector and communities. With a common knowledge base as a foundation, it would be possible to collectively build a better understanding of both present–day risks and those that will arise tomorrow. This could facilitate better pricing for investors and more informed decisions by policymakers, and ensure smoother progress towards a more resilient future.

To broaden understanding, this section outlines and explores the concept and importance of resilience measures, and introduces some of the key barriers that need to be overcome to deliver and maintain resilient infrastructure.

3.1 Background

Building resilience is a central priority for the international community. The third priority of the 2015 UN Sendai Framework[i] emphasises the need to invest in resilience ex ante, ensuring disaster risk prevention and reduction through structural and non–structural measures.

Likewise, Goal 9 of the Sustainable Development Goals (SDGs) identifies the need to "build resilient infrastructure" and has more specific aims for resilience under targets 9.1 and 9.6 *(UN, 2015)*.

[i] The Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework) is the first major agreement of the post-2015 development agenda, with seven targets and four priorities for action. It was endorsed by the UN General Assembly in 2015.

Resilience has both a static and a dynamic component. The United Nations International Strategy for Disaster Reduction (UNISDR) defines resilience as:

> *"the ability of a system, community or society exposed to hazards to resist, absorb, accommodate and recover from the effects of a hazard in a timely and efficient manner"*
> *– (UNISDR, 2009)*

DFID adopted a working definition of resilience as:

> *"the ability of countries, communities and households to manage change, by maintaining or transforming living standards in the face of shocks or stresses – such as earthquakes, drought or violent conflict – without compromising their long–term prospects"*
> *– (DFID, 2011)*

These two definitions capture the idea that resilience has both static and dynamic components:

1. Static resilience is the ability of a system to maintain function despite a shock
2. Dynamic resilience ensures efficient use of resources to repair and reconstruct after a shock

(Rose and Krausmann, 2013)

While both are crucially important, the focus of this report and specifically this section is on the ability of systems – especially those reliant on infrastructure – to maintain function despite a shock (static resilience).

Resilience can be enhanced by both hard and soft resilience measures. Creating resilience in the built environment can be thought of as "hard resilience", while "soft resilience" relates to improving social systems to withstand shocks. Both are beneficial and mutually reinforcing *(UNISDR, 2007)*.

For example, new irrigation infrastructure might provide farmers with greater resilience to flooding and extreme weather events so they can plant crops with more confidence; training can help farmers take advantage of these new opportunities by adopting different cropping

practices and ensuring that the infrastructure is used and maintained.

Although the focus of this study is tilted towards hard resilience (infrastructure), it is important to consider the complementary character of soft and hard measures to have a holistic perspective.

Resilience requires a systems perspective. Thinking about resilient infrastructure requires going beyond the notion of an infrastructure asset and considering the services this asset provides. These services are often inter-dependent. For example, the loss of power infrastructure during a disaster could cut energy supply for the sewerage system and have ripple effects for hospitals and households.

This implies that creating resilient built systems requires infrastructure managers to consider both their upstream and downstream users, and share information on the vulnerabilities and robustness of their capital *(Kunreuther, et al., 2016)*. Such systemic action may be difficult to achieve but it offers multiple benefits, extending beyond the infrastructure asset in isolation and covering all its interdependencies.

To better manage risk and to recover quickly from future disasters, infrastructure owners and operators must move beyond asset–by–asset risk management to build resilience within, and between, infrastructure systems. This requires consideration of how infrastructure performance might change when shock or stress events occur *(Arup and Lloyds, 2017)*.

3.2 The benefits of resilient infrastructure

Resilient infrastructure can reduce both the direct and indirect economic impacts of disasters and facilitate recovery. Where most national and city governments serve relatively short terms of three to five years, the political cycle can be disruptive to long–term cohesive planning and robust, sustainable infrastructure. Without committed and engaged political and/or wider multi–stakeholder collaboration, the effective implementation of long–term strategic planning is challenging.

In 2010, an earthquake of moment magnitude 8.8 off the coast of Concepcion, Chile resulted in approximately 1,000 fatalities. A lesser magnitude earthquake in Haiti in the same year resulted in 220,000 fatalities. The single biggest factor accounting for these differences was the effective implementation of new, resilience–focused building codes in Chile *(Arup and Lloyds, 2017)* that were not implemented in Haiti.

Resilient infrastructure protects human life and economic activity and when damage does strike, it can often be recovered more quickly, substantially reducing indirect damages.

3.2.1 The economic benefits of resilient infrastructure outweigh the costs fourfold

Resilience actions can have higher upfront costs but tend to be more cost–effective than disaster relief over the longer–term *(MDBs, 2015)*. A range of studies suggest that, on average, the benefits of resilience (broadly defined) outweigh the costs fourfold (*see UNISDR (2007), OECD (2015) and UK Government Office for Science (2012)*).

Figure 2 (*overleaf*), illustrates a range of analyses for resilience measures, which demonstrate these findings. All projects contain some infrastructure resilience component, although often complemented by softer resilience measures. As illustrated in Figure 3, the average benefit–cost ratio average of these projects significantly exceeds one.

Box 2: Explaining the benefit–cost ratio

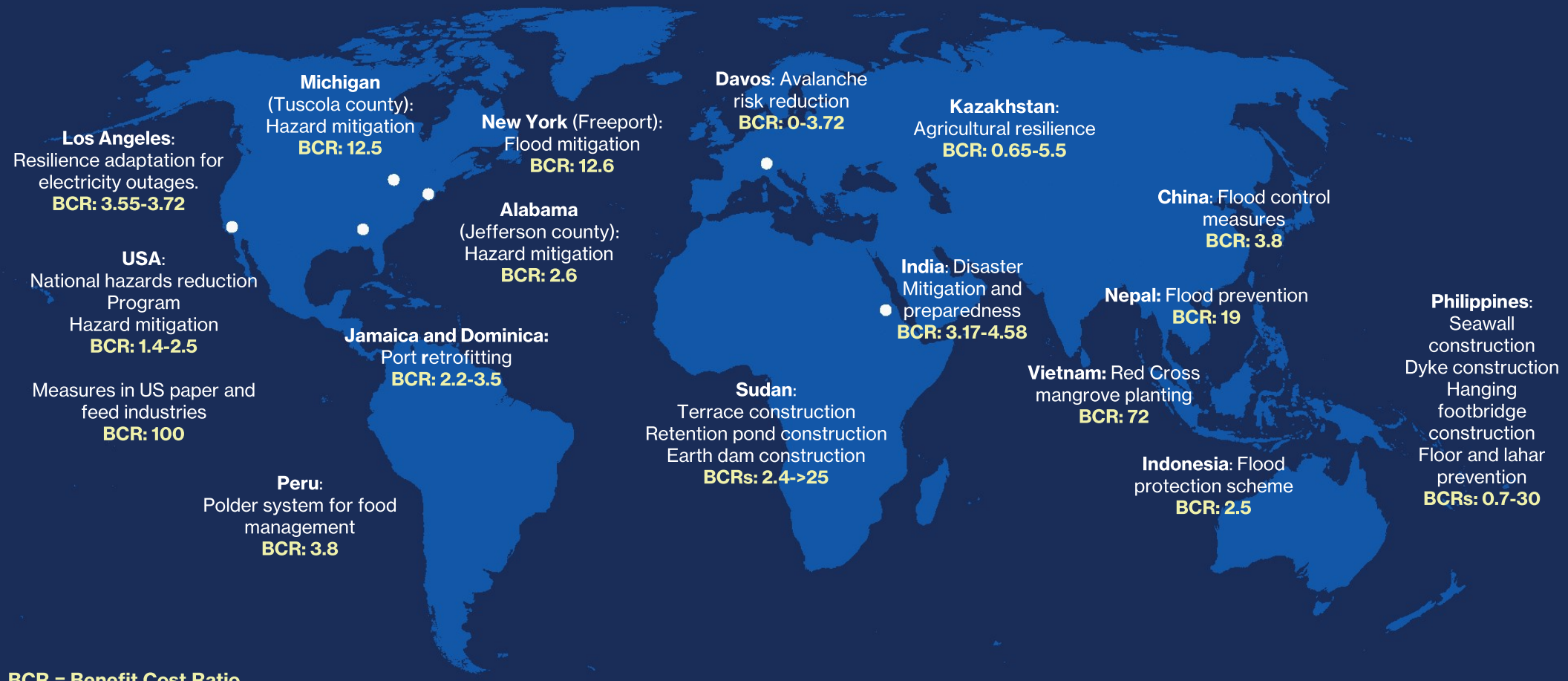
The benefit–cost ratio is a simple indicator which shows by how much the benefits of a project outweigh the costs. A ratio of 1:1 means the benefits equal the costs.

Examples

- A ratio of 72 (such is the case for mangrove plantations in Vietnam) indicates that the benefits outweigh the cost by 72 to 1. For every dollar spent, the project produces $72 in benefits.
- In Nepal a package of strengthening river banks, upgrading storm shelters and providing new early warning systems yielded an estimated $19 of benefits for every $1 spent.

The evidence demonstrates that preparing for disaster pays off; it generates a “resilience dividend”. This dividend means that resilient infrastructure is an economically logical investment.

Figure 3: The benefit-cost ratio around the world



BCR = Benefit Cost Ratio

The benefit–cost ratio is a simple indicator which shows by how much the benefits of a project outweigh the costs. A ratio of 1:1 means the benefits equal the costs. The evidence demonstrates that preparing for disaster pays off; it generates a "resilience dividend". This dividend means that resilient infrastructure is an economically logical investment.

Source: Benson, 1998; Dedeuwaerdere, 1998; FEMA, 1998; Vermeiren and Stichter, 1998; Mizina et al., 1999; Mechler, 2004a; b; Venton and Venton, 2004; MMC, 2005; IFRC, 2015; Rose, 2017

These numbers capture some of the additional benefits that resilient infrastructure provide other than reducing risk to disasters. For example, incorporating ecosystem services to improve resilience can provide co–benefits such as improved public health, improved water and air quality *(C2ES, 2018)*. Such measures can include cultivating mangroves as a buffer against hurricanes and floods, and planting "green–corridors" of trees to reduce the urban heat island effect and provide shade during heatwaves.

These are available in both the developed and developing world, as Box 3 (*below*) shows. These make use of innovative solutions such as green gutters and "radical" hillside terraces[j]. Resilient infrastructure does not just offer disaster resilience; it provides development, better livelihoods and a better environment.

Box 3: resilient infrastructure investments can generate significant co-benefits

As part of the Green City, Clean Waters initiative which seeks to make Philadelphia's storm-water infrastructure more sustainable and resilient, the city has made many resilience investments. This includes 363 public projects totalling $1.2 billion, such as green gutters (diverting excess water from rain gutters into rows of soil and vegetation) and rain gardens which reduce flood risk. Estimates suggest that these have generated 430 local jobs and $600m in economic benefits *(Econsult Solutions, 2016)*.

Rwanda's Vision 2020 Umurenge Program has established several public works such as "radical" hillside terraces (reverse sloped terraces stabilised with plants and trees on both sides) and anti-erosive ditches *(DFID, 2011)*.

The programme is the Rwandan Government's flagship initiative for social protection and poverty reduction. It has improved local resilience to flooding and landslides, while improving soil quality and food security. Their construction and maintenance has also provided a source of employment and local economic growth, aided by direct cash-transfer programs which connect labour from low-income households to the public works.

However, the economic benefits of resilient infrastructure may be even higher than these analyses suggest. Most estimates do not consider the broader non–market benefits of resilience such as the continuity of ecosystem services, or the prevention of emotional trauma from such events *(OECD, 2015)*. Resilience also has the additional ability to catalyse economic activity by reducing risk and promote greater risk–taking entrepreneurship *(Kryspin–Watson, 2017)*, encourage households to build assets and stimulate firms to invest and innovate *(World Bank, 2015b)*.

Despite the potential benefits from enhancing the resilience of infrastructure, there are numerous, interlocking barriers to financing and ensuring this resilience. The challenges operate across all scales and encompass the private and public sector:

- Political disincentives: where most national and city governments serve relatively short terms of three to five years, the political cycle can be disruptive to long–term cohesive planning and robust, sustainable infrastructure. Governments are politically rewarded for responding to disasters, and not for prevention. This can deter investment in resilient infrastructure, and incentivise spending on recovery and emergency response measures *(Neumayer, et al., 2014)*.

  This political disincentive, compounded by the infrequency of disasters, lowers the perceived urgency of implementing resilience measures *(Kunreuther, et al., 2016)*. Moreover, making complex, long–term policy changes on resilience is inherently challenging given short–term focused political structures *(UK Government, 2011)*. Without committed and engaged political and/or wider multi–stakeholder collaboration, the effective implementation of long–term strategic planning is difficult.

- Cognitive biases: Research suggests that governments, investors and individuals are not always rational *(Kahneman, et al., 1991; Tversky and Kahnemann, 1974)*. Instead, they face behavioural biases which can make long–term investments with high upfront costs, such as resilience less appealing.

  Hyperbolic discounting, where the discount rate varies depending on how far into the future a choice is being made rather than being consistent, will often lead individuals and developing country governments to sub-optimally outweigh short–term costs over long–term gains *(Groom, et al., 2005)*.

- Moral hazard: recovery programs can create a moral hazard; there is a disincentive to pay more for resilient infrastructure since losses will be reimbursed *(Neumayer, Plümper and Barthel, 2014)*.

- Information barriers: policymakers, investors and the public may not be aware of the benefits of resilience. This reflects the challenges in measuring resilience *(ClimateWise, 2016)*, security concerns over sharing information on vulnerabilities and the sparse experience that some infrastructure managers have of disasters. *(Chang et al., 2014)*.

[j] Locals in Rwanda began referring to this technique as radical due its significant difference in comparison to traditional terracing practices, as well as the large benefits in soil and water conservation. "Reverse sloping" refers to reworking the topsoil so that it runs against the downward angle of the hill. This 'bench' helps to capture water that would otherwise run-off and erode the soil.

As discussed further below, tools commonly used in the insurance industry such as catastrophe models *(Michel–Kerjan et al., 2013)* have promise in providing a common view of risk and risk reductions achieved by investment in resilience, but are not currently applicable to all classes of risk and resilience measures.

– Uncertainty: designing resilient infrastructure can be particularly difficult due to a lack of data and uncertainty over the frequency and severity of future disasters *(EOD Resilience Resources, 2016)*. There can be legitimate concerns about locking in inappropriate solutions or options that decrease the average disaster cost but increase the cost of the worst disaster *(Neumayer, Plümper and Barthel, 2014)*.

  Furthermore, there is significant uncertainty over the cost of technology. Future resilient infrastructures could be enhanced and cheaper, creating uncertainty as to whether to wait or invest now *(Fay, Iimi and Perrissin–Fabert, 2010)*.

Developing economies face several additional barriers to building resilience. For some vulnerable countries, there may be sound economic reasons for underinvestment in resilient infrastructure; for example, high discount rates or scarce resources required elsewhere.

In addition, however, institutions without strong, clear regulations and enforcement, business uncertainty and a lack of data about both infrastructure investment performance, and disaster likelihood and severity, can make investment in resilient infrastructure even more challenging *(OECD and World Bank, 2015)*.

This suggests that capitalising on the potential benefits of resilience will require novel ways to incentivise resilience financing.

3.3 Insurance makes disasters shorter, safer and cheaper

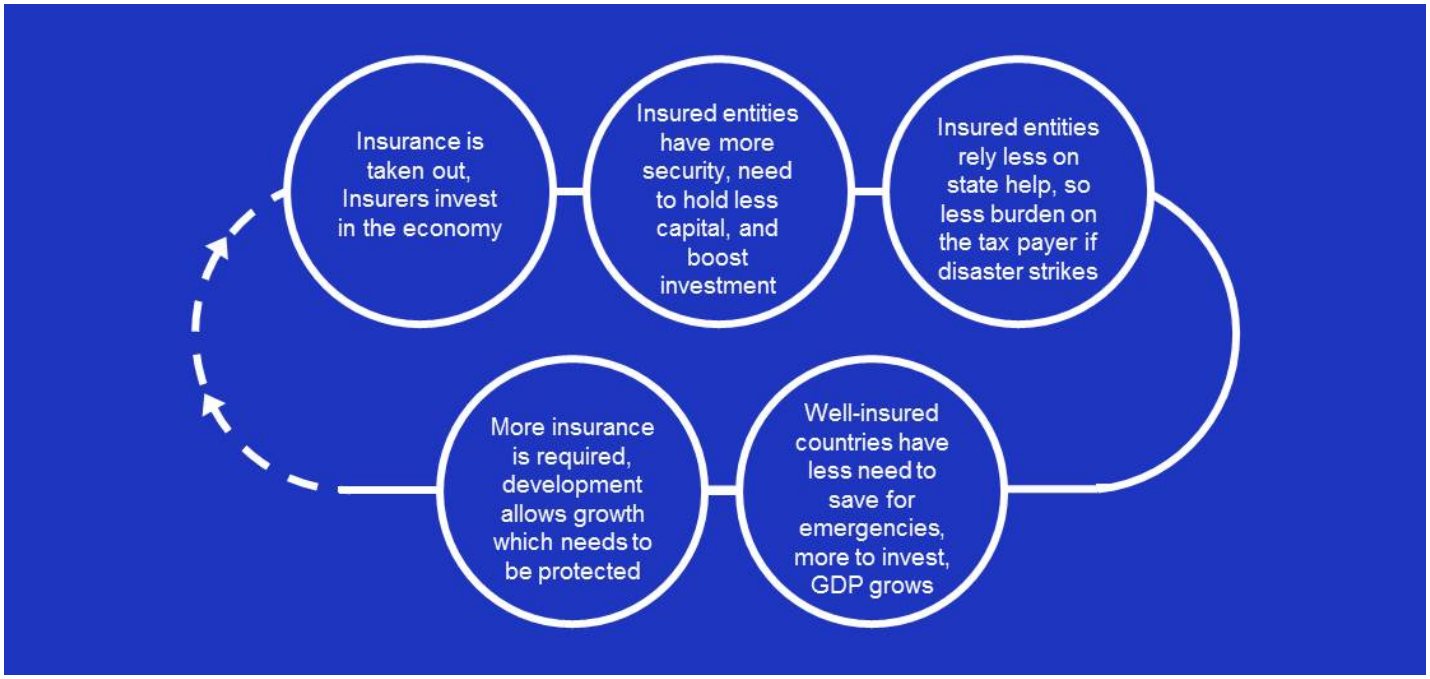
Insurance can, when well designed, encourage resilience. It provides protected finance, incentivises preplanning and promotes protective measures in the countries involved. Post disaster; structured and well governed payments can flow quickly from insurers to the centres of need, aiding faster recovery and helping to protect sovereign stability.

Countries with greater insurance coverage recover faster after a disaster, but almost as important, they also tend to be more resilient to future disasters. Stimulating insurance markets in developing countries is a proactive risk management approach.

More than half of the world's future urban spaces are yet to be built *(UN, 2014)* so there is an opportunity to build new cities which are highly resilient to both the pressures of urbanisation and a changing climate.

While building resiliently can help reduce the damages caused by disasters, some impacts cannot be avoided. Extreme events still cause acute damage and disruption to services and infrastructure. For instance, RMS analysis indicates that wind speeds from hurricanes Irma and Maria were so severe that direct economic losses across all islands would still have been about 80% of what was experienced, even if damaged buildings had been constructed to 2018 building codes *(Centre for Global Disaster Protection and Lloyd's, 2018)*.

Figure 4: insurance as a tool to support growth



Source: (Lloyd's, 2012)

In such cases, the imperative is to design infrastructure and critical services that can bounce back quickly, and for officials to prepare in advance and put in place capabilities and systems that are able to deliver rapid finance to kick–start recovery and reconstruction.

3.3.1 Insurance can assist with the challenge of delay

Insurance can play a critical role in ensuring rapid bounce back. This is most evident for "parametric insurance" – insurance that's triggered when a threshold for impacts such as rainfall levels or wind speed is surpassed – which can be deployed with no costly verification or on–site assessment in comparison to traditional indemnity policies *(Clarke and Dercon, 2016)*.

Compared with the four to nine months needed for humanitarian aid for reconstruction and recovery, pay–outs from such schemes can happen in days or weeks:

> *"In 2015, PCRAFI[k] paid out $1.9m in emergency funds within one week of Tropical Cyclone Pam hitting; in the Caribbean, CCRIF SPC[l], which has paid out just over $100m, has made every one of its payments within 14 days of the disaster striking"*
>
> – *(CCRIF–SPC, 2017)*

This rapid bounce–back can negate or even reverse the negative macroeconomic impacts of disasters. One 2012 study surveyed economic indicators, disaster data and insurance levels across 203 countries and 52 jurisdictions *(Peter, et al., 2012*). It found that while uninsured losses can lead to a reduction in economic growth, when losses are insured, growth is protected. Indeed, they found that for storms, flooding and climatological events, insurance spurs reconstruction and can even enhance short–term growth in a disaster's wake.

Planning post–disaster finance before the event, as is often required by insurance, can ensure prudent spending. Insurance is most effective when it is the central part of a coordinated pre–disaster plan. Such a plan can ensure that payments are quickly dispersed, decisions are speedily made and financing is effectively and fairly used (*Clarke and Dercon, 2016*). In the chaotic aftermath of a disaster, a previously agreed plan can establish how insurance can play a valuable role in overcoming any disaster–response coordination problems that inevitably arise.

Box 4: Kenyan Hunger Safety Net Programme

One example is the Kenyan Hunger Safety Net Programme which provides a direct, agreed cash transfer to pre-determined groups when certain drought indicators, such as reduced rainfall and crop failures, are crossed. The current arrangements resemble a parametric insurance scheme and have an additional insurance component. Farmers can purchase subsidised insurance to cover the loss of animals and fund additional resources needed to keep their livestock alive.

The project has been implemented by the Kenyan Government along with international donors and has been successful in reducing the costs of disasters. The programme likely saved thousands of lives during the 2011 famine, and has reduced average annual food gap periods – the time when households lack sufficient food – which dropped from 3.6 to 2.3 months *(European Commission, 2018)*.

By providing funds quickly and predictably, insurance is often a more cost–effective disaster recovery financing option than donor funding or public finances. Large disaster losses often outstrip the budgets of developing countries and the relief that donors can offer, making recovery slower and more costly.

A recent World Bank study for Ethiopia found that relying on insurance or insurance–like instruments combined with a disaster reserve fund for disaster risk financing, could be 5–25% cheaper than relying on disaster reserve fund with or without ex–post budget reallocation (*Clarke, 2016*).

It is also a flexible tool: one study on the potential of disaster risk finance instruments for five different countries and five different risks (drought, floods, earthquakes, cyclones and crop failures), found that insurance was the only approach applicable across all cases *(Clarke, et al., 2016*).

This suggests that the payment of premiums and financial resources to establish schemes is an opportunity for development aid to secure societal resilience by using insurance to incentivise proactive planning and informed investments in risk reduction.

[k] The Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) is a regional risk pool with 15 members. It provides disaster risk assessment and modelling tools, as well as parametric disaster risk financing.

[l] The Caribbean Catastrophe Risk Insurance Facility was formed in 2007 as a regional catastrophe fund for Caribbean governments. It was the first multi-country risk pool in the world. In 2014 it was reformed into a Segregated Portfolio Company (the CCRIF SPC). It offers parametric insurance for excess rainfall, tropical cyclones and earthquakes.

3.3.2 Insurance plays a particularly critical role for the most severe events

The value of insurance to firms and households – who are likely to place a high value on avoiding the worst outcomes (in other words, they are risk averse) – is often clear. The same can also apply to governments, especially those in small countries.

While traditional economic theory suggests that governments benefit from exposure to a diversified portfolio of risks and so are less concerned about the downside implications of any one event, this theory may break down in the case of severe events and for countries of small geographic extent with concentrated risk. For example, in the case of Hurricane Maria, when Dominica experienced losses equivalent to 224% of its GDP, the concept of diversification breaks down, due to the exceptional severity of the event and the relatively small size of Dominica in relation to the storm. This additional protection against the impact of the most extreme events is additional to any benefits insurance provides as an effective way of financing disaster recovery. In these cases, a cost–benefit calculation fails and a focus on protection against extremes is more important.

Insurance on its own should not be thought of as an alternative to more established approaches to resilience. It should instead be included as part of a broader framework, and in collaboration with governments. Donor governments can use the insurance model to demonstrate the value of relief spending to their nation and when events happen will be able to point to how quickly the funds can flow. For example, by the end of 2017 Lloyd's had already paid out more than $2bn to get businesses and communities back on their feet after Harvey, Irma and Maria *(Lloyd's, 2017)*.

The case of the Mexican Natural Disaster Fund (FONDEN) illustrates how insurance can be combined with resilience measures and other financing approaches to provide a comprehensive and cost–effective disaster risk package. It illustrates the complementary role of improved resilience measures to cost–effectively address some of the risks of smaller, more frequent disasters, while using risk financing measures to help respond to larger, more devastating events.

Box 5: Mexican Natural Disaster Fund (FONDEN)

FONDEN is Mexico's Natural Disaster Fund. Each year, a share of the national budget (0.4%) is allocated to FONDEN for the post-disaster reconstruction and recovery of low-income houses, the environment and public infrastructure (*World Bank, 2012*). In turn, FONDEN has successfully accessed the international reinsurance markets in addition to the accessing the capital markets several times over the past 12 years through parametric catastrophe bond structures, providing coverage against severe earthquakes and tropical cyclones.

This combination of reserve funding and insurance is intentional and strategic. The ex-ante budget provides a consistent and reliable funding base for most disasters while the catastrophe bond program transfers the risk of larger events that would otherwise outstrip and deplete the allocated budget to capital markets *(World Bank, 2012*). Plans are made prior to disaster that include processes for determining damages and how funding can be spent, resulting in clarity for all stakeholders, and faster recovery (*Clarke and Dercon, 2016)*.

This approach has saved lives and money by speeding up disaster recovery. FONDEN has been able to swiftly make payments following disasters. Indeed, it is legally required to make funds available with 23 days of a disaster. It also has a mechanism for immediate partial support so that a proportion of funding is provided within 24 hours to aid emergency recovery needs (*World Bank, 2012*).

This funding has been used multiple times in 10 different municipalities. This has significant economic benefits. Municipalities with access to FONDEN grew by 2-4% faster in the year following a disaster than those without access over the period 2004-2013. They also experienced an additional 76% growth in the local construction industry in the years following disaster (*De Janvry, et al., 2016*).

In addition to pure post disaster recovery, FONDEN also promotes building back better. Funds can be used to relocate infrastructure to safer areas and reconstruct buildings to higher standards (*Clarke and Dercon, 2016*). This is done through FOPREDEN, the disaster risk mitigation mechanism of FONDEN which receives an annual budget of $25m. For example, in 2007, floods caused by extreme precipitation over the course of a month in Tabasco cost $2.9bn.

This led to spending of $233m by FORPREDEN and Mexico's National Water Commission (CONAGUA) to improve flood resilience through floodways, dikes and protective walls (*FONDEN, 2011 in World Bank, 2012*). In comparison, when floods caused by two months of extreme rain hit in 2010, they resulted in losses of $570m a direct consequence of Tabasco's efforts to strengthen its resilience to extreme hydro-meteorological events.

Insurance and resilience measures can work in concert

Insurance can complement resilient infrastructure construction and maintenance. One example, as FONDEN illustrates, is the different focus that each brings in developing a comprehensive risk management package with risk reduction measures to help manage smaller, more frequent events, and insurance and risk transfer solutions for the larger events. But the complementarities extend further:

- Insurance tools can help provide the information needed to identify and assess risks
- Well–designed insurance policies can provide incentives to embed resilience

Catastrophe modelling can provide a common language for stakeholders to discuss risk, qualify investments in resilience, and measure and monitor risk reduction. Risk modelling provides insight into where the greatest resilience needs lie and allows for risk–based prioritisation of investment in resilience.

Models provide a testbed for understanding the comparative benefits of resilience measures, be it the building of a sea wall, seismic retrofitting, or the addition of roof anchors. Indeed, measurement of the resilience dividend is fundamental to cost–benefit calculations – risk models can be easily adapted to capture a range of resilience benefits, including reductions in direct economic damage, downtime and the number of people affected.

As the number of models and the amount of data available increases, so does the potential for stakeholders other than insurers to use that information to make risk assessments and to anticipate the potential impacts of hazards.

This allows governments, communities and individuals to make informed decisions about resilience, insurance, investment, wider policies and interventions. Risk

quantification is the key to being able to make transparent statements such as:

"This asset is currently resilient to 1 in 10 risk of flooding. To be resilient to a 1 in 200 risk the following is recommended…"

This kind of explicit disclosure of risk could act to encourage stakeholders to understand and maintain their own detailed risk registers, and to hold open dialogue on the risks under consideration.

As such, insurance companies can bridge the information gap needed to better understand risks and hence encourage individuals, firms and governments to adopt resilience measures. There are several initiatives in this space, such as:

- The Insurance Development Forum (IDF), a public–private partnership between the insurance industry and international organisations which seeks to extend the use of insurance and risk management tools to improve resilience *(IDF, 2018)*.
- Under the United Nations Environment Program Finance Initiative (UNEP FI) Principles for Sustainable Insurance *(2018)*, organisations have pledged to raise disaster awareness and provide new risk management tools to reduce disaster exposure.
- Representing a growing global network of leading insurance industry organisations, ClimateWise helps to align its members' expertise to directly support society as it responds to the risks and opportunities of climate change. The Societal Resilience Programme convenes impact–orientated, collaborative research to help insurers proactively respond to the widening climate risk protection gap *(ClimateWise, 2018)*.
- A recent, innovative example is the Oasis Loss Modelling Framework. This is an open–source, online modelling platform for catastrophic risk provided by more than 30 members of the insurance industry, and underpinned by 80 models *(Oasis Loss Modelling Framework, 2017)*.

  The platform is open source: it allows for catastrophe modelling, including a results and exposure database, and also facilitates the development of new models. In so doing, it complements the expertise and models developed over many years by commercial institutions.

The design and pricing of insurance policies can help encourage resilience *(Arup and Lloyds, 2017)*. For example, in the late 1990s, United Insurance actively promoted resilient infrastructure by offering premium discounts of up to 40% for businesses and 25% for households.

The benefits were clear following Hurricane Jose in Antigua in 1999: average losses were around 10% of the total sum insured, but only 4.75% of the sum was insured in the case of retrofitted projects. The discounts also attracted new clients for the insurer *(Benson and Clay, 2004)*. Other insurers have offered discounts for clients who implement resilience measures such as hurricane shutters, relocation away from coastlines and retrofits to make structures more hazard–proof *(Benson and Clay, 2004)*.

Similarly, four state governments in the US. Alabama, Georgia, Missouri and North Carolina all have regulatory frameworks stipulating that insurance discounts or credits be given to consumers who undertake certified resilience measures *(Fortified Home, 2017)*.

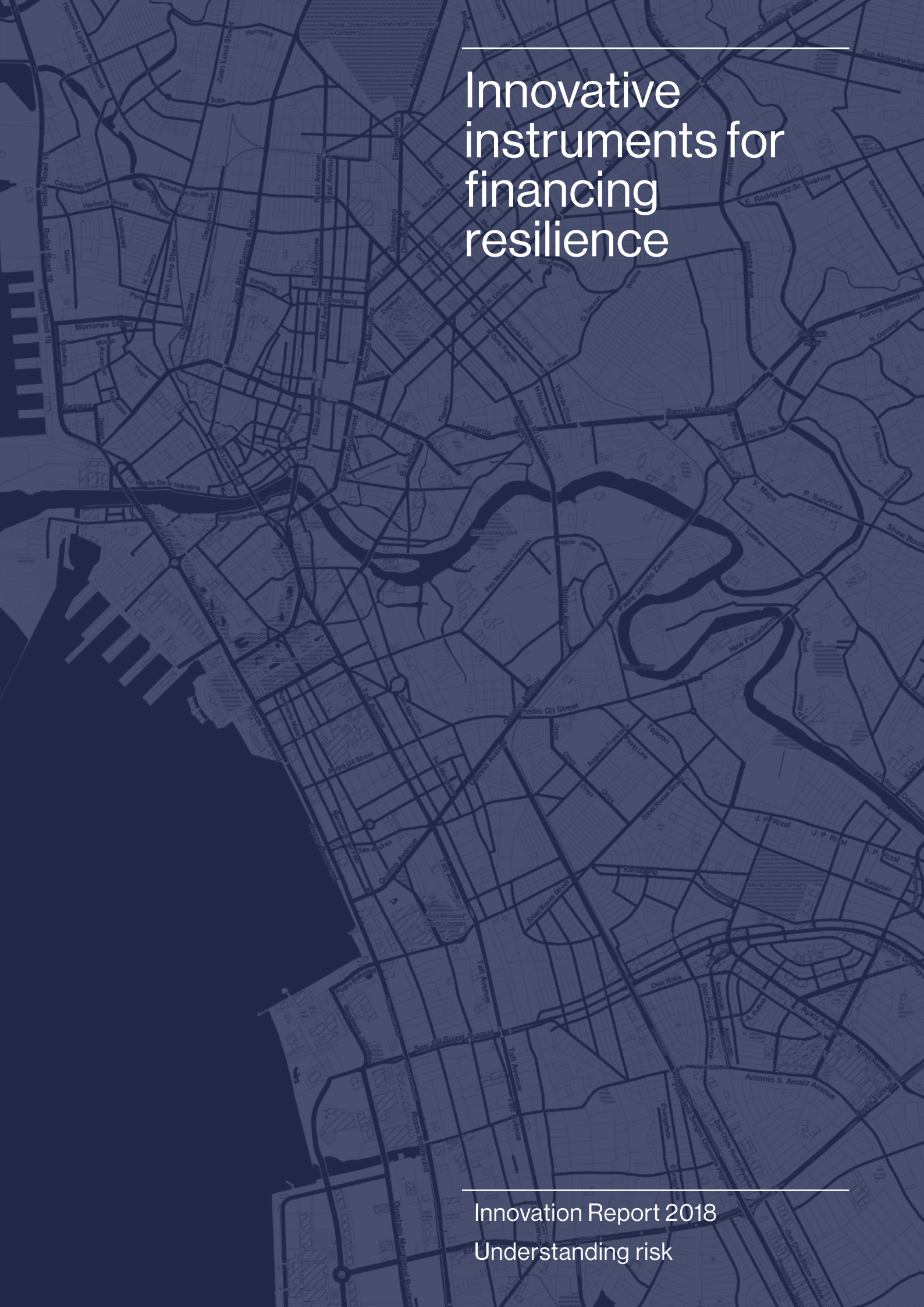
In designing such schemes, a number of important factors need to be taken into account, such as the treatment of assets that already benefit from more resilient measures and the benchmark from which improvements in resilience are recognised – in order to make sure that the mechanism is robust and does not undermine insurance penetration *(RMS, 2010)*.

However, pricing has its limits. Annual contracts can limit the incentive for both insurer and insured to consider resilience investments, but multi–year contracts will typically make insurance more expensive. For example, one study estimates that capital requirements are around 50% higher for a 10–year contract than an annual contract and the annual premium around 5.5% higher, reflecting both higher capital requirements and the greater uncertainty involved in anticipating long–term risk *(Maynard and Ranger, 2013)*. Moreover, risk is only one factor in determining insurance premiums.

There may be significant challenges for insurers in providing risk–appropriate premium reductions for property when administrative costs are a large fraction of the total premium *(Maynard and Ranger, 2013)*. In addition, smaller geographic regions and developing countries tend to transfer large proportions of their insurance portfolios to reinsurers who commonly apply blanket portfolio reinsurance premium rates, limiting the ability to offer price discounts (while maintaining financial robustness of insurance companies). For example, in the Caribbean, 85% of gross property insurance premiums are transferred to reinsurers.

Making resilience a precondition for insurance contracts can also be powerful. For example, the Government of Fiji made mortgages conditional on acquiring cyclone insurance *(Benson and Clay, 2004)*. In turn, insurance could only be obtained when buyers provided a certificate confirming compliance with the 1985 National Building Code. This appears to have enhanced resilience at the national level: Fiji self–reported a disaster risk preparedness score of 4.95/5 in its 2014 National progress report on the implementation of the Hyogo Framework for Action[m] *(Fijian Government, 2014)*. It has also contributed to Fiji having a $95m insurance market, the second largest among Pacific island countries *(World Bank, 2015a)*.

[m] The Hyogo Framework for Action (2005-2015) was replaced by The Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework) is the first major agreement of the post-2015 development agenda. Both were endorsed by the UN General Assembly.



Innovative instruments for financing resilience

Innovation Report 2018

Understanding risk

4. Innovative instruments for financing resilience

This section outlines four innovative finance instruments to better promote resilience: insurance–linked loans, resilience impact bonds, resilience bonds and resilience service companies[n]:

- Insurance–linked loan packages: this approach, requiring only small modifications from current practice, explicitly integrates risk–transfer solutions and resilience conditions into the loans provided by international financial institutions.

  The product may be well–suited to large infrastructure projects in high–risk regions, ideally involving a portfolio of multiple assets. It can be easily modified to facilitate the participation of donors keen to reduce interest costs on loans for critical resilient infrastructure.

- Resilience impact bonds: a payment for a performance contract between an outcomes funder (donor) focused on resilience and social goals, and a group of investors. The donor makes payments to the investors depending on the success of the investors in delivering physical, operational and financial resilience measures.

  This product is particularly well–suited to cases where the benefits of resilience are spread widely across a community, such as for the services provided by schools, social care bodies and hospitals.

- Resilience bonds: an innovative risk–linked financing mechanism that augments the existing catastrophe bond model to take account of the impact of resilience measures. Under this structure, when resilience measures are implemented, coupon payments on the bond are reduced. This reduction in coupon payments can be securitised to provide a financing mechanism for the resilience investments.

  This product is well–suited to cases where several different stakeholders have a common interest in enhancing the resilience of services provided by a critical asset, such as a coastal road or port.

- Resilience–service companies (ReSCos): this product/business model involves an agent who pays upfront for an insured asset in return for a share of future insurance premium savings. The approach was inspired by the innovative financing mechanisms employed by energy service companies.

  It may be best suited where there are many diffuse but similar assets, such as residential or commercial property assets, that are all subject to frequent disaster events.

These solutions were created within the first Innovation Lab of the Centre for Global Disaster Risk Protection. The Lab brought together experts from the public and private sector, in an open discussion format, to generate new solutions to meet identified problems. Participants worked from real–world use cases prepared in a pre–lab session to identify, develop and stress–test possible solutions.

The solutions each combine two features:

1. Incentives for the ex ante, resilient construction of infrastructure, including its continued maintenance. As section two shows, the additional costs needed to increase the capacity of infrastructure to provide services following disasters is easily offset by the long–term economic benefits generated, typically by a benefit-cost ratio of around 4:1. However, such infrastructure faces several critical barriers that need to be overcome.
2. An insurance element such that, in the event of disasters, there are reliable resources made readily available to ensure that communities, businesses and countries can bounce back quickly.

[n] The insurance-linked loan and resilience impact bond are developed out, backed up by risk and financial modelling, while the other two products are set out at a higher level.

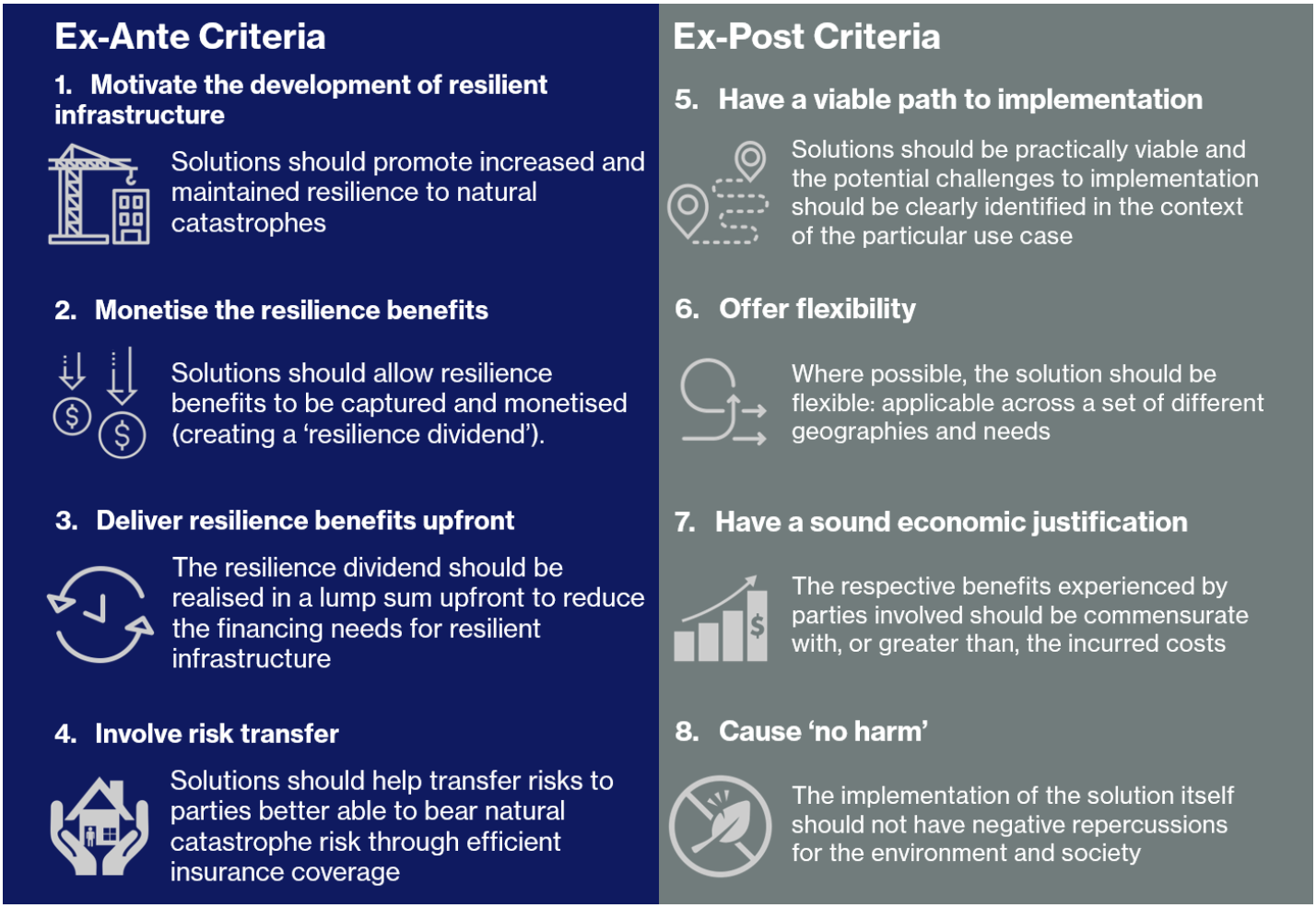
Each solution seeks to provide incentives to create resilient infrastructure by trying to capture and monetise some of the resilience dividend. The resilience dividend is the sum of the benefits of greater resilience, which often exist as a societal-level benefit that is hard to formally quantify and attribute. In each of the financial instruments, some of this dividend is quantified and monetised to help finance the costs of more resilient construction and to build back smarter.

This mechanism provides the strongest incentive for more resilient construction when the dividend can be made available upfront to defray some of the additional costs of building resiliently. In most of the products, it is only the reduction in physical damage that is monetised, through reductions in insurance premiums; with other aspects of the resilience dividend remaining untapped, such as the impact on land values or social benefits such as poverty reduction, reduce air pollution and employment depending on the type of proejct.

This is different for resilience impact bonds where, in principle, the central role of the outcomes funder (donor) allows for all aspects of the resilience dividend to be captured. Product designs rely on the use of catastrophe models to determine the base level of risk and the risk reduction that can be achieved through investments in resilience. Catastrophe models have been widely used within the insurance industry to quantify risk reductions from common retrofit measures and resilience design features for standard residential, commercial and industrial structures. Certain structures or bespoke design features may require additional engineering assessment to quantify the resilience benefit.

The ideas are assessed against eight criteria (*see Figure 5, below*). The first four criteria (ex ante criteria) relate to the design of the intrinsic features of the instrument. The other four criteria (ex post criteria) relate to various aspects of the benefits of implementing the product. This scoring helps to identify key issues that will need to be resolved in future product development.

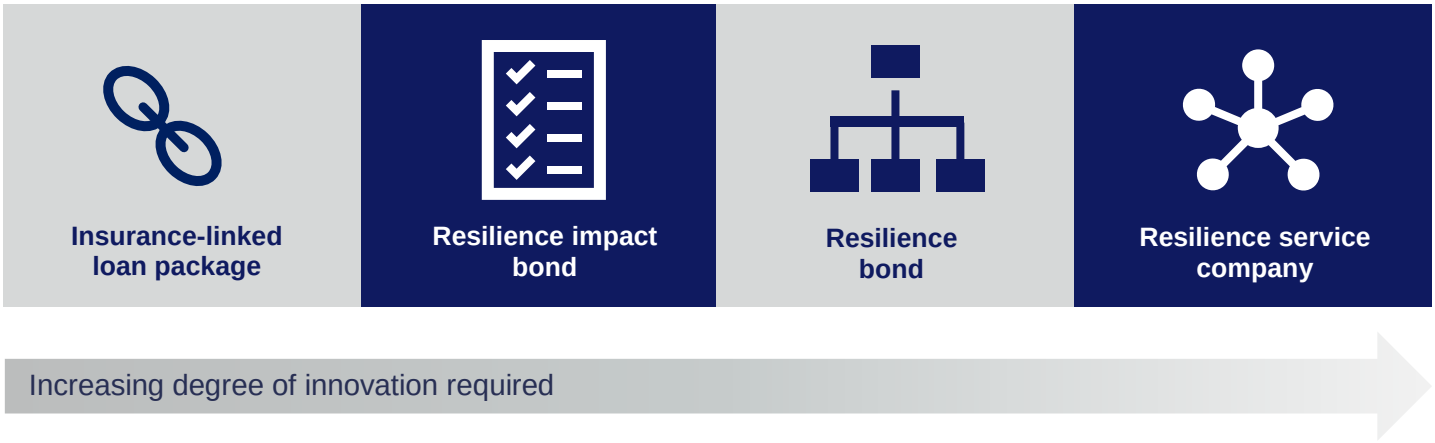
Figure 5: The products are assessed against eight success criteria



Source: Vivid Economics

The solutions vary in the ease and speed of deployment. As Figure 6 *(below)* illustrates, the four ideas range from those that have already been developed but which can be re–purposed and brought to market quickly (insurance–linked loan packages and resilience impact bonds), through to ideas that hold significant potential but will require greater time and effort to implement (resilience service company):

Figure 6: Product concepts



Note: The products vary from those that require little innovation to those which that are substantially different to current solutions.

4.1 Insurance–linked loan package

A. Introduction

This approach, requiring only minor modifications from current practice, explicitly integrates risk–transfer solutions into the (concessional) loans provided by international financial institutions for financing new infrastructure or infrastructure upgrade programs.

Loans would be allocated by an international finance institution towards infrastructure programs where resilience is explicitly built into the design. The loan would cover both the costs of the resilient infrastructure program and the costs of a parallel multi–year insurance product. The infrastructure program costs, including the additional costs of resilience, would be disbursed using standard procedures. In addition, a separate portion of the loan to cover insurance costs would be disbursed to a separate resilience fund, potentially to be managed by a separate special purpose vehicle (SPV)[o]. Under this structure, donor funds could be used to make the terms of both portions softer by blending donor funds.

The loan amount to cover insurance would be based on the expected insurance premiums *without* the resilience measures. By contrast, the actual cost of insurance would take account of the resilience measures built into the infrastructure design. The result would be a series of savings on the insurance premiums – the resilience dividend – which could be transferred to the financing portion of the loan. This could either be realised over time or, potentially, made available upfront.

[o] The separate treatment of the loan portion to cover the insurance costs reflects the typical need of IFIs to disburse loan amounts over 3-5 years, while the insurance premia would need to be paid over a longer period. If donors are involved in the structure, then the amount could alternatively be paid into a trust fund as a returnable grant. While not discussed in this product description, either of these two options – SPV or trust fund – could also provide a vehicle for covering maintenance costs.

The product would meet two fundamental criteria of interest:

- Resilience incentive: the total expected savings on insurance premiums from additional resilience measures are transferred to financing a portion of the loan. This reduces financing needs relative to a situation in which insurance is taken out, but the premiums are not reduced to reflect resilience measures and may also result in a lower financial burden than building in a non–resilient way and forgoing the insurance premium savings.
- Insurance element: insurance is integral to the product to generate the resilience dividend. Dependent on scale, insurance cover could be sought through multi–year contracts or capital markets placements, with the ability to reset contracts and re–assess the underlying risk and subsequent premium at regular intervals.

B. How would it work in detail?

B1. Key stakeholders and product components

The product would typically involve five key stakeholders:

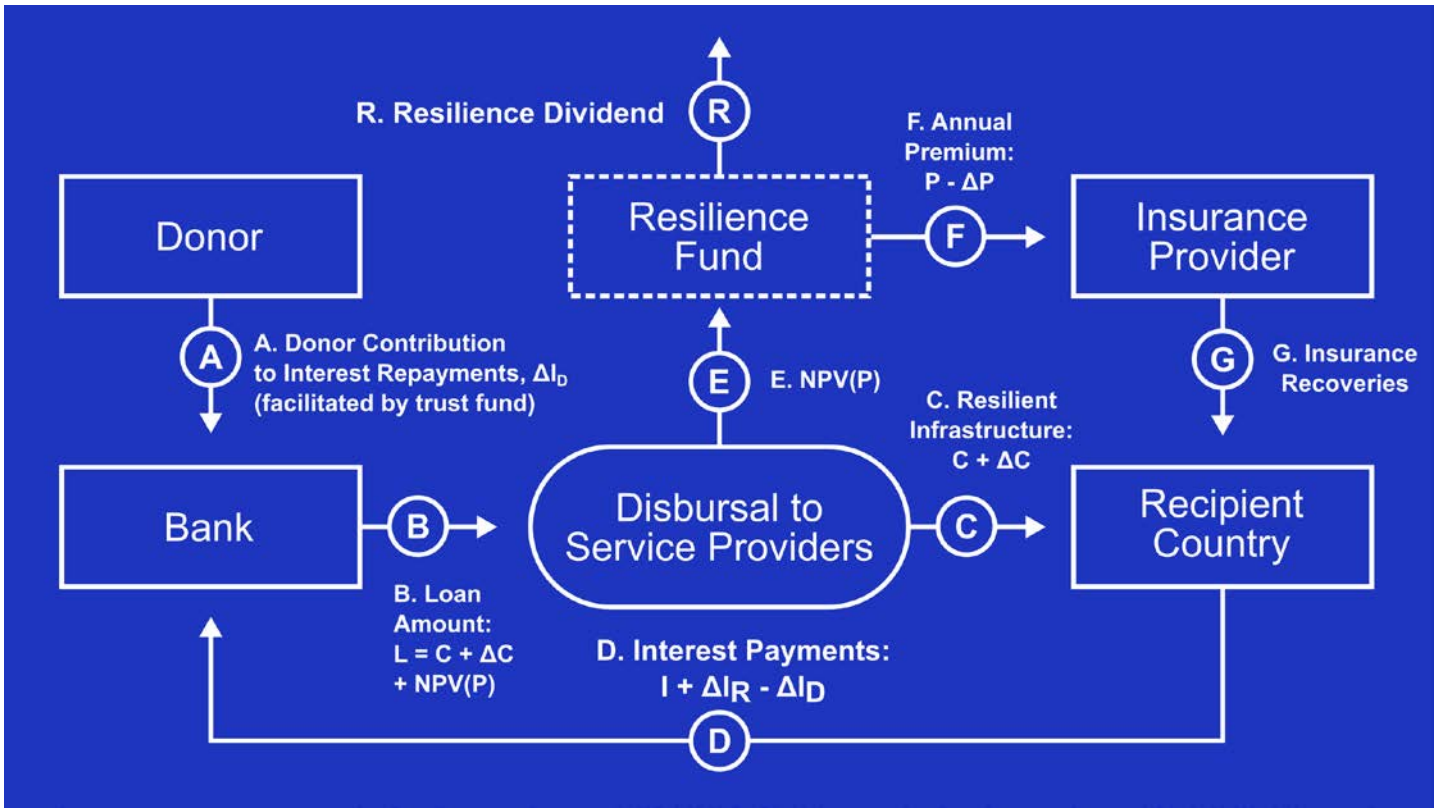
- A development bank that would provide a loan sufficient to cover both an investment/retrofit with resilience measures, and the expected insurance premiums associated with that asset if it were built non–resiliently. The insurance–linked loan is an attractive option to achieve development goals whilst effectively managing the financial risks of providing loans.
- A beneficiary, typically a national or local government, which receives the loan proceeds and uses them to invest in infrastructure measures that have additional resilience, as well as insurance cover to secure socio–economic development.
- The development bank and recipient may need to jointly facilitate the setting up a separate resilience fund that would receive the loan proceeds associated with the insurance premiums and make these payments as demanded.

– An insurer who provides a multi–year insurance product (with regular opportunity for reset) for the resilient infrastructure asset, and who is willing and able to assess the risk reduction resulting from the resilience measures and pass on the benefit in the form of reductions in premiums.
– (Potentially) a donor, who further supports the investment in resilience by offering concessional resources to be blended with the development bank's loan, to reduce the interest payments of the recipient.

B2. Flow of funds

Figure 7 *(below)* shows the generic flow of funds in the structure, with the table providing more details on each element:

Figure 7: Cash flows between agents from the insurance–linked loan instrument



Component		Funding Mechanism	Timing/Delivery
Infrastructure financing			
Base cost of infrastructure	C	Loan – recipient country bears cost	Project outset, disbursed over 3–5 years through procurement process
Base interest repayments	I	Paid by recipient country	Over 15–25 years
Insurance			
Annual insurance premiums	P	Financed by development bank through loan and ultimately borne by recipient country	Net present value (NPV) of future expected insurance premiums managed in a Special Purpose Vehicle SPV or trust fund for future disbursement and transferred to insurer in a series of multi–year contracts.
Resilience features			
Additional cost of resilient building	ΔC	Financed by development bank through loan and ultimately borne by recipient country. Potential for donor contribution.	Project outset, disbursement dependent on funding mechanism
Additional interest repayments due to additional cost of resilience	ΔI_R	Financed by recipient country	Over 15–25 years
Rebate on insurance premiums	ΔP	Either reduced cost of insurance upfront or used to part–fund interest repayments	Reduced future insurance premiums or reduced upfront cost of insurance
Optional concessionally spread to reward resilience	ΔI_D	Financed by donor	NPV of concessionality spread funded by donors at outset

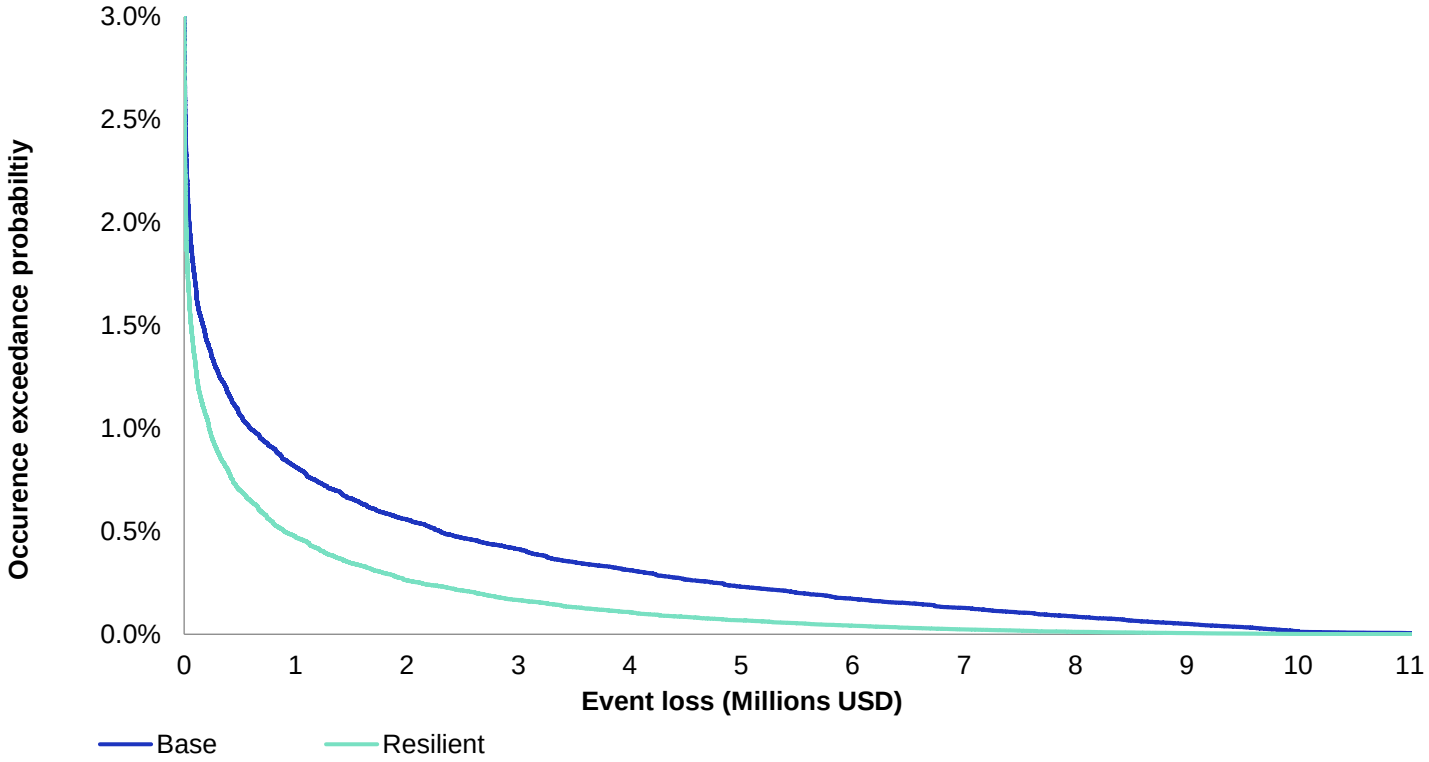
C. Worked example

The application of this product to the reconstruction of 10 schools in a hurricane–prone middle–income small island developing states (SIDS) country can help illustrate more concretely how the product would work[p].

The schools can either be reconstructed without resilience measures for $10m, or more resiliently – incorporating features such as roof sheathing, roof covering, opening protection, roof anchor, roof geometry – at a cost of $10,695,000 (a 6.95% increase).

The exceedance probability (EP) curves in Figure 8 (below) demonstrate the reduction in risk that can be expected from building resiliently when compared with a non-resilient ('base') construction. The EP curves show the probability of exceeding (y-axis) a range of loss thresholds (x-axis) for the resilient and base examples.

Figure 8: Loss occurrence exceedance probability (EP) curves for base and resilient cases



Source: RMS, 2018. Produced using the RMS North Atlantic Hurricane Models.

[p] The building and marginal cost assumptions for this case study have been derived from internal RMS expertise and research underlying the development of the RMS North Atlantic Hurricane Models. Costs are expected to vary by region, although relative costs and risk reductions will be largely conserved

The resilience measures reduce the average financial loss incurred from physical damage in an average year (average annual loss) by almost 50%, from $36k to $19k. They also reduce the volatility of average annual losses (AAL), as measured using the standard deviation of AAL, in any one year by around 40%. It is expected that this reduction in average annual loss reduces the annual insurance premium on the assets from $71.9k to close to $38.0k. This assumes a premium loading factor of 2x modeled AAL.

The loan beneficiary is assumed to face a choice between taking out a 25–year amortising loan with an interest rate of 4.0%, covering either the cost of a non–resilient asset (base cost of construction, C) and the cost of insurance; or b) the resilient cost of construction (C+ ΔC) and the cost of insurance. In either case, the loan is disbursed over five years as the assets are constructed. Reflecting the incentives of donors, the analysis also assumes that if the beneficiary chooses to construct resiliently, a donor will reduce the overall interest repayments by providing an upfront amount equivalent to the additional interest paid on the cost of resilience measures.

With this set up, cash flow analysis shows that the insurance savings plus donor contribution for resilience (d) are larger than the additional costs of resilience. This provides a financial incentive to build resiliently. The net benefit is $20,700 (using a discount rate of 5%). However, in this set up, this net benefit does partly rely on donor support: the net present value (NPV) of insurance savings are estimated to be around 70% of the additional costs of building resiliently, implying that these savings make an important contribution to resilience building but are insufficient by themselves.

Sensitivity analysis shows that in contexts where the cost of the resilience measure is lower, the absolute risk reduction from the resilience measures is higher, whether through achievement of higher percentage risk reduction or through greater baseline risk, or the discount rate is lower than the economic viability of the product increases. In contexts where these factors move in the opposite direction, the viability of the product falls.

The economic viability of the product is also highly sensitive to insurance pricing assumptions, where proportional loading is assumed, higher loading factors increase the net benefit as the insurance savings increase. This holds true where the volatility (as measured by standard deviation) of average annual losses is considered in the pricing formula as volatility sees similar relative reductions to the reduction in average annual loss.

D. Assessment against criteria

Evaluation

Encourages resilient infrastructure	✓	Has a viable path to implementation	✓
Monetizes resilience dividend	✓	Offers flexibility	✓
Makes resilience dividend available upfront	✓	Has a sound economic justification	✓
Involves risk transfer	✓	Causes ‘no harm’	✓

Encourages resilient infrastructure

- Product only made available for infrastructure where resilient options being considered.
- Depending on the specifics of the case, the rebate resulting from reduced insurance premiums significantly, or entirely, offsets the additional cost of resilient infrastructure. Further incentives can be provided by donor support.
- Product can be structured to enable support for ongoing maintenance of infrastructure.

Monetises resilience dividend

- The reduction in insurance premiums monetises the benefits of resilience.

Makes resilience dividend available upfront

- The product design allows for the reduction in insurance premiums to be transferred from the insurance portion of the loan, managed by the resilience fund, to the financing portion of loan.
- If all parties agree, and the recipients can commit to building resiliently, this can be done prior to infrastructure construction, reducing the overall size of the loan needed. However, the risk associated with non–delivery of the resilience benefits would need to be allocated.

Involves risk transfer

- Risk–based insurance contracts are the vehicle through which the resilience dividend is realised and are essential to this product. This can support the broader development of the insurance market.

Viable path to implementation

- International development bank loans are a significant source of infrastructure financing and this product represents incremental development to pre–existing products.
- The most significant challenges remain in accessing risk–based insurance pricing, developing the resilience fund and, as necessary, developing appropriate multi–year policies which also meet the needs of the insurance provider.

Offers flexibility

- The product has simple defining characteristics, namely the set–up of the resilience fund to manage the insurance funds provided by the loan, and the monetisation of risk reductions in the form of reductions in premium payments.
- The precise structuring and loan amounts can be tailored to consider individual cases, insurance and maintenance requirements.

Has a sound economic justification

- The applied example above indicates there is a positive net resilience benefit to the proposed structure compared to a situation where insurance is taken out on equivalent terms on a non–resilient asset, although in this specific case, the product relies on a degree of donor funding to be viable.
- The existence and extent of the benefit will depend on the marginal costs of resilience compared with the risk reduction and associated premium reduction.

Causes ‘no harm’

- The benefit of the product is illustrated with reference to a situation where insurance is taken out on a less resilient asset. Relative to a situation where no insurance is taken out, the product will require a higher loan amount and greater interest payments.
- However, as noted extensively earlier in the report, there are also significant wider benefits from resilience–building and insurance, which are not captured in the cash flow modelling. There is also scope for donor involvement in offsetting the interest costs on the additional loan amount.

E. Next steps

This product could come to market quickly, taking into account three factors:

1. The key role that international financial institutions already play in financing infrastructure in developing countries, which has been rising rapidly in recent years to account for almost half of all development assistance for infrastructure
2. That insurance is often procured during the construction phase and the first years after completion
3. The increased focus by international financial institutions, and donors, on resilience and the role for insurance within this

The key challenges, and hence areas for ongoing work to realise this product, include the following:

– Designing the insurance product. There is a need to further develop the insurance product to integrate it within the loan package. A multi–year insurance product will give other parties the greatest confidence as to the enduring nature of the resilience dividend on which the product relies. However, Lab participants indicated the maximum insurance contract length would be three years with built in resets/renewals at the end of each three–year period.

  This suggests a pool of participating insurers would be needed, and that future pricing would need to be, as far as possible, adjusted in a pre–determined way, while not exposing insurers to too much reinsurance pricing risk. Key to product viability is recognition of the risk–reduction rather than the static baseline insurance pricing. Coverage could be reduced to accommodate future increases in premium resulting from a changing risk environment or funds could be topped up to maintain initial coverage levels.

– Uncertainty surrounding the implementation of building standards and resilience measures, as well as efficacy of resilience measures. This uncertainty will make it more difficult to convert the modelled reduction in average annual losses into a monetised resilience dividend, and then more difficult again to make this resilience dividend available upfront prior to the investment being undertaken. This may be mitigated by regular inspections during and on completion of construction. Solutions at a sovereign level might include introduction of building certification policies.

  A decision needs to be taken on how the risk that resilience measures do not perform as expected is allocated, with the likelihood that if this risk is placed with insurers, the premium adjustment for the introduction of resilience measures will be notably smaller, potentially undermining the viability of the product.

– Robust quantification of risk reduction associated with some resilience measures and infrastructure types. The product relies on stakeholders having confidence in the modelled estimates of the reduction in risk from resilience measures. This makes it most likely that this product can be developed for resilient building design features for residential, commercial and industrial structures for key natural perils such as wind and earthquake risk.

  Implementation is also likely to be most feasible for portfolios of assets where uncertainty in engineering performance and modelling is reduced. More work may be required before this product can be applied to risk reductions related to green infrastructure (e.g. mangroves, storm water storage systems) and some types of heavy infrastructure (e.g. roads and energy).

4.2 Resilience impact bond

A. Introduction

The resilience impact bond is a pay–for–performance contract between a donor (outcomes funder) and an investor, where the return for the investor depends on how well they ensure the implementation of resilience measures associated with one asset or a series of assets.

Development impact bonds are increasingly being used in the development community to transfer the risk of delivering specific outputs or outcomes to investors. They can be an attractive instrument, where the delivery of outputs or outcomes is uncertain and investors have a good ability to influence the output/outcome delivery. A small selection of use cases include:

- Reducing the rates of sleeping sickness in Uganda
- Improving child and maternal health in Rajasthan, India
- Malaria prevention in Maputo Province, Mozambique
- HIV prevention and treatment in Gauteng Province, South Africa
- Reducing unemployment in youth migrants in Brussels

The discussion in Section 3 identified a range of barriers to delivering resilience which are difficult for governments and/or donors to control. A resilience impact bond pilot would test whether private investors are well–placed to overcome these barriers. It would define a series of physical, operational, and financial resilience indicators associated with infrastructure assets, including adequate insurance of the assets.

Meeting these criteria would require a capital outlay by a set of investors. If all the indicators were successfully met the investors would receive an attractive return paid by a donor; progressively missing more targets would result in lower returns. Specific rules would also apply in cases where the assets were affected by a disaster.

The product meets the two fundamental design features:

- Resilience incentive: investor returns would be highest in cases where various metrics of resilience were successfully achieved. The donor, who seeks to achieve resilience outcomes, uses the pay–for–performance contract to align investor interests with this public policy goal.
- Insurance element: the requirement to take out insurance to cover losses associated with disasters would be specified as one of the measures of resilience against which the donor would make a payment.

  In addition, the impact investor may also choose to take out insurance to ensure it has sufficient resources to implement disaster response and contingency plans needed to meet the criteria for payment. The investor may also seek insurance to protect against the risk of receiving a smaller pay–out from the donor, on account of not meeting all of the resilience metrics.

B. How would it work in detail?

B1. Key stakeholders and product components

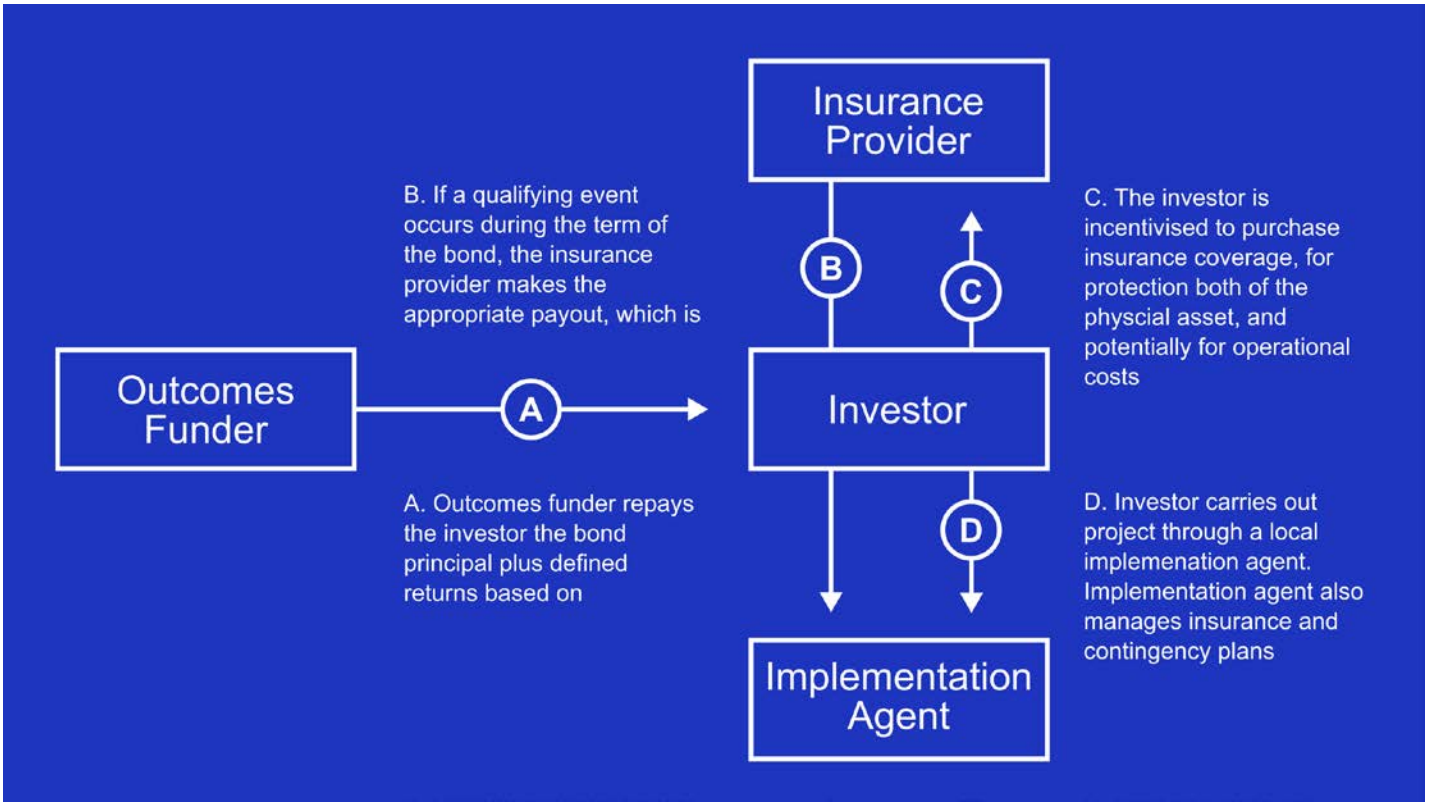
The product requires four main actors:

1. Outcomes funder (e.g. donor): designs the structure of, and then implements, the impact bond, determining how payment depends on the 1) the initial loan amount and 2) performance metrics which measure success in delivering various dimensions of resilience. These performance criteria would include measures of physical resilience e.g. designing and constructing (or retro–fitting) disaster resistant structures and evidence of ongoing maintenance activity; operational resilience such as the existence of robust disaster contingency planning and continued delivery of services reliant on infrastructure during all 'normal' periods; and financial resilience such as evidence that insurance is in place to cover physical losses from events and evidence that appropriate financing mechanisms are in place to support immediate disaster response needs and contingency plans.
2. Impact investor: provides project capital and appoints an implementation agent to manage the delivery of the project. Receives a return on invested capital, which is calculated based on how well the project performs against pre–defined performance indices. The performance indices are designed to reflect the outcome funders desired project objectives.
3. Implementation agent: acts on behalf of the impact investor to implement project locally. Responsible for ensuring that the project delivers expected outputs and outcomes.
4. Insurance provider: structures and supports insurance products that provide coverage for, at least, the physical assets, and possibly also the operational costs of disaster, and investor cash flows as required.

B2. Flow of funds

Figure 9 *(below)* shows the generic flow of funds in the structure, with the table below providing more details on each element.

Figure 9: The flow of funds from the resilience impact bond



C. Worked example

To further illustrate how the product might work, the analysis below discusses a use case in Dominica where a resilience impact bond is used to increase the resilience of 10 schools against hurricane risk and maintain the provision of education services.

Investors are expected to design, finance and deliver a programme that covers three dimensions of resilience:

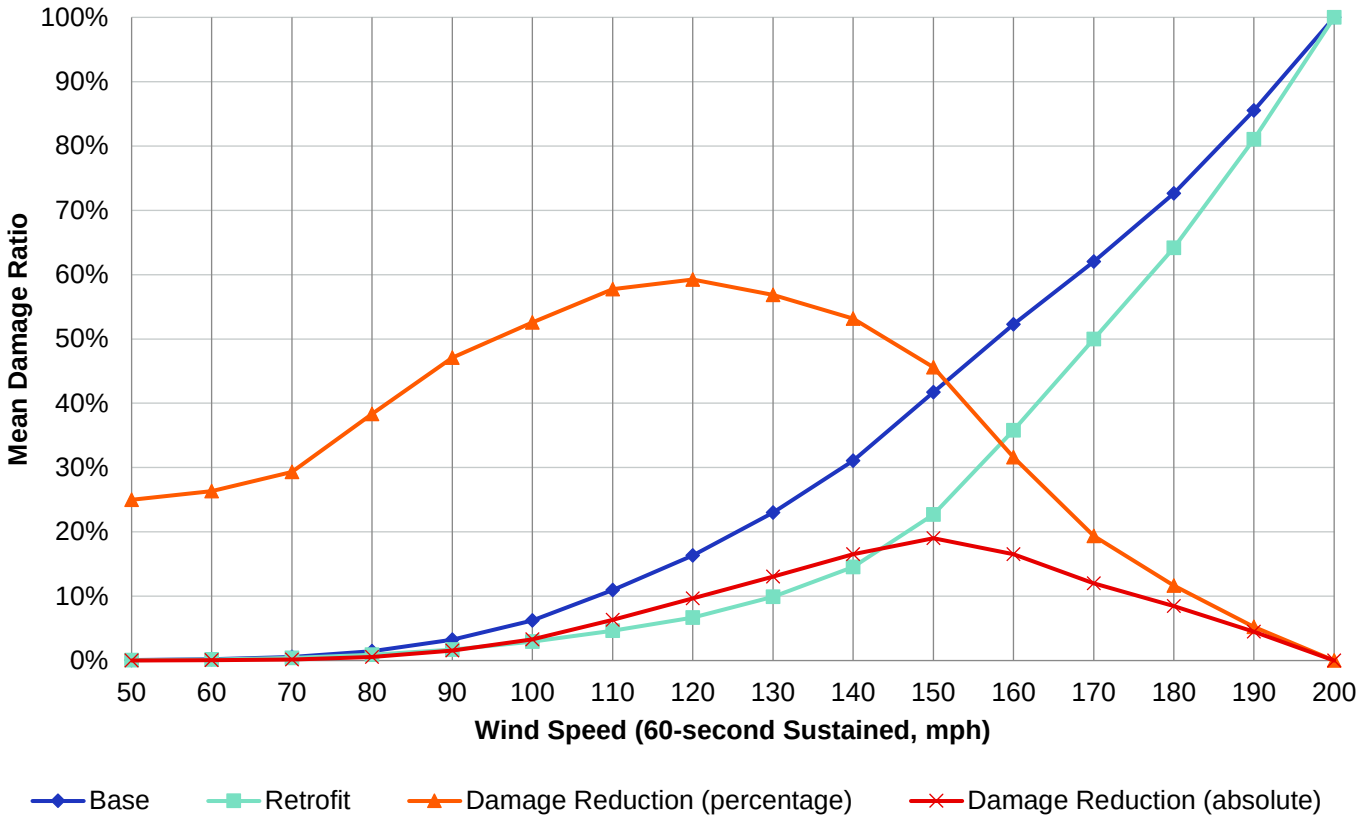
1. Physical resilience through a wind retrofit program to upgrade the structural resistance to wind damage
2. Operational resilience through the establishment of disaster response and contingency plans to ensure continuity of service following disaster. Prior to the programme starting, these plans do not exist
3. Financial resilience through a requirement to purchase asset insurance (in relation to damages from wind speeds more than 100mph) and to establish suitable funding mechanisms to support disaster response and recovery costs

The return to the investors is through payments made by the outcomes funder according to the success of the investor in meeting these three criteria. The term of the bond is five years – resilience measures are expected to be implemented across the portfolio of schools throughout this period, and success against indicators capturing the three dimensions of resilience would be assessed annually.

The physical resilience measures of the retrofit program are a crucial component of the product. The analysis is based on this consisting of upgrades to the roof sheathing and covering (*FEMA, 2013a*), and additional opening protection (*FEMA, 2013b*). It is assumed that these cost $590,000 in total per school ($400,000 for opening protection, $150,000 for roof covering and $40,000 for roof sheathing). This raises the insurable value of each school from £10m to $10.59m. The building and retrofit cost assumptions have been derived from internal RMS expertise and additional research.

Figure 10 *(below)* quantifies the expected reduction in damage and loss from these measures for the 10 schools across a range of wind speeds. Average annual losses are expected to reduce by 46% as a result of retrofitting, falling from $43.6k to $23.5k. The volatility of average annual losses is expected to fall by the same proportion. Assuming a 2x technical loading factor, this would reduce the annual premiums of insurance covering all events from $87.3k per annum to $47.0k.

Figure 10: Significant damage reduction potential is shown from building resiliently



Source: RMS, 2018. Vulnerability curves for the hypothetical school portfolio are created using the RMS North Atlantic Hurricane Models.

Building these resilience measures into a series of cash flows associated with the RIB requires assumptions on how the RIB might be structured to incentivise the different aspects of resilience. Based on the structures for similar products, our analysis assumes that:

- A low rate of return (1.5%) is applied to the funds needed for physical reflecting, reflecting that this is an output almost exclusively dependent on the investor's ability to design, implement and maintain pre–agreed measures to the required resilience level (0% if measures are not delivered).
- Because the delivery of operational resilience outcomes, especially continued service availability, is riskier for the investor and less in their control, this is remunerated at a 15% return. The return is 0% if the operational measures are not delivered.
- The asset insurance is remunerated through both a return rate (15% to reflect the potential difficulty of procuring insurance where risk transfer markers are underdeveloped) and the reduction in premiums, as the return is based on the cost of insurance for a non–resilient asset. It is also an obligatory component of the product[q]. Investments required to ensure that there are sufficient funds to cover the operational costs of implementing disaster plans, is remunerated at a high rate of return (15%) so long as asset insurance is in place, but at 0% if this is not in place.

A further complicating aspect of this product is what happens when there is a disaster event. For any wind event above 175mph, the bond is reimbursed immediately – it "converts". Given the extent of damages and the investor's capital at risk (value of retrofit), it is unrealistic to expect investors to continue services or deploy a sufficient disaster relief plan for events of such magnitude.

From this perspective, the structure is a mix between an impact bond and a resilience bond with tail risk events borne by the outcome funder. For any wind event above 100mph, the investor is expected to implement the operational resilience measures for one year, before it then converts.

The nature of the product is such that a wide variety of different cash flows can be realised depending on the combination of performance criteria that are met, and the realisation of an event in any one year. The chart below *(Figure 11, overleaf)* shows a range of potential combinations of performance and events, and shows how the return on investment and the payments by the outcomes funder vary.

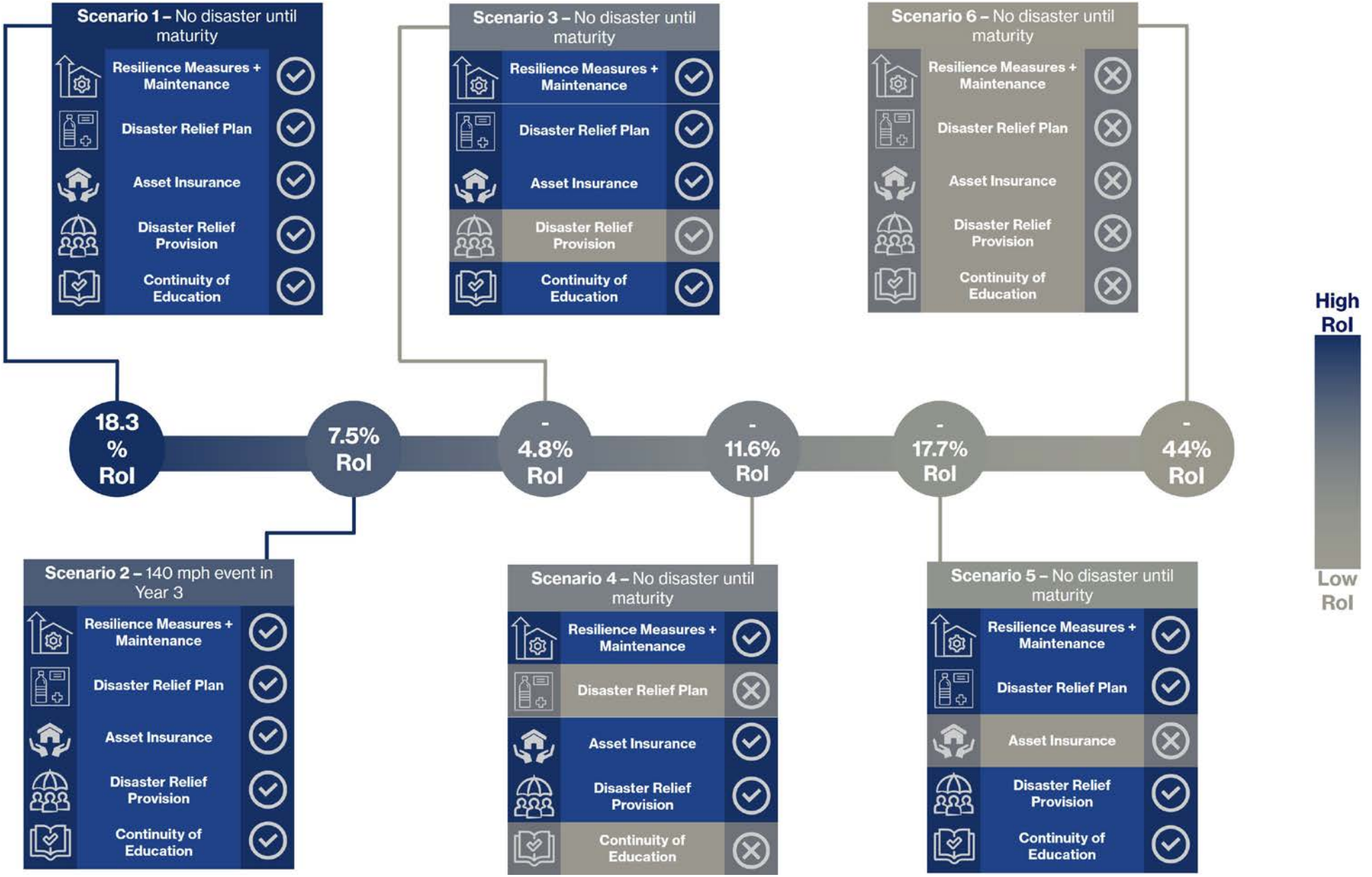
The chart illustrates clearly the fundamental feature of this product: the investor return on investment is higher (and the outcome payments made by the donor are higher) when the investor is successful in meeting the performance metrics associated with the dimensions of resilience. Across the scenarios considered, investor return on investment varies from +18.3% to –43.9% depending on the extent to which the resilience metrics are met.

The analysis also illustrates how the requirement to take out insurance for the assets transfers risk away from the outcomes funder. For example, in scenario 2 – where a 140mph wind event strikes in year three, where 40% of schools have been made resilient, the investor receives a total of $378,322 from the outcomes funder for having taken out insurance.

By contrast, the event causes damages to the resilient schools of $582,400 while the non–resilient schools suffer damages of $1,865,400. This is the cost that would need to be made by the outcomes funder to the investor to ensure the investor would not exit the structure.

[q] It is obligatory because the capital outlay of the investor on the retrofit measures is only a very small proportion of the total asset value. Without obligatory insurance, in the event of a disaster, the investor would rather exit the structure rather than bear the costs of rebuilding the whole asset. On the calibration involved in this example, the obligation would likely apply for damages caused by wind speeds in excess of 100 mph.

Figure 11: The return on investment will depend on how well the investor meets the criteria and whether an event occurs



D. Assessment against criteria

Evaluation

Encourages resilient infrastructure	✓	Has a viable path to implementation	✓
Monetises resilience dividend	✓	Offers flexibility	✓
Makes resilience dividend available upfront	~	Has a sound economic justification	~
Involves risk transfer	✓	Causes 'no harm'	✓

Encourages resilient infrastructure

The pay–for–performance design of the structure explicitly aligns the incentives of investors with the outcomes funder to promote physical, operational and financial dimensions of resilience.

Monetises resilience dividend

The resilience dividend is monetised in two ways:

- The investor's return on investment is linked to the resilience benefit that the retrofit generates. For example, the investor makes a return on investment of 18.3% in cases where the resilience measures are fully implemented, and no event occurs but makes negative returns in the cases where some or all the resilience measures are not met.
- The resilience dividend is captured again through reduced asset insurance costs – depending on who purchases the insurance, the savings can pass through to any of the impact investor, outcomes funder, or service provider.

Makes resilience dividend available upfront

The structure relies on the credible commitment by the outcomes funder to the investor being sufficient to incentivise the investor to undertake the upfront and other measures that promote resilience. In other words, rather than the resilience dividend being provided upfront, it is transferred to an investor who, because of contractual commitments with the outcomes funder, is patient enough to receive the monetised resilience dividend over time.

Involves risk transfer

There are multiple roles for insurance within the resilience impact bond, including:

1. Asset insurance for the underlying infrastructure
2. Parametrically triggered funds to cover the operational costs of disaster, and
3. Insurance intended to provide coverage for the impact investor, so they can protect future cash flows and expenditures against the risk of disasters impacting the project.

Viable path to implementation

There are many examples of impact bonds, and pay–for–performance contracts more broadly, being implemented. This paves the way for a resilience impact bond focused on resilience. However, the complexity of the product, and the need to tailor this complexity to each application, may limit its scalability (*see below*).

Offers flexibility

The performance criteria can be tailored to reflect different desired project outcomes. The structure also offers flexibility to set different rates of return for different performance criteria, allowing different outcomes to be more or less heavily incentivised according to donor preferences.

Sound economic justification

Further work needs to be undertaken to assess the value for money of this instrument compared to alternative structures. This research would need to assess the probability of the different aspects of resilience being undertaken with and without the pay–for–performance contract.

The mandating of insurance assumed in the structure is needed given the difference between the amount invested in the retrofit and the underlying value of the asset. This mandate would need to be assessed in

terms of the wider economic benefits it could bring, as discussed earlier in the report.

Causes ‘no harm’

There are built–in performance criteria which aim to minimise disruption to services.

E. Next steps

The product offers an innovative and exciting way to overcome many of the challenges that impede resilience–building by transferring the risk of non–provision of resilience to a single accountable set of investors, who suffer financial losses if it is not delivered.

However, several aspects need to be addressed, either before or during a pilot, to further test the robustness of the product and its widespread suitability.

- Complexity: the impact bond for resilience has a significant number of complex and interconnected elements. The performance indices require a range of bespoke qualitative and quantitative methods for both their design and measurement, which may need to be adjusted for each application.

  While this offers flexibility, it may also introduce significant transaction costs that are difficult to justify for smaller interventions. Moreover, due to the uncertain nature of quantifying resilience benefits, some of the performance criteria are necessarily subjective, which introduces the risk of disputes over performance assessment.
- Efficiency: more work is required to understand the efficiency of this structure in terms of value for money for the outcomes funder. This requires an assessment of how much more likely it is that the resilience measures will be delivered through this product compared with through a more conventional donor–funded program.

In addition, the product relies entirely on resources from the outcomes–funder, which may limit the sustainable scalability of the product.

4.3 Resilience bond

A. Introduction

A resilience bond is an innovative, risk–linked financing mechanism that takes the existing model of a catastrophe bond (cat bond), in common usage within the insurance linked securities market, and also accounts for the impact of resilience measures. The framework and design for this instrument was developed by re:focus as a way to both transfer catastrophe risk and help to fund projects to boost resilience pre-disaster.

Like cat bonds, sponsors pay premiums on an insurance contract and these premiums are used to make interest payments to bond investors. In the event of an eligible disaster, investors lose all or a portion of their investment and the bond principal is transferred to the bond sponsors as an insurance pay–out.

Unlike cat bonds, resilience bonds explicitly account for the impact of resilience measures by reducing bond interest payments as the measures are implemented and thus reducing the financial risk born by bond investors.

The difference in interest payments is credited to the resilience measures and can be securitised to provide upfront project capital through project revenue bonds or various types of project loans. re:focus have already undertaken research into the theory and application of this product, including a report with illustrative case study examples of developing coastal protection systems in Hoboken, seawall upgrades in Miami Beach and funding flood barriers in Norfolk *(re:focus, 2017)*.

In a development application, resilience bonds could be sponsored by a consortium of stakeholders that have an interest in implementing the resilience measures or in minimising future disaster recovery costs. Consortia members might include local asset owners and homeowners, local business and industry interests, regional economic development authorities, international development banks, aid agencies and national governments.

B. How would it work in detail?

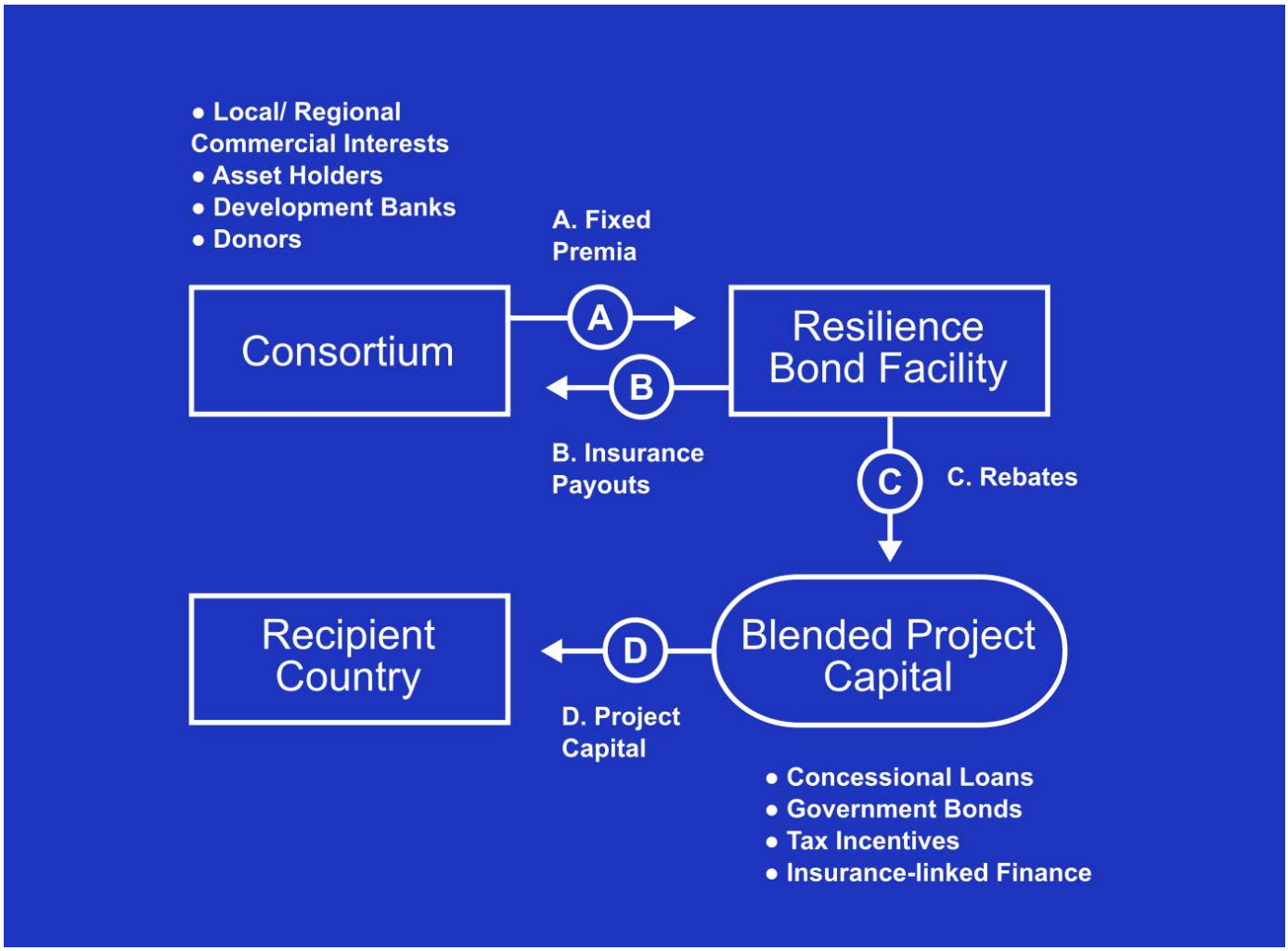
B1. Key stakeholders and product components

The key stakeholders in this structure would be:

- Sponsoring stakeholder consortia: those with a common collective strong interest in ensuring the resilience of a set of assets, including asset owners, those who rely on the services provided by the assets, economic development authorities and international financial institutions.
- The consortia would need to establish a resilience bond facility which would issue a resilience bond. The sponsoring stakeholder consortia would pay fixed premiums into the resilience bond facility to cover the interest costs of the resilience bond.
- A blended capital facility would provide capital to invest in resilience measures identified by the sponsoring stakeholder consortia. This capital raising would be supported by securitising the difference between the premiums paid by the sponsoring stakeholder consortia and the resilience bond interest payments after the resilience measures have been introduced.

B2. Flow of funds

Figure 12: Cash flows underpinning the resilience bond



- A: Consortium premiums paid on an insurance contract to the resilience bond facility.
- B: Insurance pay–outs issued by the resilience bond facility in the event of a qualifying natural disaster.
- C: “Rebates” paid by the resilience bond facility to the source of project capital, which mirrors the reduction in interest payments made to investors as the resilience measures reduce the risk to investor principle.
- D: Upfront capital provided to the resilience project based on projected “rebates” attributable to the project.

C. Assessment against criteria

Evaluation

Encourages resilient infrastructure	✓	Has a viable path to implementation	?
Monetizes resilience dividend	✓	Offers flexibility	✓
Makes resilience dividend available upfront	✓	Has a sound economic justification	?
Involves risk transfer	✓	Causes ‘no harm’	✓

Encourages resilient infrastructure

The product is only relevant when there is a consortium of stakeholders who recognise a shared interest in enhanced resilience.

Monetises resilience dividend

The resilience dividend is monetised by the reduction in bond interest payments upon the successful delivery of the resilience measures.

Makes resilience dividend available upfront

The resilience dividend is only made available as the resilience measures are introduced and the differences between the bond interest payments and the premiums payments crystallises. However, the predictability of this difference allows for the rebate to be securitized which allows the blended capital facility to provide upfront capital.

Involves risk transfer

The essence of the product is a cat–bond, a familiar risk transfer instrument.

Viable path to implementation

Despite its potential, more work is needed to assess the ease of bringing this product to market. This mechanism involves multiple stakeholders with complicated incentives structures and requires integrating the resilience bond with a blended capital facility. There are likely to be significant political and administrative challenges associated with aligning and managing large consortia of resilience bond beneficiaries and stakeholders.

Offers flexibility

The project concept can be tailored to suit a range of contexts, although the economic viability of applying the instrument would need to be considered afresh in each context.

Sound economic justification

Previous analyses of resilience bonds have shown their economic viability, although more work needs to be done to assess this in a development context.

Causes ‘no harm’

So long as the governance arrangements of the sponsoring stakeholder consortium are robust, the product should satisfy this criterion.

D. Next steps

Further risk and cash flow modelling is required to assess the product viability in one or a series of use cases.

4.4 Resilience company

A. Introduction

The idea of the ReSCo was inspired by the innovative financing mechanisms employed by energy service companies (ESCOs). ESCOs develop, build, and fund projects that create energy savings. They pay for the project upfront and rely on receiving some proportion of the savings that are realised due to the reduced energy usage to make a return on their initial investment.

A similar innovative mechanism could be used in conjunction with insurance policies to generate resilience savings for particular assets. Retrofitting a building, for example, reduces risks and results in lower insurance premium (assuming these are risk–based). The ReSCo would offer to undertake the retrofitting of the building at its own risk, and realise a return by receiving some proportion of the savings that are realised due to reduced insurance costs.

The R structure could be suited to disaggregated retrofit solutions with small scale yet 'easy win' resilience options, ideally where insurance is already in place. These would likely need to be resilience options which were effective at reducing losses from short return period events e.g. roof anchors and roof opening protection to increase resilience to hurricane wind damage.

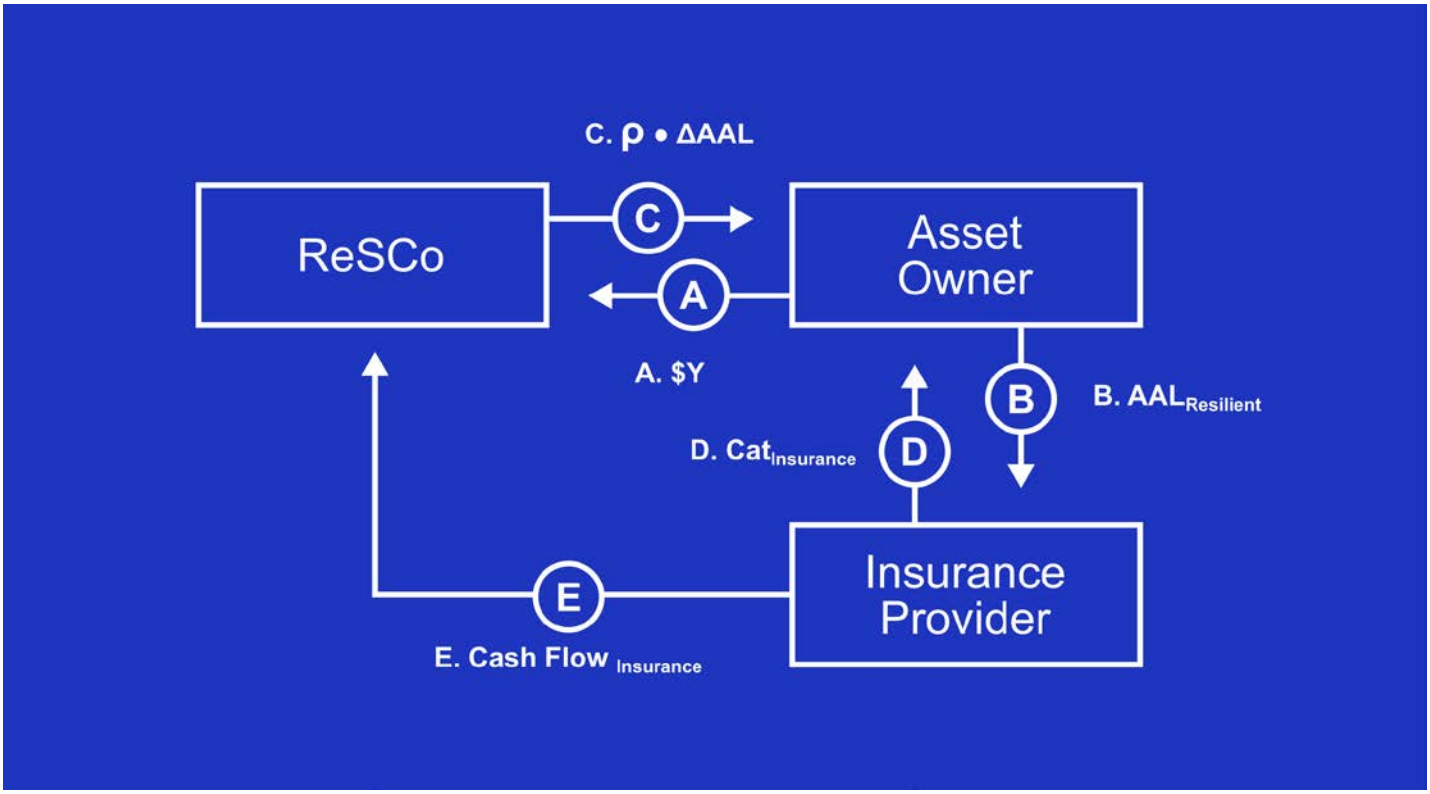
B. How would it work in detail?

The three core actors needed for the product are:

- The ReSCo: this type of company would need to be established. It would offer contracts to asset owners to undertake retrofit measures and commit the associated capital.
- Asset owner (house owner): the asset owner would be the counterparty to the ReSCo and agree to have retrofit measures undertaken on its property. The product also requires that the asset owner has insurance on the asset.
- Insurance provider: the insurer would offer an insurance contract to the asset owner. Contractual agreements between the insurer, asset owner and ReSCo would be needed to ensure that the impact of resilience measures is recognised in insurance premiums, and that this financial benefit flows from the insurer to the ReSCo, via the asset owner.

  There could also be a role for a donor both in helping to instigate the creation of a ReSCo – the novelty of the idea implies that a public private partnership is needed – and potentially in subsidising the cash flows received by the ReSCo, in cases where insurance premiums were insufficiently risk–based to make the product viable.

Figure 13: a schematic of the ReSCo cash flows



- **(A) –** $\$\boldsymbol{Y}$: The cost of the resilience measure, funded by the ReSCo.
- $\boldsymbol{AAL_{non\ resilient}}$, $\boldsymbol{AAL_{resilient}}$: The annual average loss for non–resilient and resilient assets.
- $\Delta\boldsymbol{AAL} = \boldsymbol{AAL_{non\ resilient}} - \boldsymbol{AAL_{resilient}}$: The insurer reduces the premium that the house owner pays, to account for the reduction in risk: the resilience dividend is equal to the reduction in average annual loss. The house owner now pays a fraction, $\boldsymbol{\rho}$, of the resilience dividend to the ReSCo each year, to payback the initial cost of the resilience $\$Y$.
- $\boldsymbol{Cat_{insurance}}$: The payment by the insurers if a catastrophe occurs.
- $\boldsymbol{CashFlow_{insurance}}$: The cost of insurance taken out by the ReSCo to cover their cash flow to cover a situation whereby the ReSCo does not receive the agreed payment from the asset owner.

C. Assessment against criteria

Evaluation

Encourages resilient infrastructure	✓	Has a viable path to implementation	?
Monetises resilience dividend	✓	Offers flexibility	✓
Makes resilience dividend available upfront	✓	Has a sound economic justification	?
Involves risk transfer	✓	Causes ‘no harm’	✓

Encourages resilient infrastructure

This product creates a business model around the concept of providing ‘resilience solutions’. The ReSCo would be incentivised to identify and market how resilient infrastructure solutions would offer benefits to a wide range of stakeholders.

Monetises resilience dividend

The resilience dividend is monetised by the reduction in insurance premiums that provides an income generating potential for the ReSCo.

Makes resilience dividend available upfront

The resilience dividend is only made available as the resilience measures are introduced and the reduction in insurance premiums crystallises. The product, in effect, transfers the resilience dividend to a set of investors who are sufficiently patient to receive that dividend over time.

Involves risk transfer

Insurance contracts are fundamental to the realisation of the resilience dividend.

Viable path to implementation

Despite its potential, more work is needed to assess the ease of bringing this product to market. Most importantly, there are currently no ReSCos in existence. A lot of incubation work may be needed to translate the concept into companies that are equipped to offer resilience solutions and take the associated risk on their performance. Pilots may be needed involving public (donor) support.

Offers flexibility

The product concept can be tailored to suit a range of contexts, although the economic viability of applying the product would need to be considered afresh in each context.

Sound economic justification

This needs to be tested to better understand whether and in which circumstances the reduction in average annual losses will be sufficient to offer an attractive return to the ReSCo investors. As noted above, the ReSCo structure could be suited to disaggregated retrofit solutions with small scale yet 'easy win' resilience options, such as roof anchors and opening protection to increase resilience to hurricane wind damage.

Causes ‘no harm’

There would likely need to be light regulation of any ReSCo to ensure sufficient consumer protection to any asset owner entering into a contractual relationship with a ReSCo.

D. Next steps

Further risk and cash–flow modelling is required to assess the product viability in one or a series of use cases.

Conclusion

Innovation Report 2018

Understanding risk

5. Conclusions

Disasters are currently characterised by growing costs, significant underinsurance, poor infrastructure and greater losses due to delayed recovery.

Resilient infrastructure is one way to help reduce the growing costs of disasters and speed recovery. Resilience has a significant potential dividend, with the total benefits usually outweighing the costs by four to one. This dividend is rarely recognised, and resilient infrastructure is underinvested in.

Even more resilient infrastructure will sometimes be subject to disasters that affect its performance and undermine the critical services that infrastructure provides. In these cases, insurance can help communities respond more effectively to disaster, access post recovery finance more quickly and hence bounce back faster. Insurance is also often the vehicle through which the resilience dividend can be monetised, helping to provide a financial incentive for resilient infrastructure construction.

This paper outlines four innovative insurance instruments that combine insurance capital provision to provide a monetary incentive for resilient infrastructure. These instruments include: insurance–linked loan packages, resilience impact bonds, resilience bonds and resilience service companies.

- Insurance–linked loan packages: explicitly integrate risk transfer solutions into the (concessional) loans provided by international financial institutions for the financing of new infrastructure or infrastructure upgrade programmes.
- Resilience impact bonds: a pay–for–performance contract in which private investors cover the costs of providing various aspects of resilience and are repaid by a donor based on the benefits of the project. Resilience Bonds are insurance products that require sponsors who will pay insurance premiums in order to access the rebate. This may be a challenge in markets with low insurance penetration.
- Resilience bonds: cat bonds that offer reduced interest in return for resilience measures. These reduced interest payments can be securitised as project revenue bonds or project loans to help cover the upfront costs of resilient infrastructure.
- Resilience–service companies (ReSCo): an independent agent who pays for and implements resilience measures in exchange for returns from future insurance premium discounts. ReSCos have an analogous example in the energy sector but are untrialled in insurance.

Each of these instruments offer potential solutions to the challenges of financing and promoting resilience but will require further development to apply them in practice. This study has further developed the insurance–linked package and resilience impact bond, illustrating with risk and cash flow modelling how they might work. For these, the next stage is to convene a group of interested stakeholders to pilot the products in a specific context: in both cases, there is significant practical experience that can be drawn on. In the case of resilience bonds and ReSCos, more research is needed to demonstrate proof of concept, following similar analysis to that deployed in this report.

Policymakers have a critical role to play in driving forward the development of these and similar products, tailoring their design and sponsoring pilots. The significant public benefits from resilience investments justify the public funding these products will often likely require to be successful. This should be part of a broader effort by policymakers to invest in risk data gathering and monitoring, prepare and plan in key sectors, and implement systems and tools to facilitate resilience.

The insurance industry needs to engage with policymakers by providing advice on risk modelling and assessment, guidance on risk financing tools and support to push resilience up the political agenda. Insurers can help to drive resilience themselves by better pricing risk and resilience into insurance premiums.

References

Arup. 2014. Toolkit for Resilient Cities [online]. Available at: https://www.siemens.com/content/dam/internet/siemens-com/global/company/topic-areas/intelligent-infrastructuree/resilience/toolkit-for-resilient-cities.pdf

Arup and Lloyds. 2017. Future Cities: Building Infrastructure Resilience [online]. Available at: https://www.lloyds.com/~/media/files/news-and-insight/risk-insight/2017/arup/lloyds_arup-future-cities-2017.pdf

Benjamin, N., Beegle, K., Recanatini, F. and Santin, M. 2014. Informal Economy and the World Bank [online]. Washington D.C. Available at: http://documents.worldbank.org/curated/en/416741468332060156/Informal-economy-and-the-World-Bank

Benson, C. 1998. The Cost of Disasters In: J. Twigg, ed., *Development at Risk? Natural Disasters and the Third World*. UK National Coordinated Committee for the International Decade for Natural Disaster Reduction (IDNDR): Oxford, UK, pp.8–13.

Benson, C. and Clay, E.J. 2004. Understanding the economic and financial impacts of natural disasters. [online]. Available at: https://openknowledge.worldbank.org/handle/10986/15025

C2ES. 2018. Policy Options For Climate–Resilient Infrastructure [online]. Available at: https://www.c2es.org/site/assets/uploads/2018/01/policy-options-for-resilient-infrastructure-01-2018.pdf

Cavallo, E., Galiani, S., Noy, I. and Pantano, J. 2010. Catastrophic Natural Disasters and Economic Growth [online]. Available at: http://www.economics.hawaii.edu/research/workingpapers/WP_10-6.pdf

CCRIF–SPC. 2017. CCRIF Reaches US$100 Million Milestone in Payouts [online]. Available at: https://www.ccrif.org/news/ccrif-reaches-us100-million-milestone-payouts

Centre for Global Disaster Protection, and Lloyd's. 2018. Innovative finance for resilient infrastructure. Availablet at: https://www.lloyds.com/~/media/files/news-and-insight/risk-insight/2018/innovative-finance-for-resilient-infrastructure.pdf

Chang, S.E., Mcdaniels, T., Fox, J., Dhariwal, R. and Longstaff, H. 2014. Toward disaster–resilient cities: Characterizing resilience of infrastructure systems with expert judgments Risk Analysis, 34(3), pp.416–434.

Clarke, D. 2016. Impact Appraisal for Sovereign Disaster Risk Financing and Insurance: Towards Better Evaluation and Evidence [online]. Available at: https://openknowledge.worldbank.org/handle/10986/22420

Clarke, D., Mahul, O., Poulter, R. and Teh, T.L. 2016. Evaluating Sovereign Disaster Risk Finance Strategies: A Framework [online]. Available at: https://openknowledge.worldbank.org/handle/10986/24637

Clarke, D.J. and Dercon, S. 2016. Dull Disasters? How Planning Ahead Will Make a Difference. First ed. Oxford University Press: Oxford, UK.

ClimateWise. 2016. Investing for Resilience [online]. Available at: https://www.cisl.cam.ac.uk/resources/sustainable-finance-publications/investing-for-resilience

Dedeuwaerdere, A. 1998. Cost–benefit analysis for natural disaster management: A case study in the Philippines. Brussels, Belgium.

Deloitte. 2015. Four years on: Insurance and the Canterbury Earthquakes [online]. Available at: https://www.vero.co.nz/documents/newsroom/deloitte-vero-four-years-on-insurance-canterbury-earthquakes-report-february-2015.pdf

DFID. 2011. Defining Disaster Resilience: A DFID Approach Paper [online]. Available at: https://www.gov.uk/government/publications/defining-disaster-resilience-a-dfid-approach-paper

Econsult Solutions. 2016. The Economic Impact of Green City, Clean Waters: The First Five Years [online]. Available at: http://gsipartners.sbnphiladelphia.org/wp-content/uploads/2016/02/SBN_FINAL-REPORT.pdf

EOD Resilience Resources. 2016. Designing for Infrastructure Resilience [online]. Available at: https://assets.publishing.service.gov.uk/media/57d6bc5be5274a34fb00002e/Designing_for_Infrastructure_Resilience_July_2016_external.pdf

European Commission. 2018. Ethiopia's Safety Net Programme Enhances Climate Change Resilience of Vulnerable Populations [online]. Available at: https://europa.eu/capacity4dev/file/69806/download?token=IkCUIAGa

Fay, M., Iimi, A. and Perrissin–Fabert, B. 2010. Financing Greener and Climate–Resilient Infrastructure in Developing Countries– Challenges and Opportunities EIB Papers, 15(2), pp.34–58.

FEMA. 1998. Protecting Business Operations: Second Report on Costs and Benefits of Natural Hazard Mitigation. Washington D.C.

Fema, 2013a. Roof Coverings and Best Practices [online]. Available at: https://www.fema.gov/media-library-data/20130726-1706-25045-9347/chapter8.pdf

Fema, 2013b. Windows, Doors, and Opening Protection [online]. Available at: https://www.fema.gov/media-library-data/20130726-1707-25045-9020/chapter10.pdf

Fijian Government. 2014. National progress report on the implementation of the Hyogo Framework for Action (2013–2015) – Interim [online]. Available at: https://www.preventionweb.net/english/policies/v.php?id=41004&cid=60

Fortified Home. 2017. Regulatory Framework for FORTIFIED Insurance Incentives [online]. Available at: http://disastersafety.org/wp-content/uploads/FORTIFIED-Home-Incentives_IBHS.pdf

Groom, B., Hepburn, C., Koundouri, P. and Pearce, D. 2005. Declining discount rates: The long and the short of it. Environmental and Resource Economics, 32(4), pp.445–493.

Insurance Council of New Zealand (ICNZ). 2018: Cost of natural disasters [online]. Available at: https://www.icnz.org.nz/natural-disasters/cost-of-natural-disasters/

IDF. 2018. Insurance Development Forum: About Insurance Development Forum [online]. Available at: http://theidf.org/

IFRC. 2015. Economic Efficiency of Community–Based Disaster Risk Reduction: Lessons Learnt from IFRC Programming. Geneva, Switzerland.

IIASA. 2015. Sound Public Investment and Financing Decisions based on Broader Understanding of Risk Information [online]. Available at: https://www.iosco.org/library/pubdocs/pdf/IOSCOPD505.pdf

IPCC. 2014. Summary for Policy Makers In Climate Change 2014: Impacts, Adaptation and Vulnerability Part A Global and Sectoral Aspects Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

IPPC. 2012. Summary for Policymakers In: Managing the risks of extreme events and disasters to advance climate change adaptation. Cambridge University Press.

Irfan, U. 2018. Puerto Rico's blackout, the largest in American history, explained Vox [online]. Available at: http://webcache.googleusercontent.com/search?q=cache:FYH8unihLsYJ:https://www.vox.com/2018/2/8/16986408/puerto-rico-blackout-power-hurricane&num=1&hl=en&gl=uk&strip=1&vwsrc=0

De Janvry, A., del Valle, A. and Sadoulet, E. 2016. Insuring Growth The Impact of Disaster Funds on Economic Reconstruction in Mexico [online]. Available at: https://openknowledge.worldbank.org/handle/10986/24631

Kahneman, D., Knetsch, J.L. and Thaler, R.H. 1991. Anomalies: The Endowment Effect, Loss Aversion, and Status Quo Bias Journal of Economic Perspectives, [online] 5(1), pp.193–206. Available at: http://pubs.aeaweb.org/doi/10.1257/jep.5.1.193

Kryspin–Watson, J. 2017. Quality Infrastructure Investment: Resilient Approaches and Examples from East Asia and the Pacific [online]. Available at: http://pubdocs.worldbank.org/en/754021486603959498/20170209-Quality-Infrastructure-Investment-Resilient-Approaches-and-Examples-from-East-Asia-and-the-Pacific.pdf

Kunreuther, H., Michel–Kerjan, E. and Tonn, G. 2016. Insurance, Economic Incentives and other Policy Tools for Strengthening Critical Infrastructure Resilience: 20 Proposals for Action [online]. Available at: https://web-oup.s3-us-gov-west-1.amazonaws.com/showc/assets/File/CIRI_Tonn_Insurance%20Economic%20Incentives%20and%20other%20Policy%20Tools%20for%20Strengthening%20Critical%20Infrastructure%20Resilience%2020%20Proposals%20for%20Action.pdf

Lloyd's. 2012. Global underinsurance report [online]. Available at: https://www.lloyds.com/news-and-risk-insight/risk-reports/library/understanding-risk/global-underinsurance-report

Lloyd's. 2017. Lloyd's end of year update to the market [online]. Available at: https://www.lloyds.com/news-and-risk-insight/news/lloyds-news/2017/12/lloyds-end-of-year-update

Maynard, T. and Ranger, N. 2013. Multi–year contracts to improve risk management culture? [online]. Available at: http://www.lse.ac.uk/CATS/Assets/PDFs/Publications/Papers/2013/MaynardRanger-AsiaInsuranceReview-Feb2013.pdf

MDBs. 2015. From Billions to Trillions: Transforming Development Finance. Washington D.C.

Mechler, R. 2004a. Natural Disaster Risk Management and Financing Disaster Loss in Developing Countries [online]. Available at: https://d-nb.info/1005509913/34

Mechler, R. 2004b. Cost-benefit analysis of natural disaster risk management in developing countries [online]. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.475.2075&rep=rep1&type=pdf p45-61

Michel–Kerjan, E., Hochrainer–Stigler, S., Kunreuther, H., Linnerooth–Bayer, J., Mechler, R., Muir–Wood, R., Ranger, N., Vaziri, P. and Young, M. 2013. Catastrophe risk models for evaluating disaster risk reduction investments in developing countries Risk Analysis, 33(6), pp.984–999.

Mizina, S. V., Smith, J.B., Gossen, E., Spiecker, K.F. and Witkowski, S.L. 1999. An Evaluation of Adaptation Options for Climate Change Impacts on Agriculture in Kazakhstan Mitigation and Adaptation Strategies for Global Change, 4(1), pp.25–41.

MMC. 2005. Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities: Volume 2–Study Documentation. Washington, D.C., US.

Munich Re. 2018. Natural Catastrophe Review: Series of Hurricanes Makes 2017 Year of Highest Insured Losses Ever [online]. Available at: https://www.munichre.com/en/media-relations/publications/press-releases/2018/2018-01-04-press-release/index.html

Neumayer, E., Plümper, T. and Barthel, F. 2014. The Political Economy of Natural Disaster Damage Global Environmental Change, 24, pp.8–19.

Oasis Loss Modelling Framework. 2017. Oasis Loss Modelling Framework [online]. Available at: https://oasislmf.org/

OECD. 2015. Economic Aspects of DR [online]. Available at: https://www.wcdrr.org/wcdrr-data/uploads/871/B.%20Brief%20issue%20paper.pdf

OECD and World Bank. 2015. Risk and Return Characteristics of Infrastructure Investment in Low Income Countries [online]. Available at: https://www.oecd.org/g20/topics/development/Report-on-Risk-and-Return-Characteristics-of-Infrastructure-Investment-in-Low-Income-Countries.pdf

Palliyaguru, R.S., Amaratunga, D. and Haigh, R. 2007. Effects of Post Disaster Iinfrastructure Reconstruction on Disaster Management Cycle and Challenges Confronted: The Case of Indian Ocean Tsunami in Sri Lanka [online]. Available at: http://usir.salford.ac.uk/9844/

Pestano, A. 2016. Ecuador Earthquake Reconstruction to Cost $3.3B UPI. [online] Jun. Available at: https://www.upi.com/Top_News/World–News/2016/06/02/Ecuador–earthquake–reconstruction–to–cost–33B/5231464880611/

Peter, G. von., Dahlen, S. von. and Saxena, S. 2012. Unmitigated disasters? New Evidence on the Macroeconomic Cost of Natural Catastrophes [online]. Available at: https://www.bis.org/publ/work394.htm

Ranger, N. and Surminski, S. 2013. Disaster Resilience and Post–2015 Development Goals: The Options for Economics Targets and Indicators [online]. Available at: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2014/03/PP-disaster-resilience-post-2015-development-goals-economics.pdf

RE:Focus. 2017. A Guide For Public-Sector Resilience Bond Sponsorship. [online]. Available at: http://www.refocuspartners.com/wp-content/uploads/pdf/RE.bound-Program-Report-September-2017.pdf

RMS. 2010. Study of Florida's Windstorm Mitigation Credits: Assessing the Impact on the Florida Insurance Market [online]. Available at: https://forms2.rms.com/rs/729-DJX-565/images/tc_2010_rms_study_florida_windstorm_mitigation_credits.pdf

RMS. 2018a. Financial Instruments for Resilient Infrastructure. Available at: https://forms2.rms.com/Lloyds_DFID_Report_Lloyds_DFID_Report.html

RMS. 2018b. Assigning a Retun Period to 2017. Available at: http://www.rms.com/exposure/assigning-a-return-period-to-2017/

Rogers, T. 2011. Nicaragua Quake Survivors Get New Homes– 40 years After Disaster Christian Science Monitor. Jun [online]. Available: https://www.csmonitor.com/World/Americas/2011/0616/Nicaragua-quake-survivors-get-new-homes-40-years-after-disaster

Rose, A. 2017. Benefit–Cost Analysis of Economic Resilience Actions Oxford Research Encyclopedia of Natural Hazard Science, (February 2018), pp.1–32.

Rose, A. and Krausmann, E. 2013. An Economic Framework for the Development of a Resilience Index for Business Recovery International Journal of Disaster Risk Reduction, 5, pp.73–83.

Swiss Re. 2018. Sigma Explorer [online]. Available at: http://www.sigma-explorer.com/

Tversky, A. and Kahnemann, D. 1974. Judgment under uncertainty: Heuristics and Biases Science, 185(4157), pp.1124–1131.

UK Government. 2011. Climate Resilient Infrastructure: Preparing for a Changing Climate [online]. Available at: https://www.gov.uk/government/publications/climate-resilient-infrastructure-preparing-for-a-changing-climate

UK Government Office for Science. 2012. Foresight: Reducing Risks of Future Disasters – Priorities for Decision Makers [online]. Available at: https://www.gov.uk/government/publications/reducing-risk-of-future-disasters-priorities-for-decision-makers

UN. 2014. http://www.un.org/en/development/desa/news/ecosoc/cities-for-a-sustainable-future.html

UN. 2015. Transforming Our World: The 2030 Agenda for Sustainable Development [online]. Available at: https://sustainabledevelopment.un.org/post2015/transformingourworld

UNDP. 2014. Disaster Risk Reduction Makes Development Sustainable [online]. Available at: http://www.undp.org/content/dam/undp/library/crisis%20prevention/UNDP_CPR_CTA_20140901.pdf

UNEP FI. 2018. Insurance Industry Commitments to Build Climate and Disaster Resilience and Promote Sustainable Development [online]. Available at: http://www.unepfi.org/wordpress/wp-content/uploads/2018/08/4-Bacani.pdf

UNISDR. 2007. Costs and Benefits of Disaster Risk Reduction [online]. Available at: https://www.unisdr.org/we/inform/publications/1084

UNISDR. 2009. UNISDR Terminoology on Disaster Risk Reduction International Stratergy for Disaster Reduction (ISDR), pp.1–30.

United Nations. 2015. Sendai Framework for Disaster Risk Reduction 2015–2030 [online]. Available at: https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf

UNOCHA. 2018. Global Humanitarian Overview 2018. United Nations. Geneva, Switzerland.

Venton, C.C. and Venton, P. 2004. Disaster Preparedness Programmes in India: A Cost Benefit Analysis [online]. Available at: https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/506.pdf

Vermeiren, J.C. and Stichter, S. 1998. Costs and Benefits of Hazard Mitigation for Building and Infrastructure Development: A Case Study in Small Island Developing States.

Woo, G. 2015. Fighting Emerging Pandemics With Catastrophe Bonds [online]. Available at: http://www.rms.com/blog/2015/01/28/fighting-emerging-pandemics-with-catastrophe-bonds/

World Bank. 2012. Mexico's Natural Disaster Fund: A Review [online]. Available at: http://documents.worldbank.org/curated/en/408711468286527149/FONDEN-Mexicos-natural-disaster-fund-a-review

World Bank. 2015a. Country Note: Fiji [online]. Available at: http://documents.worldbank.org/curated/en/993781468029722952/Fiji-country-note

World Bank. 2015b. Unlocking the 'Triple Dividend' of Resilience [online]. Available at: https://openknowledge.worldbank.org/handle/10986/21612

World Bank. 2017. Sovereign Climate and Disaster Risk Pooling [online]. Available at: https://openknowledge.worldbank.org/handle/10986/28311