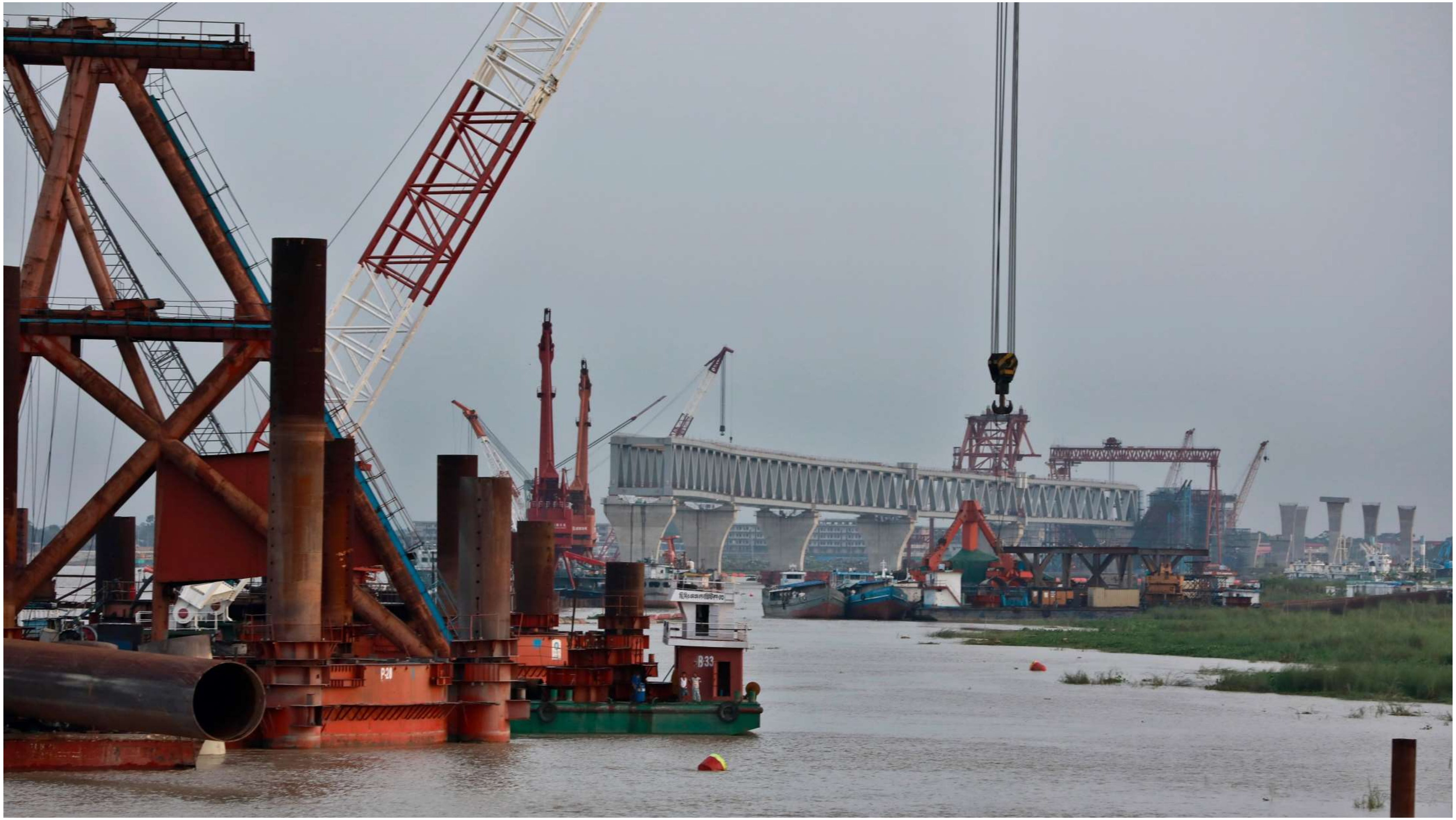
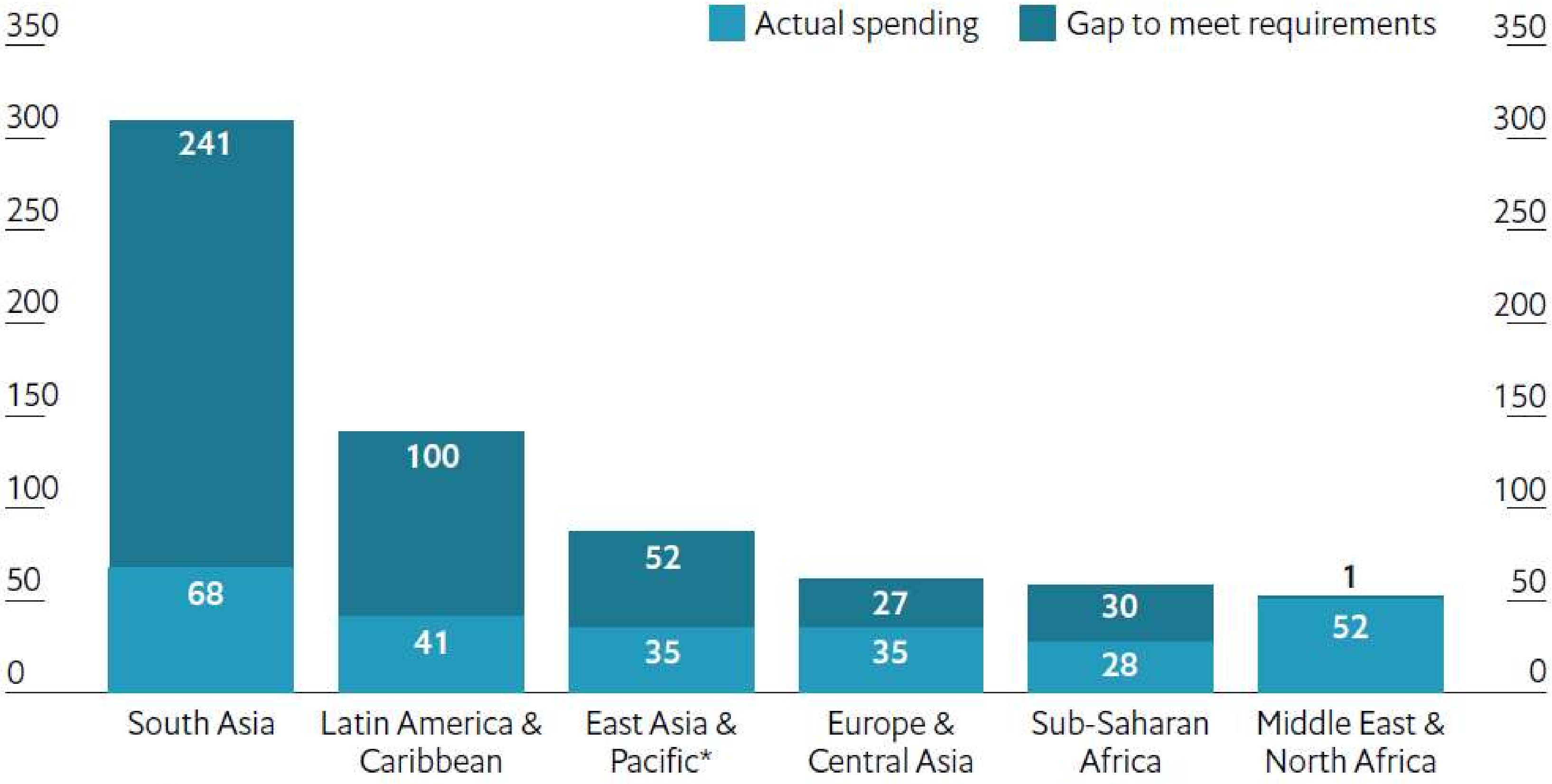
Preparing for Catastrophe: Climate-resilient infrastructure systems

Prof Jim Hall
University of Oxford


B33

Infrastructure investment requirements, actual spending and investment gap in emerging markets and developing economies, annual US$ bn over 2014-20

(US$ bn)



Source: World Bank.

Note: Excludes China, which is overinvesting in infrastructure.


Time to buy a new home ?

Castle Meads electricity substation flooded in 2007 leaving 42,000 people without power

Railway workers inspect the main Exeter to Plymouth railway line at Dawlish (2014).

December 2015 55000 homes left without power after a substation in Lancaster flooded

Why we worry about natural disasters and infrastructure:

1. Direct damage to infrastructure assets

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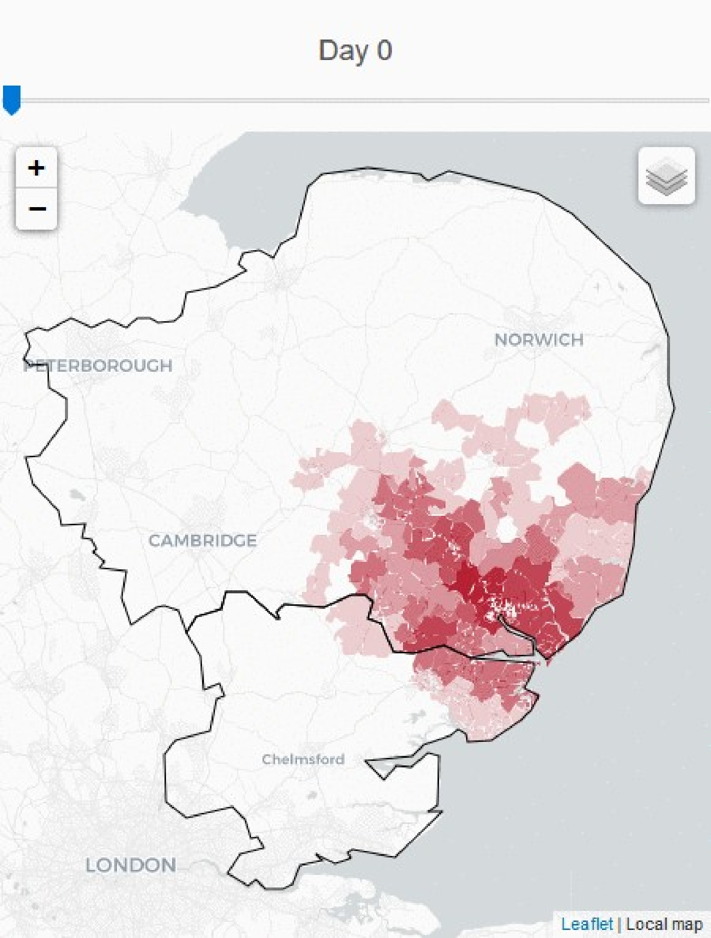
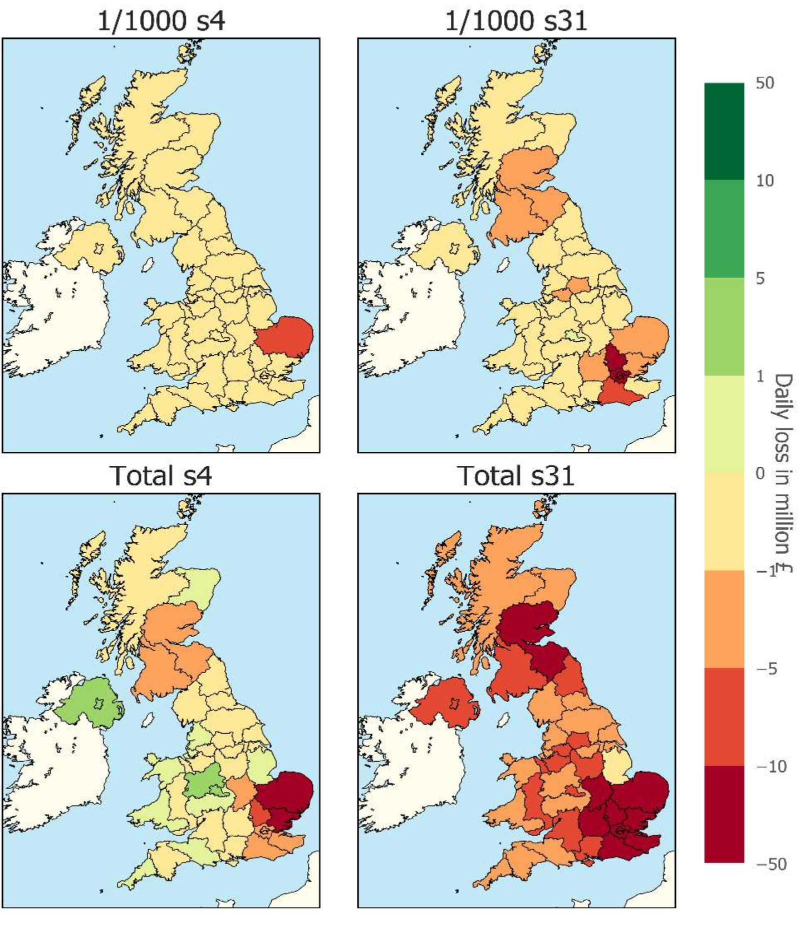
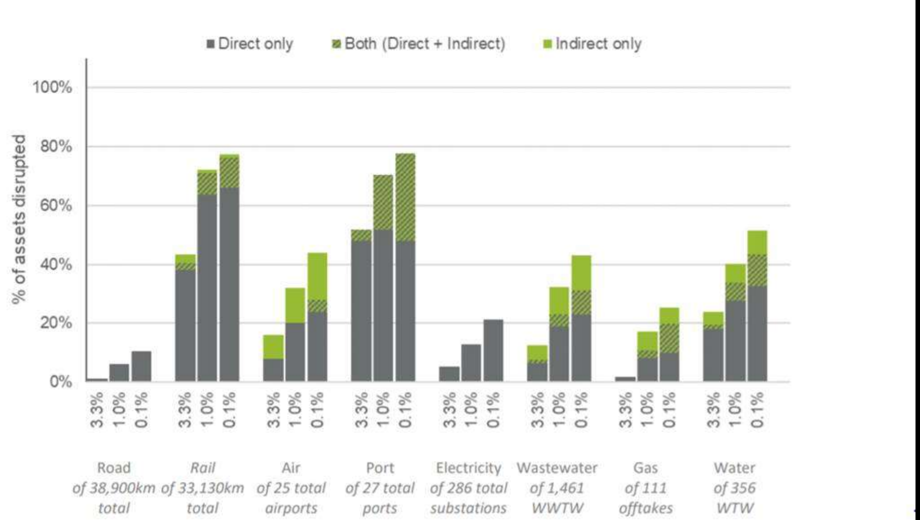
Why we worry about natural disasters and infrastructure:

1. Direct damage to infrastructure assets
2. Disruption to infrastructure services and supply chains

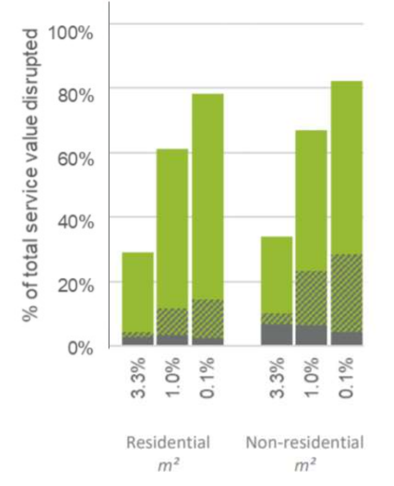




Koks, E., Pant, R., Thacker, S., Hall, J.W. Understanding business disruption and economic losses due to critical infrastructure failures, *Risk Analysis*, in review.



For some types of asset, up to 80% of assets are disrupted directly or indirectly in a 0.1% AEP flood



Eight times as many (20 million) properties are at risk of indirect disruption due to flooding of utilities infrastructure than are at risk of direct flooding from rivers and sea (2.4 million)

The total impact of flooding on infrastructure could be £2.0-£2.4 billion per day of disruption for a hypothetical 3.3% AEP flood event with nationwide coverage (and up to £5.7-£10.0 billion for a 0.1% AEP event)

TOYOTA

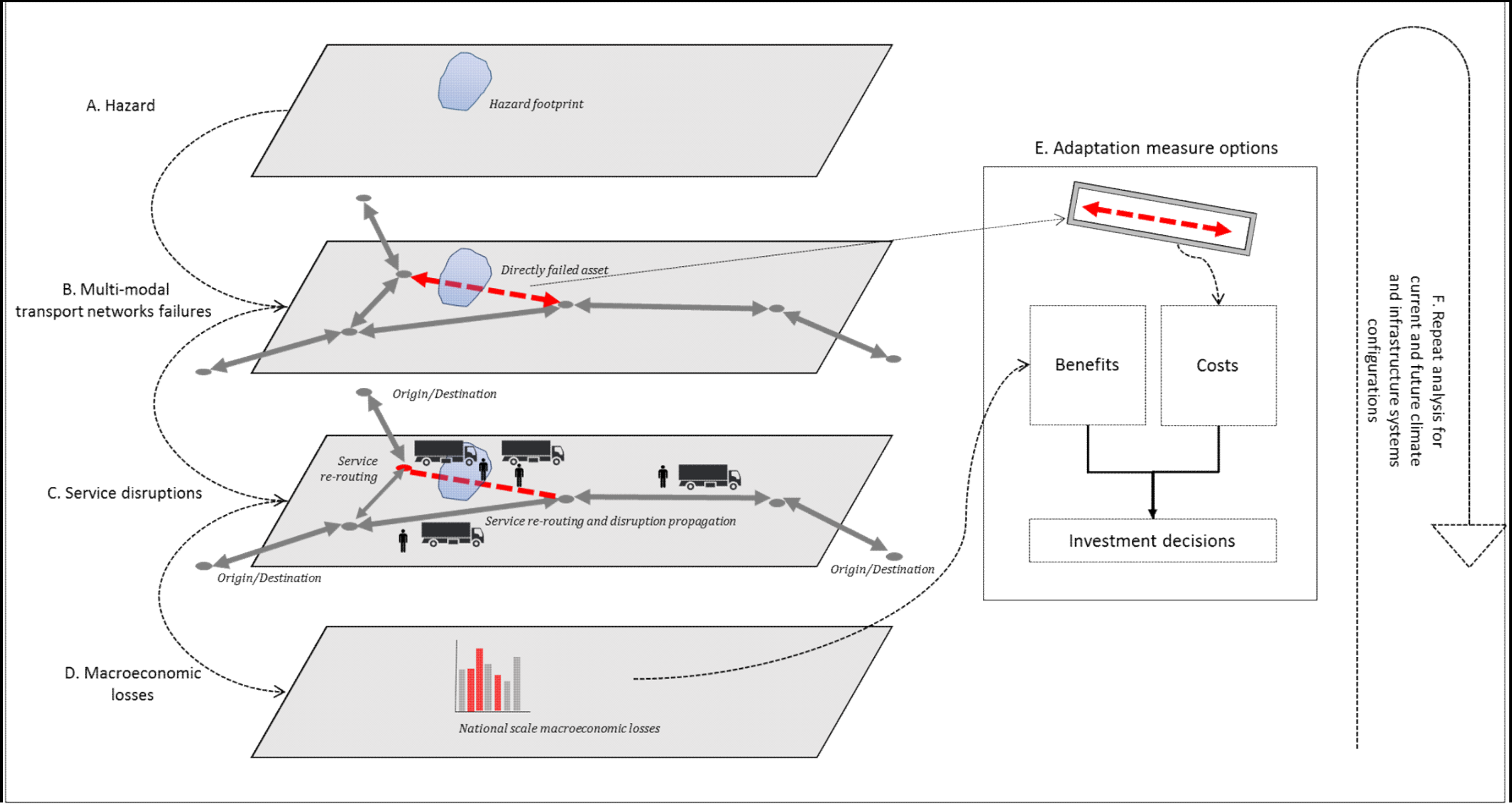
ATOMKRAFT? NEIN DANKE

Why we worry about natural disasters and infrastructure:

1. Direct damage to infrastructure assets
2. Disruption to the infrastructure services and supply chains
3. Infrastructure development increasing human and economic exposure to natural hazards

1. How big is the risk?
2. Where is it located?
3. How is it changing?
4. What are cost-effective adaptation options?

Network risk analysis forms the basis for proportionate adaptation decisions



A. Hazard

Hazard footprint

B. Multi-modal transport networks failures

Directly failed asset

Origin/Destination

C. Service disruptions

Service re-routing

Service re-routing and disruption propagation

Origin/Destination

Origin/Destination

D. Macroeconomic losses

National scale macroeconomic losses

E. Adaptation measure options

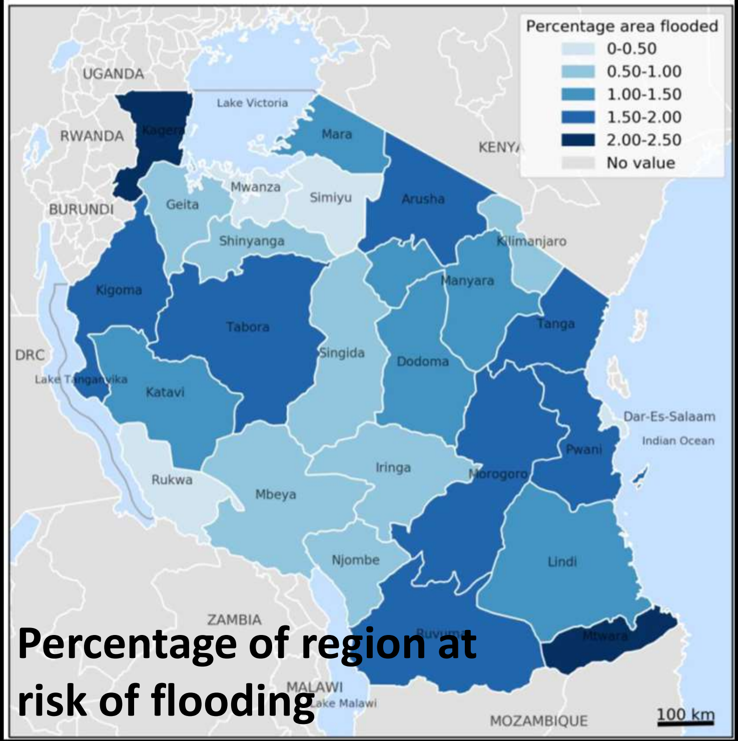
Benefits

Costs

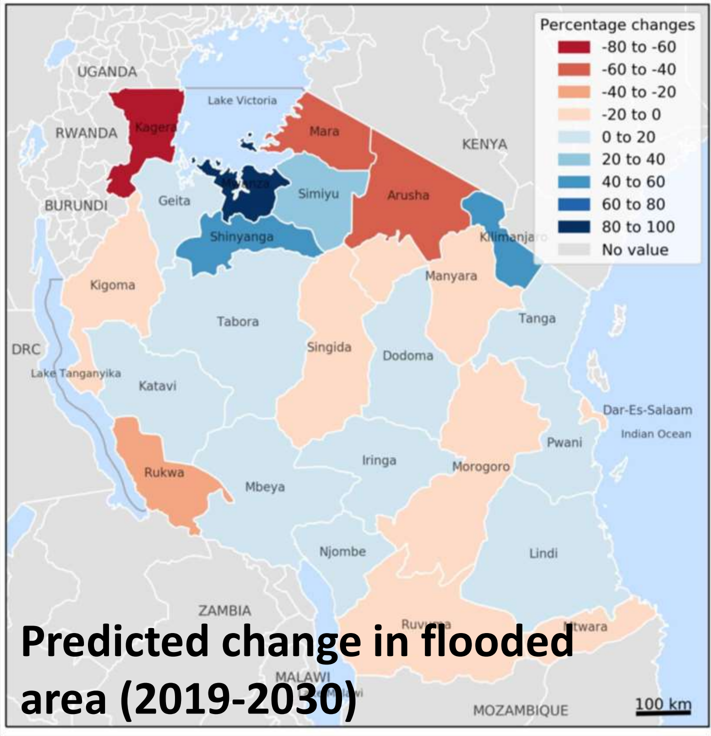
Investment decisions

F. Repeat analysis for current and future climate and infrastructure systems configurations

Quantifying the hazards, at present and in the future



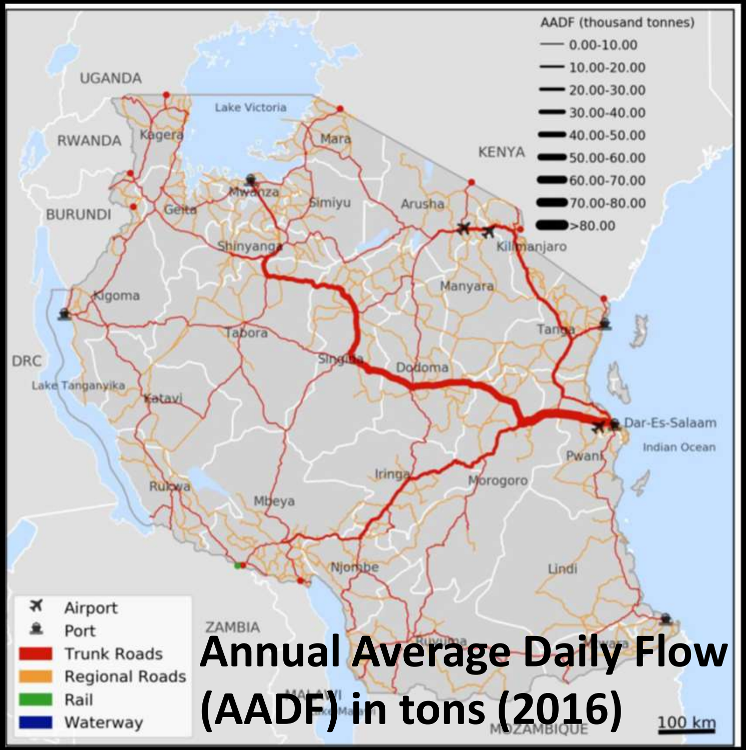
Percentage of region at risk of flooding



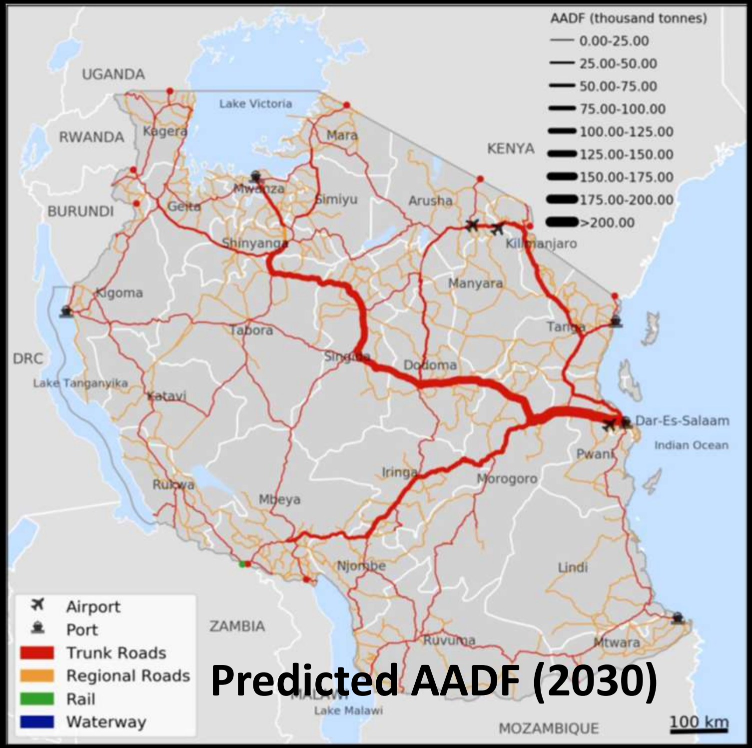
Predicted change in flooded area (2019-2030)

Pant, et al. (2018) *Transport Risks Analysis for The United Republic of Tanzania: Systemic vulnerability assessment of multi-modal transport networks*. Oxford Infrastructure Analytics Ltd.

Identifying network exposure, at present and in the future



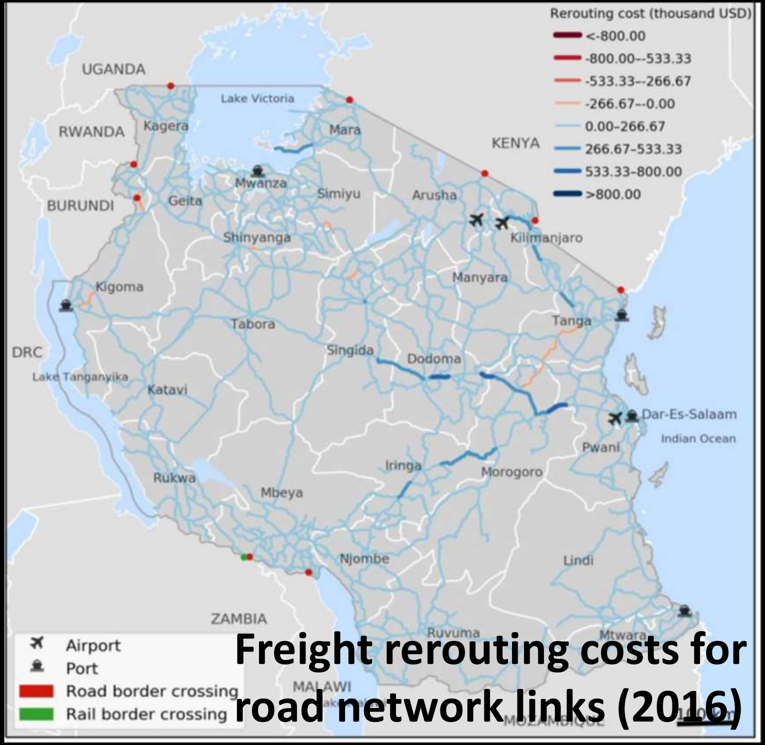
Annual Average Daily Flow (AADF) in tons (2016)



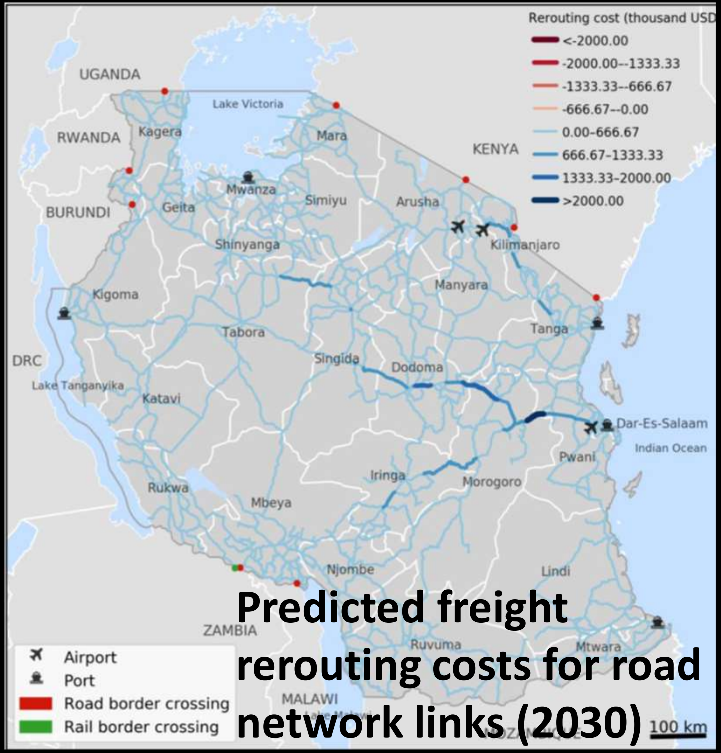
Predicted AADF (2030)

Pant, et al. (2018) *Transport Risks Analysis for The United Republic of Tanzania: Systemic vulnerability assessment of multi-modal transport networks*. Oxford Infrastructure Analytics Ltd.

Identifying highest risk locations, which are priorities for adaptation



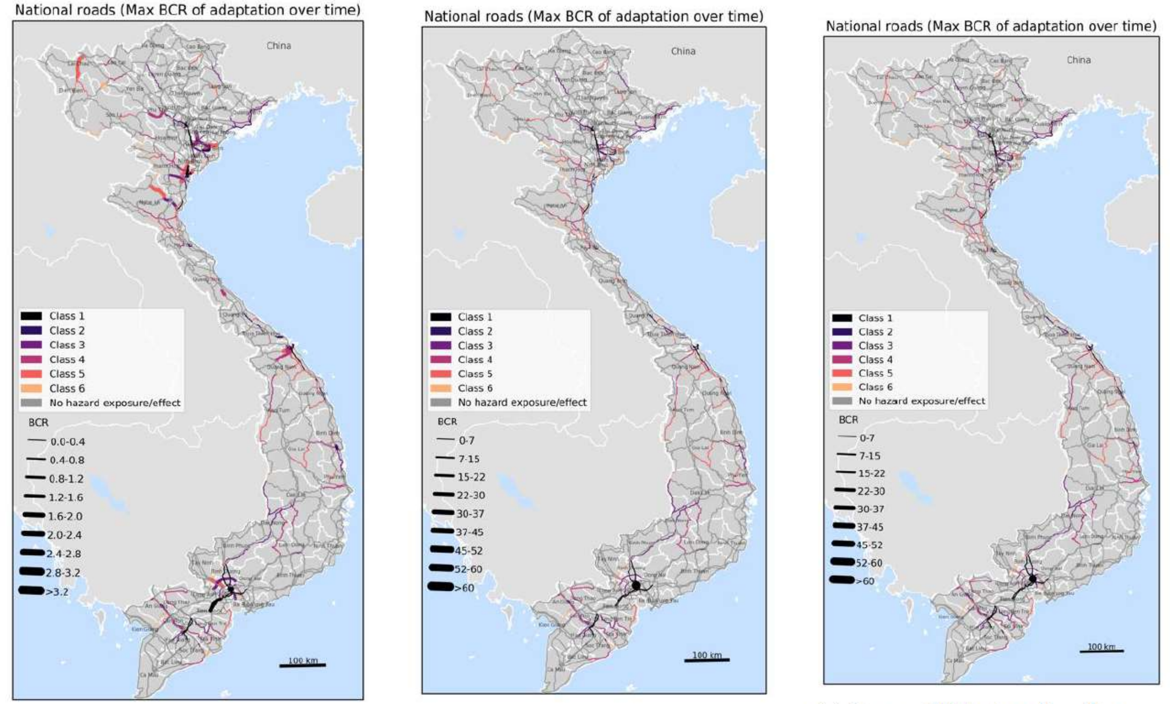
Freight rerouting costs for road network links (2016)



Predicted freight rerouting costs for road network links (2030)

Pant, et al. (2018) *Transport Risks Analysis for The United Republic of Tanzania: Systemic vulnerability assessment of multi-modal transport networks*. Oxford Infrastructure Analytics Ltd.

Benefit-cost ratios of investment in enhancing the resilience of the transport network



(a) Current 2016 river flooding

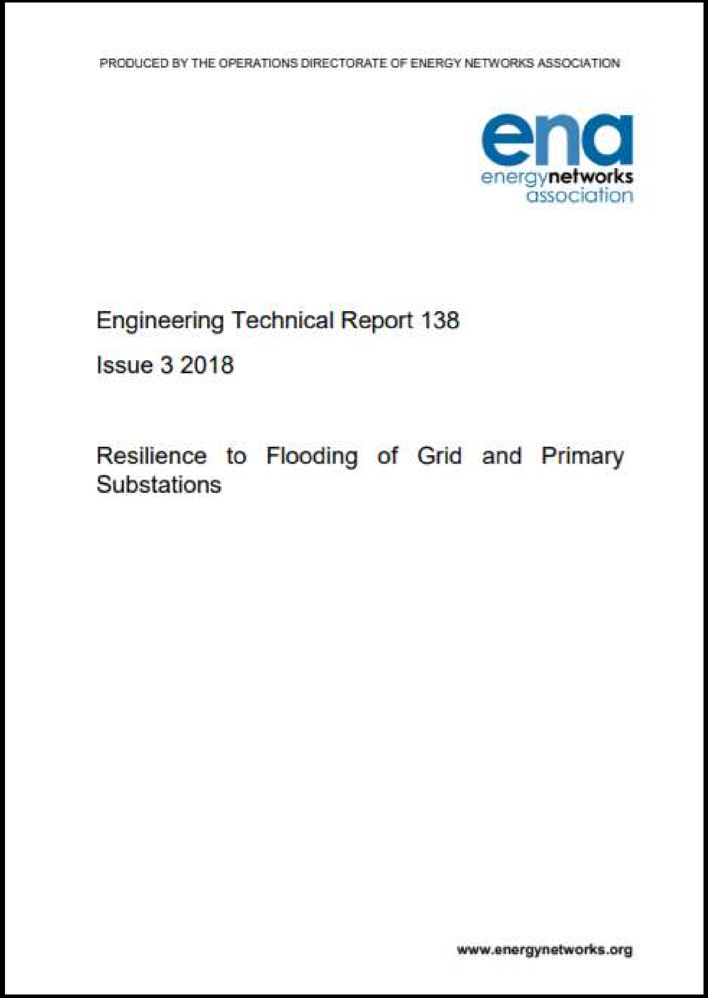
(b) Future 2030 river flooding under RCP 4.5 emission scenarios

(c) Future 2030 river flooding under RCP 8.5 emission scenarios

Pant, et al. (2019) *Analysis and development of model for addressing climate change/disaster risks in multi-modal transport networks in Vietnam. Final Report*. Oxford Infrastructure Analytics Ltd.

How do respond?

1. Disaster-proofing infrastructure assets



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Engineering Technical Report 138

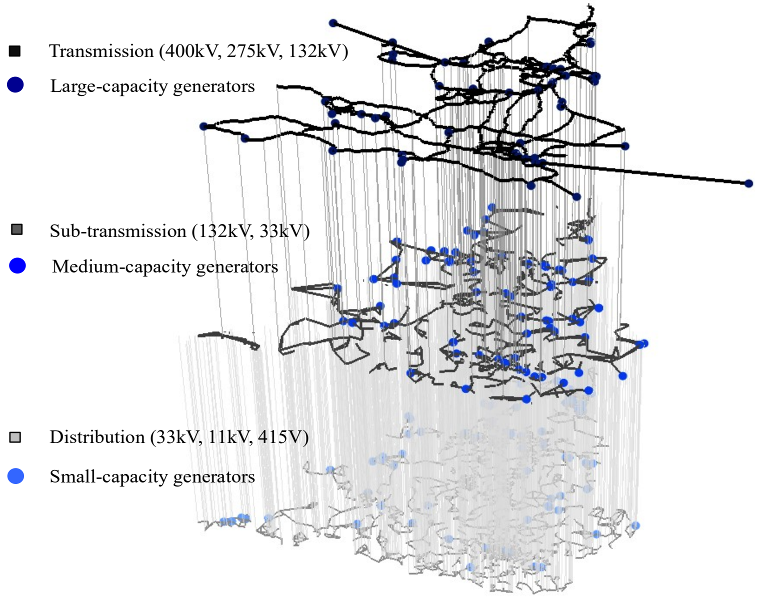
Issue 3 2018

Resilience to Flooding of Grid and Primary Substations

www.energynetworks.org

The most important electricity assets

Integrated electricity network



Infrastructures dependent on electricity for their operation

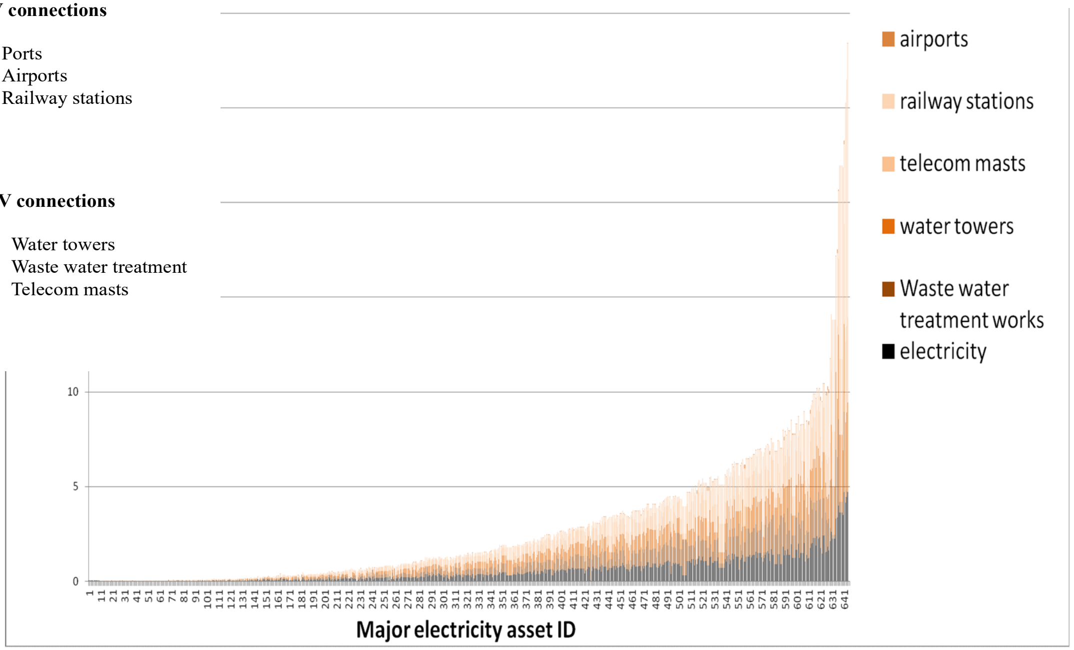
33kV connections

- Ports
- Airports
- Railway stations

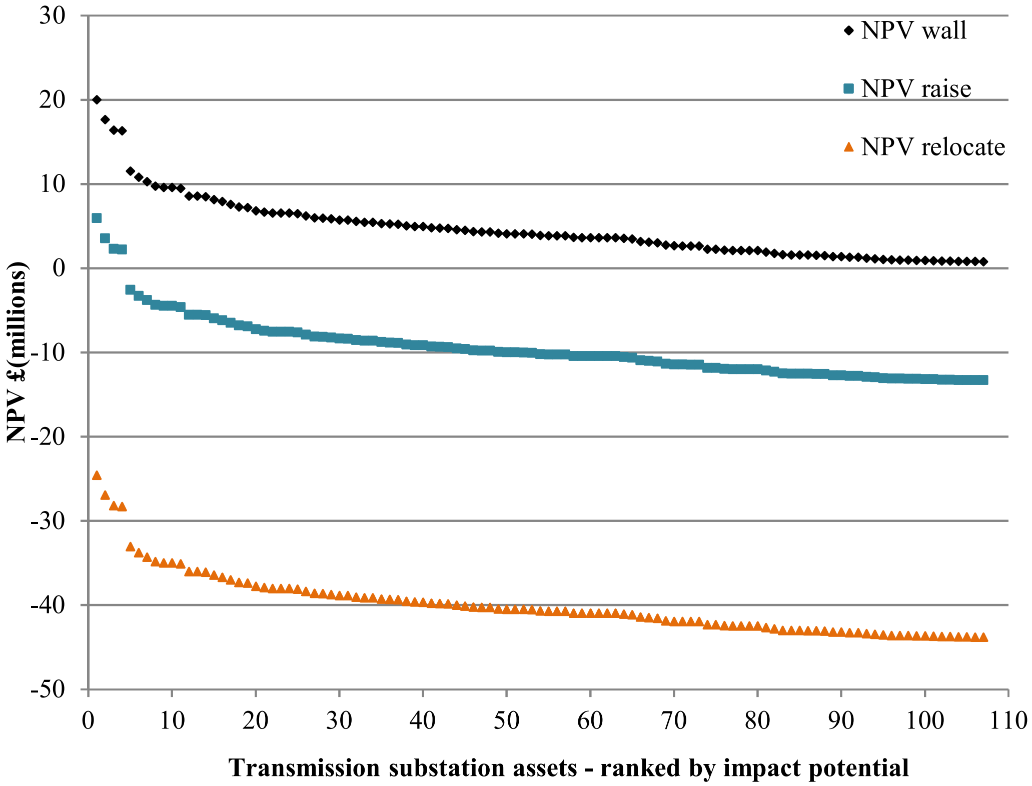
11kV connections

- Water towers
- Waste water treatment
- Telecom masts

Direct and Indirect customers impacts due to electricity transmission assets

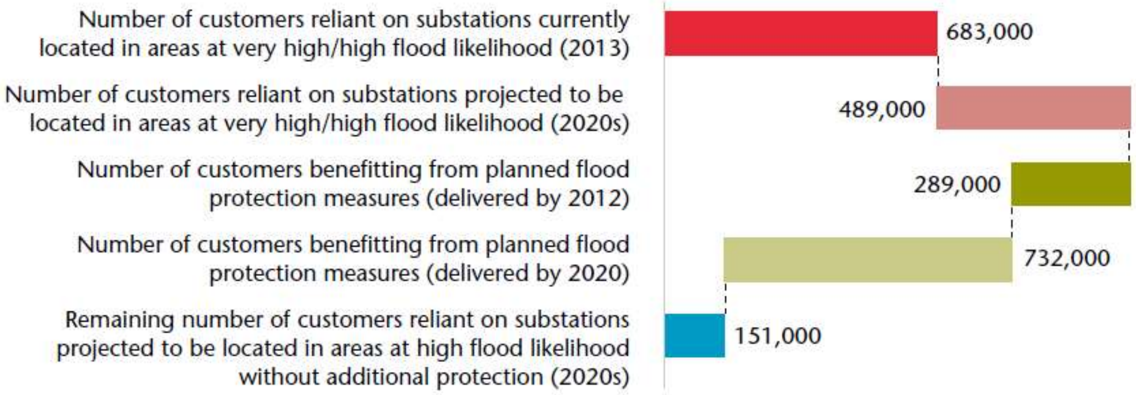


Economic benefit of alternative adaptations



Progress with adaptation

Risk	Number of sites	Completed works	Remaining
1:100	11	7	4
1:200	26	0	26
1:1000	65	0	65

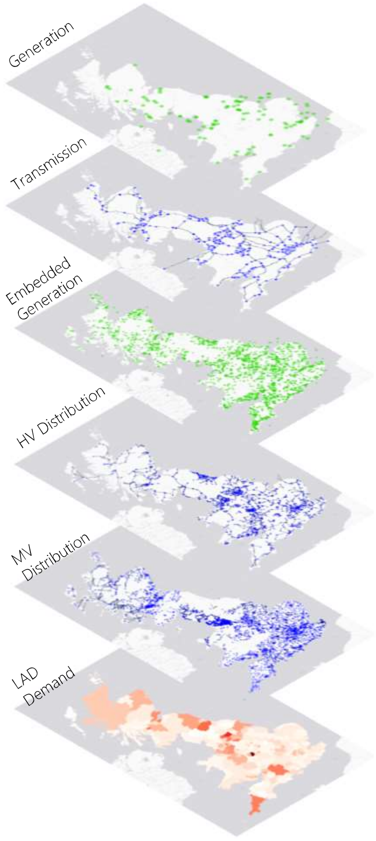


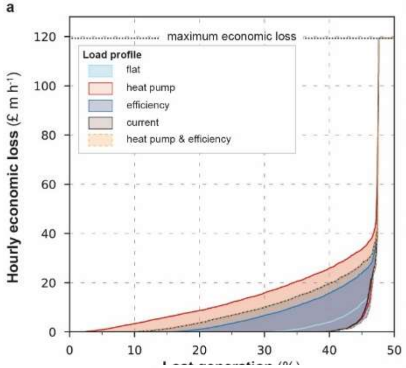
How do respond?

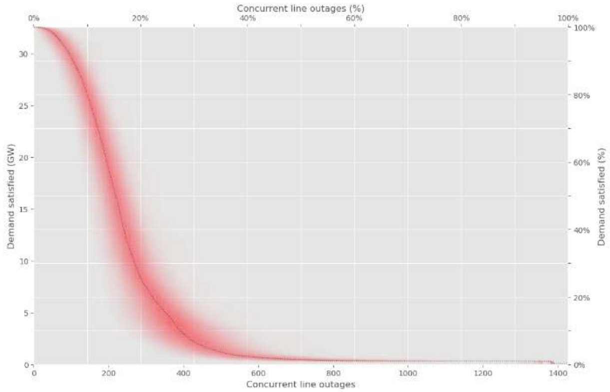
1. Disaster-proofing infrastructure assets
2. Enhancing system resilience

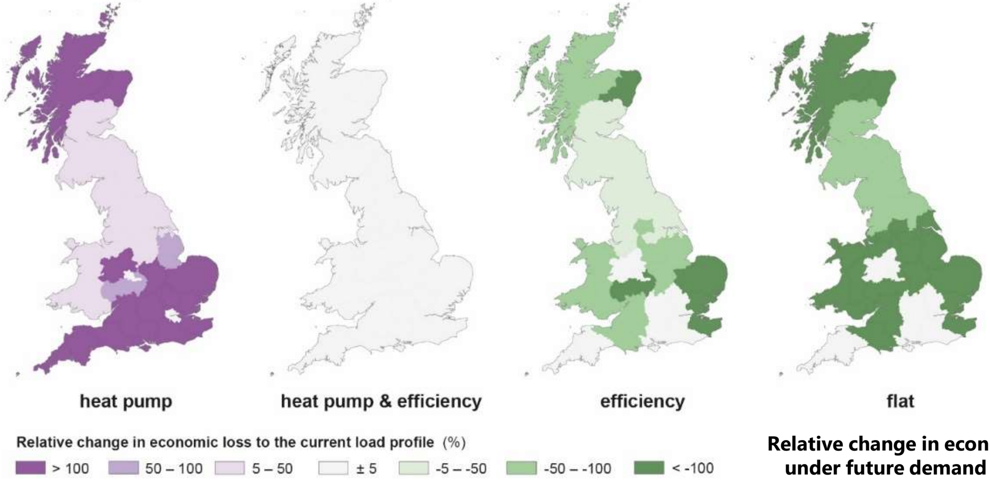

29 May 2012 07:00
CO_2 151,692 t
Containers 14,165,861
Dry 550,331 kt
Liquids 399,963 kt
Gas 62,310,488 m^3
Vehicles 10,171,048 kt

Impact of changing energy demand on power system performance





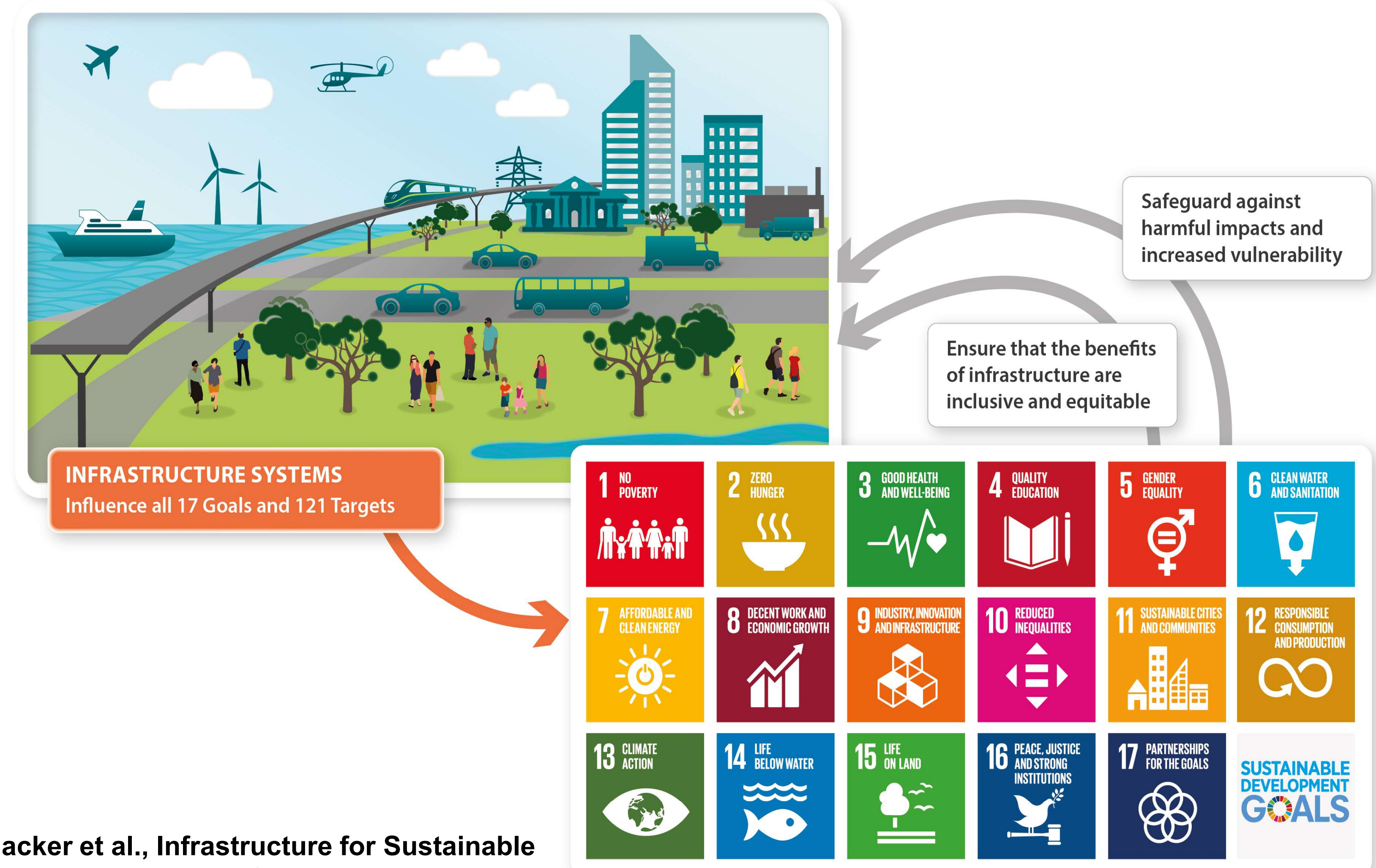




Relative change in economic losses under future demand scenarios

How do respond?

1. Disaster-proofing infrastructure assets
2. Enhancing system resilience
3. Planning for sustainable infrastructure development

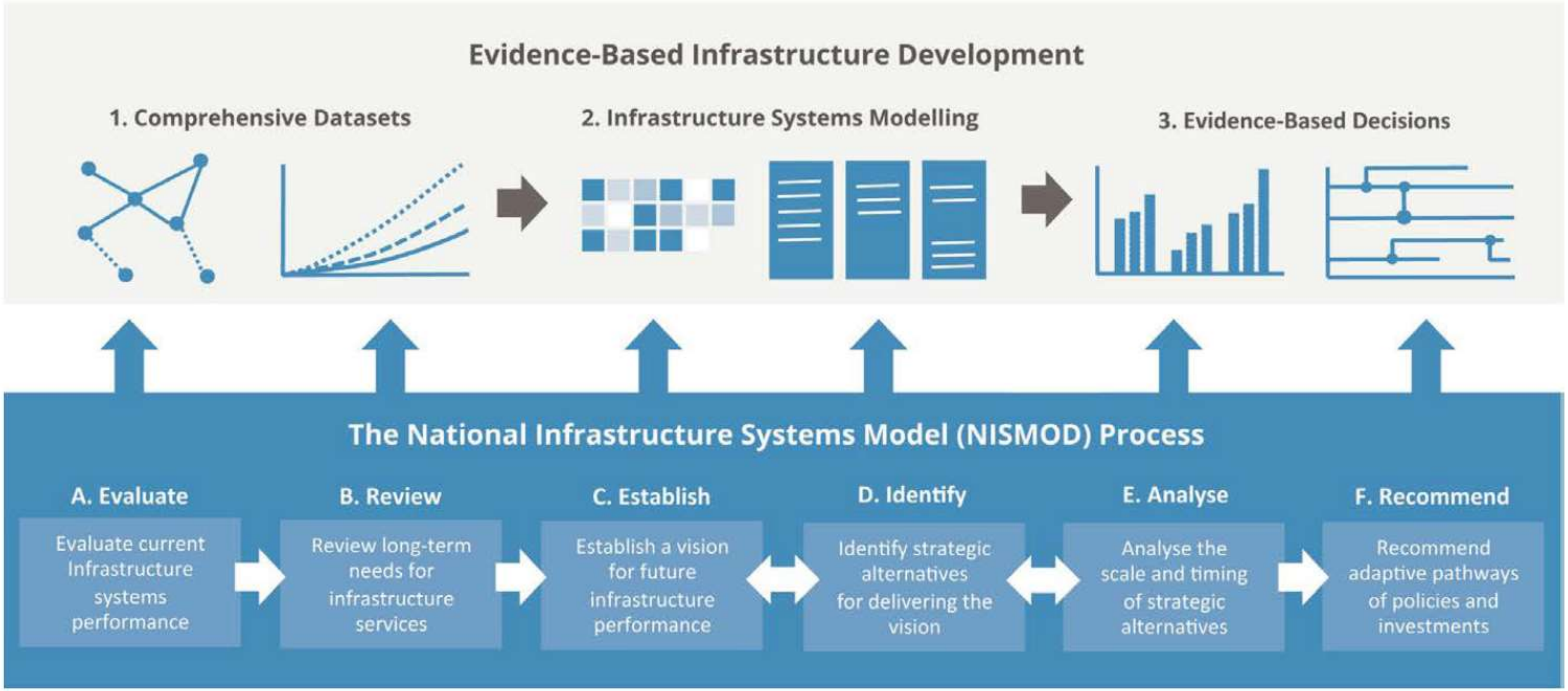


INFRASTRUCTURE SYSTEMS
Influence all 17 Goals and 121 Targets

Safeguard against harmful impacts and increased vulnerability

Ensure that the benefits of infrastructure are inclusive and equitable

Thacker et al., Infrastructure for Sustainable Development, *Nature Sustainability*, in press.


Evidence-Based Infrastructure Development
1. Comprehensive Datasets
2. Infrastructure Systems Modelling
3. Evidence-Based Decisions
The National Infrastructure Systems Model (NISMOD) Process
A. Evaluate
Evaluate current Infrastructure systems performance
B. Review
Review long-term needs for infrastructure services
C. Establish
Establish a vision for future infrastructure performance
D. Identify
Identify strategic alternatives for delivering the vision
E. Analyse
Analyse the scale and timing of strategic alternatives
F. Recommend
Recommend adaptive pathways of policies and investments

EVIDENCE-BASED INFRASTRUCTURE: CURACAO

NATIONAL INFRASTRUCTURE SYSTEMS MODELLING TO SUPPORT SUSTAINABLE AND RESILIENT INFRASTRUCTURE DEVELOPMENT

May 2018, Curacao

Ministry of
Traffic, Transport and
Urban Planning

UNOPS

University of
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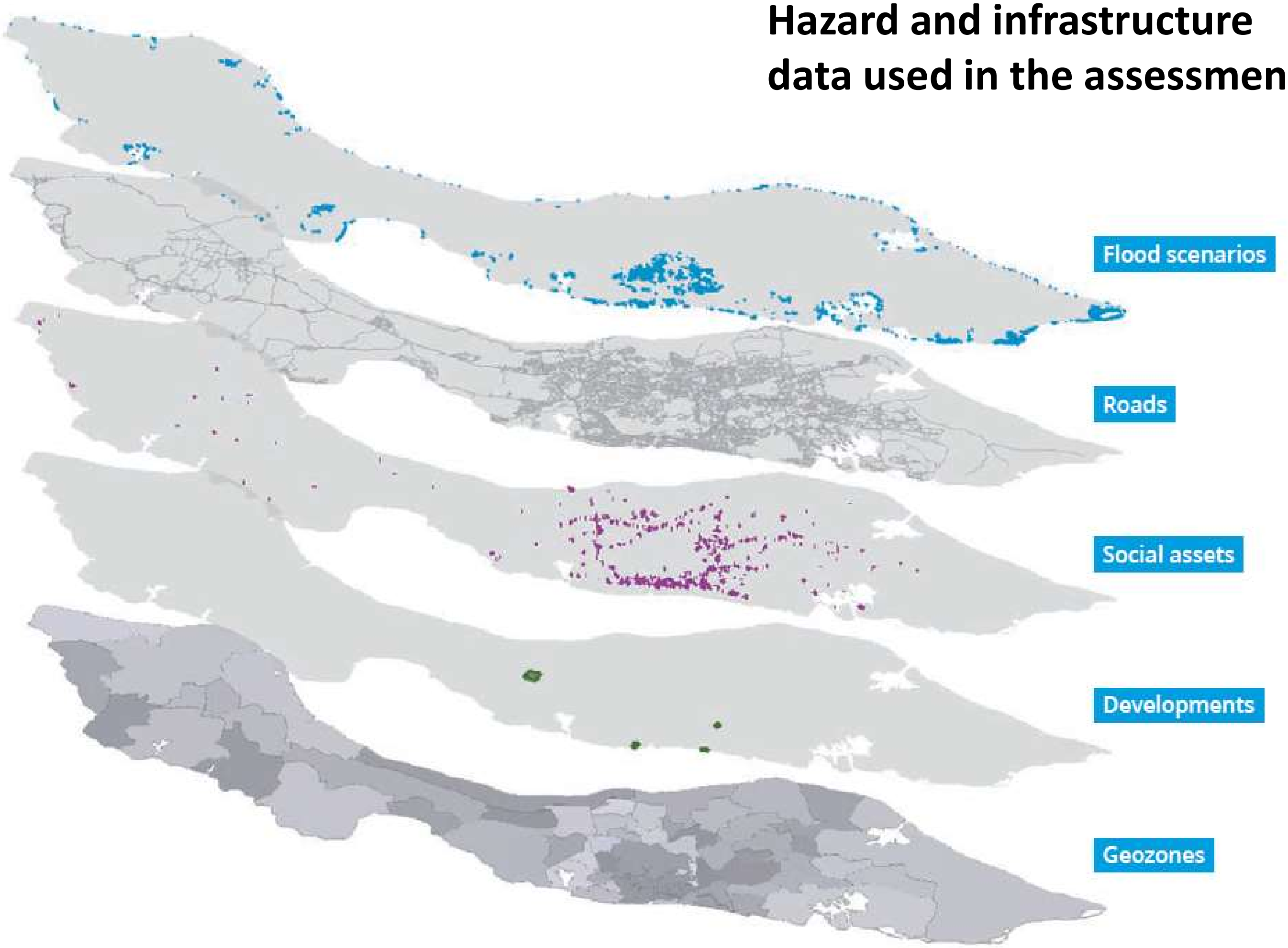
Hazard and infrastructure data used in the assessment

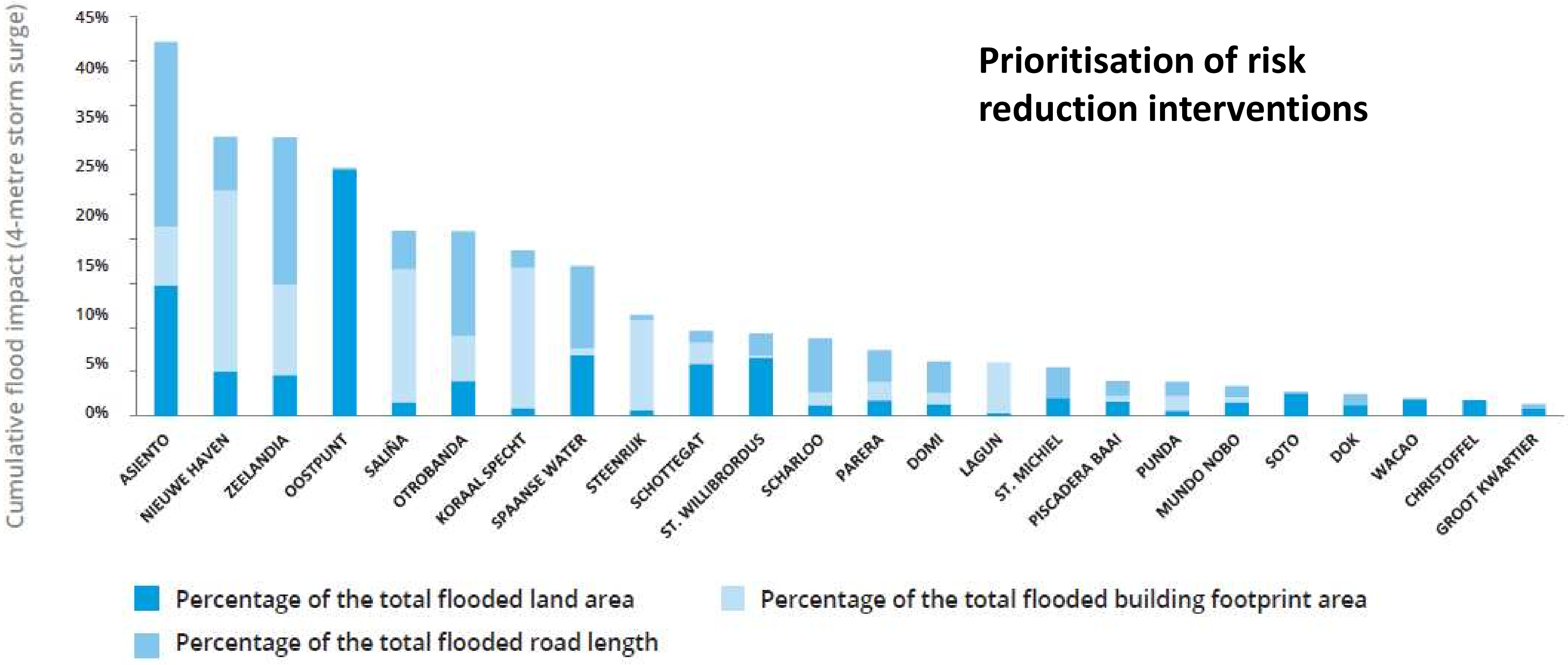


Infrastructure interdependencies

	Impacts on other sectors				
Infrastructure inputs	**Electricity**	**Transport**	**Water**	**Wastewater**	**Solid Waste**
Electricity		Electricity input to transport assets (port and airport)	Electricity input to water supply (reverse osmosis)	Electricity input to wastewater treatment plants	Electricity input to waste facilities
Transport	Tourism growth increases demand for electricity		Tourism growth increases water usage	Tourism growth increases production of wastewater	Tourism growth increases production of waste
Water		Water input to transport assets (port and airport)		Water is transformed into wastewater	
Wastewater		Sewage removal requires road transport			Wastewater sludge disposed of in landfill
Solid Waste	Waste input to electricity generation	Municipal waste removal requires road transport			

FLOOD RISK TO INFRASTRUCTURE ASSETS IN PUNDA AND PIETERMAAI

Prioritisation of risk reduction interventions



Physical flood defense infrastructure

- Large-scale, permanent structures such as sea walls provide strong defence against inundation but are implemented at a higher financial cost.

Environmental flood barriers

- Environmental barriers such as mangroves or wetland areas prioritize the natural environment and ecosystems, and can promote recreation activities and tourism growth.
- The construction of wetlands in low-density coastal zones can contribute natural flood defences to neighbouring areas.

Temporary flood protection

- Temporary flood defenses are flexible and can be moved on short notice to where there is an immediate threat of flooding. These can be used as part of a strategy incorporating early warning systems and emergency responses.

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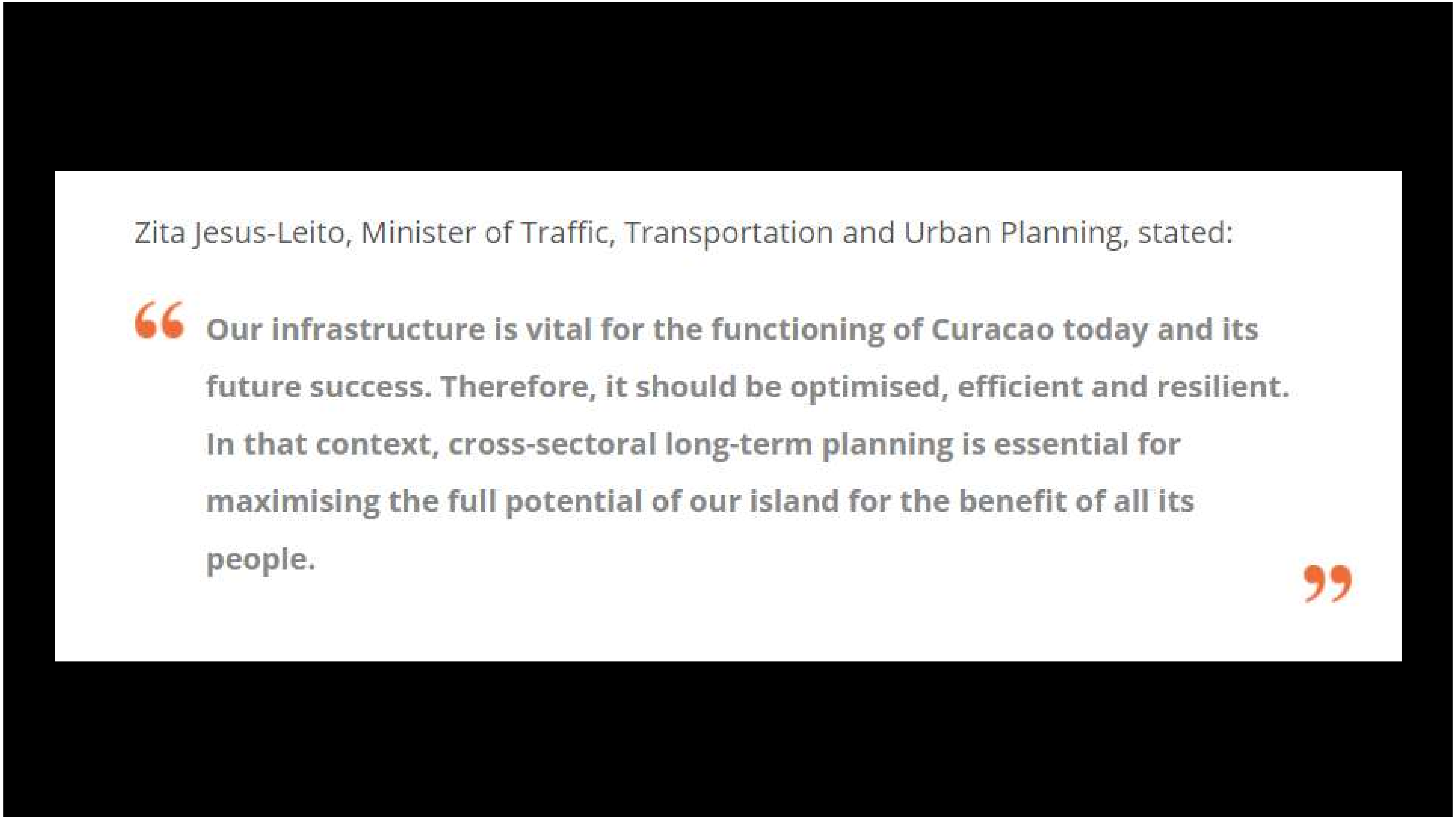

Zita Jesus-Leito, Minister of Traffic, Transportation and Urban Planning, stated:

> **“Our infrastructure is vital for the functioning of Curacao today and its future success. Therefore, it should be optimised, efficient and resilient. In that context, cross-sectoral long-term planning is essential for maximising the full potential of our island for the benefit of all its people.”**

The prize

Infrastructure that:

- Meets the needs of people and the economy, as set out in the Sustainable Development Goals
- Preserves and restores the natural environment and ecosystem services
- Is on track to achieve zero and then negative emissions
- Is resilient and adaptable to an uncertain future.

Propositions

- Investing in infrastructure to address economic inequalities between regions is a waste of money
- There are too few engineering options for ‘flexible’ infrastructure for flexibility to be a viable strategy for adaptation to climate change
- Cascading failures within infrastructure networks are a much more significant risk than interdependent failures between networks

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Prof Jim Hall
University of Oxford

Monitoring progress with adaptation

Overview of progress

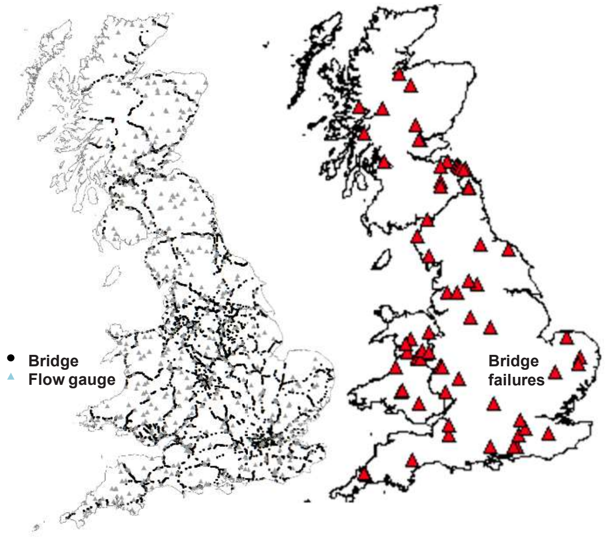
Adaptation priorities	Is there a plan?	Are actions taking place?	Is progress being made in managing vulnerability?
1. Design and location of new infrastructure	Green	Green	Amber
2. Resilience of infrastructure services	Green	Green	Amber
(a) Energy	Green	Green	Green
(b) Public water supply	Green	Green	Amber
(c) Ports and airports	Amber	Amber	Grey
(d) Roads and rail network	Green	Green	Amber
(e) Digital infrastructure	Amber	Grey	Grey
3. Infrastructure interdependencies	Amber	Green	Amber

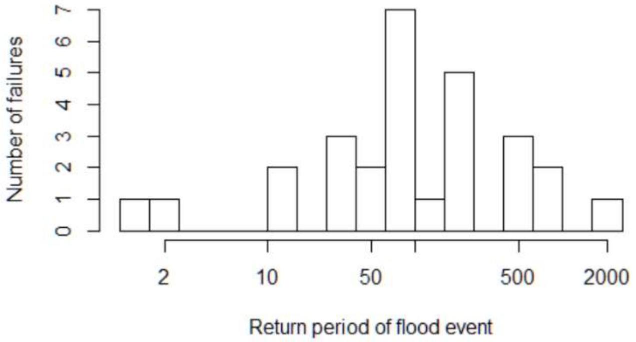
Estimating fragility

Bridge scour fragility

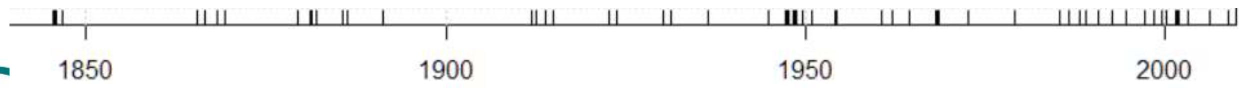
Historical scour-related bridge failures

- Unique data: 100 rail bridge failures since 1846
- Flood events reconstructed from observations

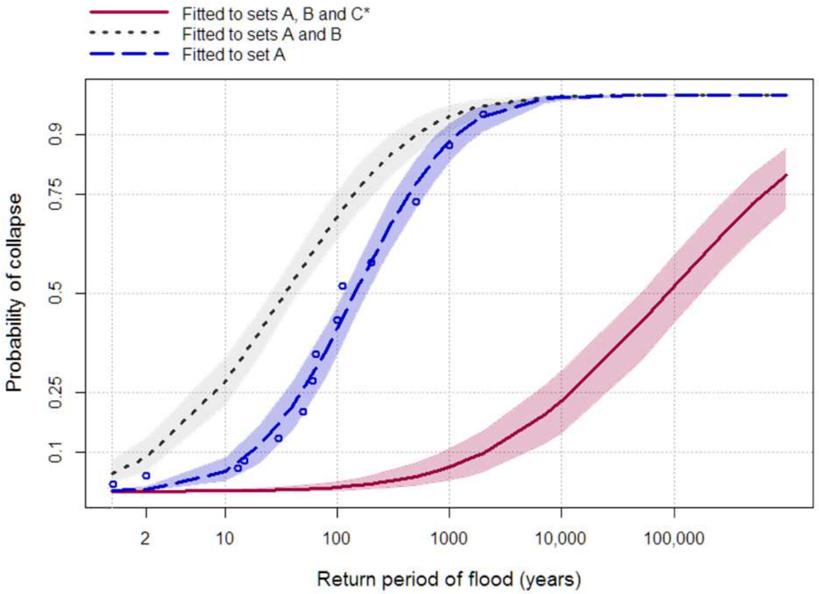




On average 1.9 structures failed per flood



Bridge scour fragility



Set A	**Historical bridge failures with associated flood event return periods, which are regarded as known values for the loading condition at failure.**
Set B	**Historical bridge failures associated with an unknown flood return period are incorporated as a form of left-censored data**
Set C	**Bridges that are assumed not to have failed (“survivors”)**

Simulated and observed numbers of failures