LLOYD'S

Emerging Risk Report 2017

Society and Security

Future Cities: Building energy infrastructure resilience

ARUP

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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.

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Executive summary

Global exposure to disasters has risen over recent decades (United Nations, 2015). This trend that is likely to continue because most global population increases will take place in Asian and sub-Saharan African cities, which are more at risk from natural hazards (United Nations, 2014b).

In addition, cities are also exposed to a greater diversity of risks than ever before, including rapidly emerging cyber threats and terrorism (Lloyd's, 2015a).

The rising costs of disasters is a growing concern for the public sector and the insurance industry alike; direct losses from disasters in the past decade are estimated at US $1.4 trillion (United Nations Office for Disaster Risk Reduction, 2014).

The Lloyd's City Risk Index found that $4.6 trillion of the projected GDP of 301 of the world's leading cities is at risk from 18 threats over the next decade.

Clearly, cities must mitigate these risks if they are to realise their growth aims but this is a complex task.

Cities are made up of a diverse and complex mix of institutions, ecosystems, assets and infrastructure that are connected and mutually interdependent. Disruption to one part of the system - utility and transport networks, communications systems and water supplies, for example – can cause failure in other parts, with far-reaching local and global implications.

This makes assessing city risk extremely challenging - secondary and cascading impacts cannot be predicted through traditional approaches such as spatial risk assessment. The task is made more difficult by the rapid growth and development of urban systems, particularly in emerging economies.

While risk management remains a priority for cities, it is not enough on its own. Increasingly, city officials, investors and insurers are looking to build resilience as a complementary approach to address urban risk and uncertainty (Cambridge Centre for Risk Studies, 2015).

In order 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.

Report overview

Lloyd's worked with Arup to develop a new set of principles to guide the planning, design, construction and operation of some of the key components of city infrastructure to improve resilience.

The study analyses four different critical infrastructure systems - energy, water supply, Information Communications Technology (ICT) and transport - through three case studies. These demonstrate how infrastructure has been impacted by catastrophic events in the past, how stakeholders responded at the time, and indicates what actions they could take in the future to effectively address risk and enhance resilience.

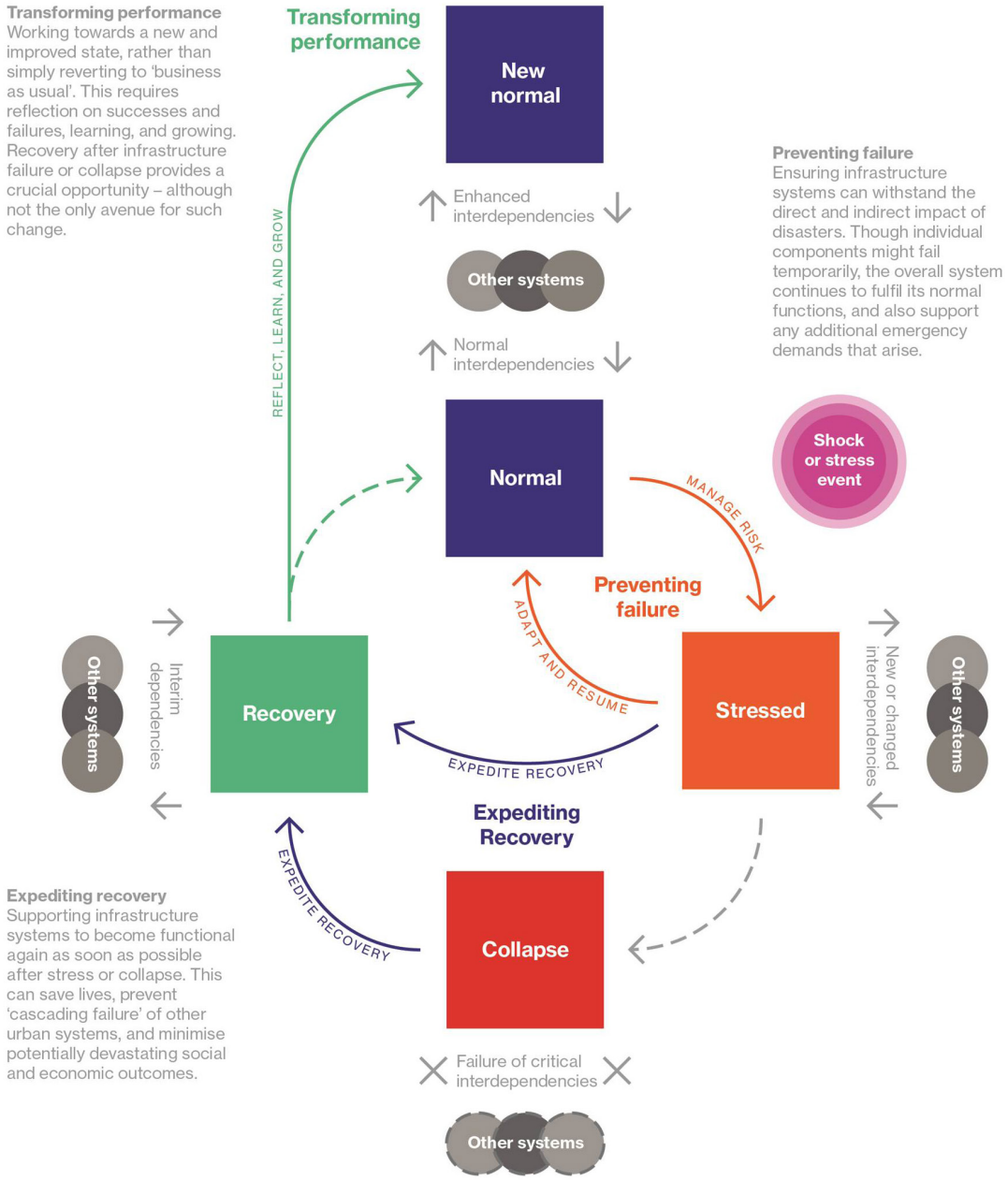
The report presents:

- An introduction to infrastructure resilience and city resilience concepts.
- An overview and analysis of the key trends that affect city infrastructure risks and resilience.
- Discussion of the key city risk and resilience principles derived from analysis of real-world case studies and consultation with infrastructure sector specialists.
- Analysis of the potential implications and considerations for the insurance industry, including sector-specific insight.
- A series of recommendations and next steps that could help move action forwards within the insurance industry.

Key findings

The report identifies three approaches or “pathways” that can improve infrastructure performance after a shock or stress event, as set out in Figure 1 (*below*):

Figure 1: Infrastructure resilience pathways



- **“Normal” state:** business-as-usual operating conditions, where an infrastructure system is performing normally or as expected.
- **“Stressed” state:** changes in infrastructure system performance can occur due to pressure from a shock or stress.
- **“Collapse” state:** collapse occurs when an infrastructure system can no longer function to a level above minimum support.
- **“Recovery” state:** infrastructure systems require additional actions or support to restore their performance after a state of stress, or on a much larger scale after system collapse.
- **“New normal” state:** in the wake of a disaster or disruption it can be tempting to focus solely on efforts to restore a system to “business as usual”. As a result, opportunities to reflect on past mistakes and successes may be missed.

Under the headings of these pathways, the report sets out a number of principles that city officials, asset owners, operators and other stakeholders can apply to planning, design and operations to improve city infrastructure resilience.

These include:

Preventing failure

- **Planning and design principles:** promoting integrated planning, valuing ecosystem services, prioritising emergency preparedness, designing for robustness, incorporating redundancy and increasing diversity of systems.
- **Operations principles:** investing in information management, maintaining assets, and expanding disaster risk management.

Expediting recovery

- **Planning and design principles:** planning the emergency response, designing with recovery in mind, and allowing "fail soft" options.
- **Operations principles:** promoting inter-agency coordination, mapping critical resources, and creating independent recovery systems.

Transforming performance

- **Overarching (planning, design and operation) principles:** building in flexibility, reflecting on the past, planning for the future, consulting widely, driving a culture of safety, developing incentives, and managing demand.

Conclusions

While the benefits of reducing asset-scale risk are often clear, managing compounding risk and building system-level resilience can be more difficult to achieve, particularly in cases where there are multiple owners, where the benefits of greater resilience are indirect, and where benefits are distributed unevenly across, or outside, the system.

The public's and policymakers' understanding of risk is critical. Insurers must work with city officials, businesses and communities to help them better understand the economic and social consequences of poor risk management, and to encourage the development of appropriate solutions.

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. Improving resilience at a city and international scale requires action at many levels. The role of education and shared understanding is fundamental to facilitating action and incentivising change.

The provision of risk transfer through insurance and reinsurance gives insureds the confidence to undertake activities that carry risk, and allows them to recover when things go wrong. To achieve this, high quality data is important, especially as risks are constantly changing.

Brokers have an important role to play in this process. They can help insureds to better understand the risks they are facing, and ensure good quality information is passed on to the underwriters so they can write better insurance policies.

Building resilience for all stakeholders means finding new ways to break down silos within and between government, the private sector and communities. This would help promote the benefits of resilience and incentivise resilience-building activities.

With a common knowledge base as a foundation, it would be possible, collectively, to build a better understanding of tomorrow's risks. This could facilitate better pricing for investors, more informed decisions by policymakers and ensure a smoother journey to a more resilient future.

Lloyd's hopes this study stimulates this discussion and, where appropriate, prompts innovation among insurers, governments and city stakeholders to help improve resilience, mitigate risk and protect infrastructure.

Principles for enhancing city infrastructure resilience: Implications for the insurance industry

The insurance industry can play a key role in supporting this report's approach by working in partnership with other stakeholders to improve city infrastructure resilience. These partnership areas are:

Data use and collection

The use of improved data collection, hazard mapping and other tools to manage and quantify increasing catastrophe risks in underwriting processes will allow more accurate risk based pricing. Additional data collection, tools and research are important to identify future trends and anticipate future risks, as well as to understand current risks better. The insurance sector is not alone in this.

By using new/better sources of data, insurers may be able to alert clients to potential losses before they occur,

assess damage in close to real-time, speed up claims processes and prevent false claims, reduce administration through automation, and create more personalised products and services (Gasc, 2016).

The use of metrics

In many cases, the report suggests that indices be created to track the current level of resilience. If such indices were created then they could, in principle, be used in models and underwriting processes as well as by city planners and other stakeholders. Ensuring that any metrics, such as those involved in the Sendai Framework for Disaster Risk Reduction, are useful and useable by stakeholders will be the key to their uptake.

Ensuring that more detailed data is available at city-wide level is important considering there can be high levels of spatial variation of risk – even at asset level. If each building had standardised data files containing agreed exposure information, this could be used directly by insurers, banks, asset managers and facilities managers.

Insurers should work with governments to help them understand their risks, and develop policies aimed at improving construction standards or building in inappropriate areas (such as flood plains). Better risk management could lead to lower risk premium pricing, reducing the overall cost to economic growth.

Models and tools development

Risk models are often created on a case-by-case basis in response to specific requests. The greatest need for this work is in developing countries and areas with low insurance penetration. Finding a way to take a strategic view to allow proactive development for countries – such as the Vulnerable Twenty Group (V20[a]) – so they can be taken off the shelf, ready to use, is an area currently being explored by the Insurance Development Forum.

Insurers need to work collaboratively with other stakeholders to provide tools that could offer a more transparent and comprehensive approach for analysing and pricing risk from extreme events. Ensuring these tools and their outputs are in an agreed format that can be used by other stakeholders will facilitate the flow of engineering and scientific knowledge throughout society.

Using models to quantify risk quantification

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 would help governments, communities and individuals to make informed decisions about resilience, insurance, investment, wider policies and interventions. Risk quantification is the key to this.

Without quantification it is difficult to assess resilience and how effective action might be taken to enhance it. Models can be used to help 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 as a way to encourage stakeholders to understand and maintain their own detailed risk registers, and to hold open dialogue on the risks under consideration.

Designing resilient assets

Infrastructure lasts a long time and risk levels are changing all the time due to ongoing global megatrends, therefore it is important to create building codes that are robust in the light of both current and future risks. Engineering studies will be necessary to achieve this since past data will not always be a good guide to the future. If such studies could be encapsulated in an index, then insurers could more easily factor this information into underwriting decision

Common building codes that include resilience provide a level playing field for insurers and other stakeholders, and make homes and buildings less vulnerable to the effects of hazards with less need for public or private disaster relief.

Incentivising investment

Resilience ratings could help investors integrate resilience considerations into all aspects of their portfolio-management activities. For example, if credit-rating agencies start to look at resilience as a measure of performance and factor this in to their assessments, this could provide an incentive to take action. Ensuring this information is in a useful and usable format will be the key to its use in city infrastructure risk assessment.

There is also a need to improve the risk/return profile of investment in green growth in this space, which can include adaptation (Climate Business Group, 2012). By focusing on reducing and managing the risk side of investment, this could facilitate the deployment of other forms of capital at the scale needed for growth.

[a] The Vulnerable Twenty (V20) Group of Ministers of Finance of the Climate Vulnerable Forum is a dedicated cooperation initiative of economies systemically vulnerable to climate change.

Incentivising resilience

It is in the interest of policyholders and governments to implement risk-mitigation measures, thereby potentially reducing both the cost of insurance and the damage from natural catastrophes. One way for the insurance industry to incentivise policyholders to introduce risk-mitigation measures is through risk-based premiums.

Another method is for insurers to give policyholders the option to share a greater proportion of the risk through offering policies with higher deductibles. All things being equal, this reduces the costs of insurance but leaves the policyholder exposed to more risk. They may, therefore, be incentivised to take action to reduce their residual risks.

Consistent with the ClimateWise "Investing for Resilience" report, insurers could also offer "resilience services", which could include aspects of facilities management, disaster recovery, "build and operate" contracts, and insurance. This could include upgrading the property covered by the service to improve its resilience, carrying out regular maintenance, recovery and repairs, and providing financial compensation in the event of a disaster.

Next steps for stakeholders

Many of the resilience principles identified in this research are already actively promoted and implemented as best practice by planners, designers, and asset owners and operators across the world. Lloyd's and Arup hope this study adds to knowledge of resilience issues, stimulates new ideas and raises new research questions.

There are numerous next steps that stakeholders could take to improve city and infrastructure resilience – the challenge remains in making change happen at scale. One starting point is the establishment of a demonstrator city to act as a testbed.

Emergency response and disaster relief agencies often hold live exercises to test their plans, which could provide a common starting point among stakeholders. Adopting a shared scenario process and risk models for a given city could help develop a broader systems model for all parties to coordinate and plan their responses. The results could be used to create a template that could be applied to all cities.

Continued innovation, reflection and collaboration across sectors and industries are critical to address any constraints on creating resilient, inclusive, prosperous cities. The framework in this report can guide all those stakeholders that are interested in ensuring tomorrow's cities are built on resilient foundations.

Methodology

This report was developed collaboratively by Lloyd's and Arup.

Arup undertook a structured research process across four key stages: a comprehensive desktop review of existing literature; development of a new research model; case study research; and consultation with key infrastructure sector specialists to develop principles for enhancing infrastructure resilience through planning, design and operation.

Lloyd's delivered a collaborative workshop involving city-sector experts and insurance practitioners to discuss the key findings in Arup's research, and identify potential implications and considerations for the insurance industry. This resulted in a series of recommendations and next steps that could help the insurance industry contribute to making cities and infrastructure more resilient.

1. Energy infrastructure

Box 1 – Global trends shaping infrastructure risk

Energy infrastructure is a critical provisioning system, which has expanded steadily across the world over recent decades alongside urbanisation and economic growth. The International Energy Agency estimates that the investment required each year to supply the world's energy needs from now to 2035 will rise steadily to US $2,000bn (International Energy Agency, 2014). Energy networks play a critical role in supporting human and economic wellbeing. The nature of energy-system growth can determine the cost and quality of consumer energy supply, and influence major global trends such as energy access and climate change (Arup and Siemens, 2016). Many rapidly urbanising cities around the world are struggling as growth in demand is rapidly outpacing network capacity. Around 1.2bn people (17% of the world's population) have very limited or no access to electricity, which poses enormous constraint on livelihoods, economic growth and community resilience to shocks and stress events (International Energy Agency, 2017).

Even where best practice is adopted in system planning and operation, today's vast urban energy networks are exposed to increasing threat from natural and manmade hazards, which can cause major social and economic disruption. For example, the 2003 US-Canada blackout affected around 50mn people and had an economic cost of around US $6.4bn (Electricity Consumers Resource Council, 2004).

Globally a number of themes are emerging in relation to energy-network resilience at a systems level, including decentralisation, diversification, adaptive management and intelligent design. Crucially, energy infrastructure forms a provisioning system that cannot be managed only from the supply side. Achieving truly resilient networks means managing demand from the consumer-side through education and awareness, incentives and appropriate pricing.

Source: Arup.

Understanding and managing interdependencies

Today's energy systems provide critical services that underpin basic human needs and are deeply interconnected with an extensive range of urban systems:

- Energy systems directly support the operation of many other infrastructure systems, including transport, information and communications technology (ICT) and water, freight and logistical infrastructure systems - for example, by providing electricity to operate water-pumping stations and traffic lights. The ability of a city to repair and reinstate its energy networks after a major disaster is a critical factor that can influence levels of human casualty and economic disruption, and determine the rate at which other infrastructure systems (including transport, water supply and ICT) can recover.
- Energy systems also indirectly support infrastructure performance in many ways, for example, by supporting the wellbeing of staff that service and operate energy networks.
- Energy infrastructure system performance is dependent upon a variety of other infrastructure systems; in particular, digital networks are increasingly critical to monitor system performance, manage loads and demand accordingly.

In addition to the overarching principles for enhancing resilience outlined at the start of this section, a number of principles specific to planning, design and operation of energy infrastructure systems are provided overleaf

Planning

1. Decentralise energy systems
Decentralised energy networks such as micro-renewables and precinct-scale heating and cooling can provide communities and businesses with protection from large-scale grid disruption.

2. Diversify energy sources
Incorporating diverse energy sources (including renewables) is particularly important to reduce the impact of diminishing global oil and gas reserves, and fuel price fluctuation.

3. Protect vital dependent functions
Protecting energy supply to vital urban functions such as hospitals can be prioritised during stress (surge) or shock (disaster) events.

Manage existing demand and plan for the future

Resilient network design will account for future demand profiles and surge scenarios to minimise the chance of extensive failure. Demand-management technologies can provide other valuable resilience services to the wider grid, such as frequency and voltage stabilisation.

Design

4. Adopt robust design approaches
Meshed microgrids and interconnectors between main grids can support networks to cope with rapid fluctuations in load and supply, and node failure, and to maintain overall system functioning during stress and shock events.

5. Isolate critical assets
Providing individual critical systems (such as hospitals and water-pumping stations) with the capability to operate in islanded mode will provide local resistance to a failure in the main grid.

6. Build in redundancy
Back-up power supplies, reserve capacity and alternative network pathways play an important role in accessing additional capacity during crises.

7. Integrate “smart” technology
Integrating real-time information and communication technology within the power grid can support operators to identify opportunities for system optimisation, more efficient generation, reduced transmission and distribution losses, and demand-side management.

8. Design for maintenance access
ICT infrastructure can pose particular access challenges for maintenance and repair – for example, cellular ICT infrastructure is commonly located on rooftops, which might be difficult to access quickly during a disaster due to building damage, physical barriers or ownership issues.

9. Allow for flexibility
ICT technology is experiencing rapid and ongoing change, meaning that designing for future flexibility is important. Avoiding over-specificity in design can help to accommodate future changes in both users and uses.

10.Integrate “smart” technology
Intelligent design of ICT networks ensures their performance is monitored on a real-time basis in order to isolate network errors and enhance integration with the range of other urban infrastructure systems they support.

Operation

11.Operate adaptively

Real-time performance monitoring enables operators to undertake more cost-effective predictive maintenance to reduce the frequency of unplanned outages, reduces risk by managing demand and reducing non-critical loads, and increases overall reliability of the system by correcting faults in real-time. This technology paves the way for more distributed and renewable energy generation.

Real-time information can also empower operators to change behaviour to minimise the impact of service interruption or reduce the cost of energy.

12.Price for repair

Owners and operators can take responsibility for ensuring contingency funds are on hand for both immediate and long-term repair and recovery in the wake of a disaster; for example, by building the cost of repair or insurance into energy pricing.

13.Prioritise vital functions

Energy network operators can take a proactive role in identifying the critical city assets and systems they service, and ensuring energy is restored to these users with priority if system-wide failure occurs to minimise loss of life and economic impact.

14.Promote coordination

Coordination across asset owners, distributors, and regulators can help spread the risk of network failure (and repair costs) in a more manageable way across different multiple stakeholders, and allow pooling of regional resources to support more effective disaster response.

15.Ensure equal access for all

Quality energy networks promote human wellbeing alongside economic growth. Asset owners, operators and regulators have a role to play in building city-level resilience by ensuring energy is safe, clean and affordable.

16.Reduce demand

User education, awareness, appropriate pricing and incentives can improve resilience by improving demand profiles and reducing overall demand.

Box 2: Constraints to implementation

While the principles outlined in this chapter reflect the key to future infrastructure resilience, their effective application has challenges grounded in often political, financial and behavioural realities.

Both general and sector-specific principles highlight the importance of effective infrastructure emergency planning and the creation of a culture of safety. Implementing these ideas can be expensive, and may not be perceived as important in developing countries as promoting economic growth and development gains. In locations with moderate or low-frequency hazard profiles, complacency towards efforts can be greater (Da Silva *et al.*, 2016) and this compounds the challenges of expensive planning. Emergency planning approaches that prioritise protection or support of certain infrastructure systems in an emergency scenario may also be controversial and difficult to negotiate, as demonstrated in the Bangkok case study around transport.

Improving resilience often requires significant capacity and resources beyond business-as-usual, for example innovative urban design or up-to-date quality infrastructure maintenance. Many cities will face challenges to effectively mobilise additional finance, and source appropriate local skills and knowledge.

Where most national and city governments serve relatively short terms of 3-5 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 difficult.

Inclusive approaches require overcoming structural barriers presented by departmental and fragmented management practices. For example, inclusive service access requires many different parties involved in delivery and operation of infrastructure, each with varying interests and objectives. Developing inclusive infrastructure systems requires strong leadership, effective infrastructure planning, strong sector regulation and enabling finance. Related to leadership is the need for effective multi-stakeholder communication and collaboration, including between regional and national parties, and across systems such as water bodies or energy networks that are transboundary in nature, potentially posing wider political challenges.

Reducing demand, effective land use and infrastructure planning are crucial across all sectors. Rapid urbanisation and urban sprawl pose significant challenges to these objectives, and emphasise the need for effective urban and regional planning and innovative technological and planning solutions.

Whilst sector diversification reduces the likelihood of complete system failure, this approach can lead to greater difficulties in addressing technical and institutional problems, as issues are spread across multiple locations and stakeholders.

Ensuring an appropriate level of infrastructure redundancy can come at the expense of efficiency and an appropriate balance needs to be found, particularly within energy and water systems.

Smart technology can contribute to the resilience of all infrastructure sectors identified in this report. Whilst this technology might enhance awareness, control and efficiency of system operation, it also creates additional dependency on ICT infrastructure. Furthermore, without appropriate supporting programming, transition to technology-based systems needs to be delivered in a way that is inclusive, providing proper skills and training, and avoiding access constraints for those that cannot afford technology.

The challenges outlined above are not insurmountable. Actively seeking to identify and acknowledge constraints enables more effective planning, education and the identification of appropriate actions. Over the past 50 years cities have witnessed dramatic and successful changes in the way that infrastructure is delivered, with significant improvement to quality reliability, safety and continuity through technological advance, effective planning and learning. As with other complex challenges, building in the ability to learn and adapt as quickly as possible is key to finding the right balance for each context. Many of the principles outlined in this research are already actively promoted and implemented as “best practice” by planners, designers, and asset owners and operators across the world. Continued innovation, reflection and collaboration across sectors and industries are critical to address constraints in support of more resilient, inclusive, prosperous cities.

2. Recommendations for enhancing city infrastructure resilience: implications for the insurance industry

To facilitate the pathways for infrastructure resilience identified in this report, there are a number of areas where Lloyd's believes the insurance industry can work in partnership with other stakeholders. Local insurance markets will have an important role to play in starting meaningful dialogue with governments, businesses, and asset owners, and to take these infrastructure pathways forwards in their own city perspectives.

1. Shared understanding

There is a need to understand how all the components and stakeholders of cities interact, and what the key areas and concerns are for each stakeholder. The role of education and shared understanding is fundamental to facilitating action and incentivising change.

Crisis management and disaster response are significant parts of what the Lloyd's market specialises in, but with most of the world being either uninsured or underinsured there are too many disasters where the (re)insurance industry suffers little loss and does not play a significant part in the rebuilding (Lloyd's, 2015b). For the insurance industry, there remains an education challenge.

Public and policymaker understanding of risk is critical, and governments, insurers and other stakeholders should work together to ensure there is a greater understanding of the role of all parties in the economic and social consequences of poor risk management, and to allow the development of appropriate solutions.

One way to do this could be to work with a city to develop a proof-of-concept framework that could be tested with the goal of applying the framework at a replicable, worldwide scale. This concept is described in "Next steps" (*see p19*), in this section.

2. Data for decisions

Improved data collection, hazard mapping and other tools to manage and quantify increasing catastrophe risks in our underwriting processes will allow more accurate risk based pricing. Additional data collection, tools and research are important to identify future trends and anticipate future risks, as well as to better understand current risks, and the insurance sector is not alone in this.

Over the past five years the world has reached a point where some aspirations of resilience could be met by fully embracing the technology of today. There has been an exponential increase in data availability. In 1906 airships were used to survey damage from the San Francisco earthquake to be studied by people to make damage assessments (Taylor, 2016).

Today, satellites can capture imagery in a variety of image bands to derive various datasets (Bulter, 2013), which can then be processed by automatic classification software to detect access roads, damage patterns and the extent of the damage (Jean et al., 2016; International Disasters Charter, 2017; Satellite Applications Catapult, 2012).

This technological capability has the potential to be pushed forwards again with the rise of the "Internet of Things"b (Meola, 2016). By using new sources of data, insurers may be able to alert clients of potential losses before they occur, assess damage in real time, speed up the claims process and prevent false claims, reduce

[b] A network of internet-connected objects able to collect and exchange data using embedded sensors (Meola, 2016).

administration through automation, and allow more personalised products and services to be developed (Gasc, 2016), aiding overall response. City officials might also be able to track maintenance, manage responses and model impacts for more integrated decision-making. Assigning responsibility at the lowest key stakeholder during multi-stakeholder scenario and response planning could unlock administrative red tape and confusion in the wake of events.

3. Establishing metrics

This report considers many areas in which resilience can be enhanced. In many cases we have suggested that indices be created to track the current level of resilience. If such indices are created then they can, in principle, be used in models and underwriting processes as well as by city planners and other stakeholders.

Ensuring that any metrics, such as those involved in the Sendai Framework for Disaster Risk Reduction, are useful and useable by stakeholders will be key to their uptake. Conversely the absence of such indices will severely affect the degree to which insurers can actively incorporate resilience into our process given the level of complexity and number of locations involved.

If each building had a standardised data file containing agreed exposure information this could be consumed directly by insurers.

This report has called for indices in the following areas:

- Efficacy of natural defences
- Degree of diversity
- Asset maintenance levels
- Emergency response times
- Levels of critical resources
- Levels of independence of recovery services.

These could be combined into a single index or better still made available individually. Indeed indices relating to any of the items included in the Rockefeller Foundation City Resilience Framework would be useful.

Any data collection would need standards to ensure it is collated in a usable and useful format. Ensuring that data is available at greater granularity on a city-wide level is important, given there can be high levels of spatial variation. In the workshop held as part of information gathering process for this report, one of the attendees commented that the UK's Department for Environment, Food, Economic and Rural Affairs (DEFRA) flood models take a mean value across the data available. This can result in information that is not usable as the actual risk underwriters are being asked to take isn't always at the granularity needed for an asset-level decision.

Insurers should work with government to administer policies aimed, for example, at improving construction standards or discouraging building in inappropriate areas. Better risk management could lead to lower pricing, reducing the overall cost to economic growth.

Initiatives such as Building Research Establishment Environmental Assessment Method (BREEAM, 2017) and Building Information Modelling (BIM) (Davidson, 2014) demonstrate the potential to generate demand and incentivise action by pushing initiative adoptees to engage in the design criteria. The next stage of BIM, level three, aims to get people working together and sharing data through defined processes, metrics and technology by using a single, shared project model that is held in a central repository (NBS, 2017).

If each building had standardised data files containing agreed exposure information, this could be consumed directly by insurers, banks, asset managers and facilities managers.

4. Developing models and tools

Models are often created on a case-by-case basis in response to requests. Finding a way to take a strategic view to allow proactive development for countries – such as the Vulnerable Twenty Group (V20c) – so they can be taken off the shelf, ready to use, is an area currently being explored by the Insurance Development Forum.

There is a need to provide tools that could offer a more transparent and comprehensive approach for analysing and pricing risk from extreme events. Ensuring that models are developed and maintained in a collaborative way is also an area to consider. As was seen in Hurricane Katrina, levee failure wasn't fully understood and accepted by some stakeholders but was well recognised by others. The scale of the risk was underestimated, and the response was insufficient to prevent or limit the impacts that unfolded.

Modelling potential scenarios and their impacts may also help in the debate on sustainability and general risk management in the built environment. The role of tools and models in informing actions to prevent failure and improve recovery is clear, but their potential role in supporting insurers and decision-makers to support long-

[c] The Vulnerable Twenty (V20) Group of Ministers of Finance of the Climate Vulnerable Forum is a dedicated cooperation initiative of economies systemically vulnerable to climate change.

term transformation towards improved practice might also be considered.

Ensuring these tools or their outputs are in an agreed format that can be integrated into other stakeholder systems will allow integration. The greatest need for this work is in developing countries and areas with low insurance penetration. A suggestion could be made to pool resourcing through initiatives such as the Insurance Development Forum to build the knowledge and capacity of developing and emerging countries, to allow them to manage and implement sustainable financing, and resilient investment.

The Oasis Loss Modelling Framework (Oasis LMF) is one initiative looking to support the use of catastrophe models beyond the (re)insurance industry to facilitate risk-informed planning and decision-making. It aims to generate an open marketplace for models and data, to lead to wider access to understandable tools for catastrophe risk assessment (Oasis Loss Modelling Framework, 2017).

The framework provides "plug and play" data interfaces and web services that enable members to calculate the economic and insurance consequences of catastrophe events. The open-source aspect means that the latest thinking on natural disasters and climate change can be incorporated into Oasis' models. For example, government agencies could use the Oasis LMF to build their own flood model and work with an engineering firm to model the financial impacts of building mitigation infrastructure (Lloyd's, 2014).

If initiatives such as this are adopted and used by a wider set of stakeholders it could demonstrate the potential for insurance models to be used by all sectors to provide common understanding and a shared knowledge base to understand cities and risks as systems to help inform action to enhance resilience.

5. Use models to quantify risks

With the increase in the model availability and amount of data available comes the potential to use that information to make assessments about risks and to anticipate the potential impacts of hazards. This would help governments, communities and individuals to make informed decisions about resilience, insurance, investment, and wider policies and interventions. Quantification is the key to this.

Models can be used to help 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 as a way to encourage stakeholders to understand and maintain their own detailed risk registers, and to hold open dialogue on the risks under consideration. Initiatives such as the "1-in-100 Initiative" are working towards this (United Nations, 2014a). It could also allow understanding about the differences between return periods and security.

Models are only as good as the data they are based on, and the insurance industry needs improved data collection, hazard mapping and other tools to assess increasing natural catastrophe risks in its underwriting processes. These overlap to some extent with what local and regional adaptation planners require to plan, and make recommendations for government-funded or mandated risk mitigation and adaptation measures.

Improved resilience to some risks is likely to result in more residual risks becoming, or remaining, insurable. This is an area to develop, as increasing resilience in one area can adversely change the resilience of others; for example, improvements to energy performance through insulation products led to unacceptable fire loads that could lead to a total loss (Zurich Municipal, 2011).

6. Design resilient assets

Infrastructure lasts a long time and risk levels are changing due to many megatrends, therefore it is important to create building codes that are robust to both current and future risks. Engineering studies will be necessary to achieve this since past data will not always be a good guide to the future.

Common building codes that incorporate resilience provide a level playing field for insurers and other stakeholders and make homes and buildings less vulnerable to the effects of hazards with less need for public or private disaster relief.

The study illustrates a range of tools and methods that could be relevant to the planning stage; the challenge is building them into the process, and establishing where they could be integrated. Equipment and other infrastructure components may be replaceable and upgradeable but many aspects of infrastructure performance that are set out at the design stage can be expensive and difficult to change.

Foundations and other parts of building envelopes can typically be in place for 50 years or more (Vaughan and Turner, 2013) – what meets current building and design

codes of today may not meet future requirements to prevent infrastructure system failure.

Even if the impact of future catastrophes were known with certainty, it would not necessarily be understood exactly how the standards would need to be adjusted to reflect new levels of stress and resilience. Engineering research and network studies could help to identify the gaps between current standards for resilience, and the standards required under increasingly connected, human driven risks.

When stakeholders can rely on common sets of codes for planning, design, construction, and modelling, it is easier to assess and track appropriate metrics to understand critical infrastructure. Common building codes that should be applicable after a disaster strikes can encourage a "build back better" system but, at the same time, provide a level playing field for insurers. If this is only offered as an option within policies it can lead to low take up since premium rates are often higher, as a consequence of the costs of delivering increased resilience.

7. Incentivising investment

Finding ways to finance or support investment is a key challenge that often comes back to what information is available, and the way that knowledge is presented and used.

The ability to rate the resilience of assets would also be of use on the investment side, and resilience ratings could enable investors to integrate resilience considerations into all aspects of their portfolio-management activities. For example, if credit-rating agencies start to look at resilience as a measure of performance and factor this in to their assessments, this could provide an incentive to take action.

Underwriters can integrate indices and metrics into their assessment of risk. Ensuring that information is in a useful and usable format will be the key to effective adoption in the risk-assessment process.

This is an area that has received increasing attention from financial regulators in the past 18 months with initiatives such as the Financial Stability Board Taskforce on Climate-related Disclosure (FSB-TCFD). The group is working towards developing voluntary, consistent climate-related financial risk disclosures for use by companies. This information would provide information to investors, lenders, insurers, and other stakeholders to aid their decision-making processes by classifying risks (Sitt, 2016).

There is also a need to improve the risk/return profile of investment in green growth in this space, which can include adaptation (Climate Business Group, 2012). By focusing on reducing and managing the risk side of investment, this could facilitate the deployment of other forms of capital at the scale needed for growth.

The challenge of getting investors to commit funds has been recognised at the highest level by the G20 Green Finance Study Group. The group is working with the private sector and centres of excellence to develop a forum on environmental and financial risk, to facilitate knowledge on risk analysis and management within the financial sector (Cambridge Institute for Sustainability Leadership, 2016).

This is a complicated area that requires further research and dialogue as there is the potential for short-term moral and ethical questions for those with poor resilience ratings if they become unattractive risks. Yet this process could also help cities in the long-term to understand and communicate their risk and resilience strategies to stakeholders.

8. Incentivising resilience

It is in the interest of policyholders and governments to implement risk-mitigation measures, thereby potentially reducing both the damage from natural catastrophes and the cost of insurance.

One way the insurance industry incentivises policyholders to introduce risk-mitigation measures where local regulation prevails, is through risk-based premiums for implementing appropriate mitigating actions (Lloyd's 2011).

Another method is for insurers to give policyholders the option to share a greater proportion of the risk through offering policies with higher deductibles. Other things equal this reduces the costs of insurance but leaves the policyholder exposed to more risk, as such they may they are incentivised to take action to reduce their residual risks.

By offering risk-based premiums to asset owners or managers who have mitigated risk, the premiums would tend to be lower than average, other things being equal. In some cases this could even be made a condition for insurance.

Another option is for policyholders to share a greater proportion of the risk through choosing policies with higher deductibles. This provides a financial incentive for policyholder to implement cost-effective risk-mitigation measures in order to keep losses as low as possible below the full deductible amount. The incentive is also provided in part through savings in insurance premiums in return for them bearing more of the risk.

It is important to note that not every loss is recoverable under an insurance policy or may be a loss inside the deductibles. As such, individuals and businesses may experience resilience benefits if city policymakers and Administrators take action to enhance their resilience to events.

Offer resilience services

Consistent with the ClimateWise “Investing for Resilience” report, insurers could offer “resilience services”, which could include aspects of facilities management, disaster recovery, “build and operate” contracts, and insurance (CISL 2016). This could include upgrading the property covered by the service to improve its resilience, carrying out regular maintenance, recovery and repairs, and providing financial compensation in the event of a disaster.

This point was raised in a recent ClimateWise report (CISL 2016), raising a key innovation and development area for those working in the resilience space. The foundations of resilience service provision can be seen in the risk-management advice and assistance already provided by many insurers and brokers.

Resilience services could potentially be attractive to small and medium enterprises (SMEs) and larger corporates alike, who are accustomed to outsourcing parts of their operations. It could also be of interest to governments to help illustrate the value of insurance and how it can be integrated into government finance budgets as a value delivery aspect.

Providers of resilience services could also be incentivised to improve the resilience of the broader environment surrounding a property. These providers might be insurers, or might include other service providers. In this instance, risk transfer becomes one part of the overall service for risk that cannot be managed through other means.

3. Next steps

This report promotes a continual process of reflection, learning and action to promote infrastructure system improvement and transformation towards a "new normal" state; responding to global trends such as climate change, demographic change and technological advancement that can alter risk, demand, and performance requirements over time. However, there are challenges of implementation and adoption as the insurance industry is often presented with a final risk for assessment, rather than having been involved in the design, planning and procurement stages where change can reasonably take place.

There are many examples of individual initiatives that have tried to solve these issues, including but in no way limited to:

- 100 Resilient Cities
- African Risk Capacity
- Insurance Development Forum
- G7 InsurResilience
- My New Home
- R4 Rural Resilience Initiative

The challenge remains in making change happen at scale – ultimately insurers are competing entities and coverage levels may differ in the approaches taken, so there is real importance in making collaboration happen in the precompetitive space.

Insurers often assume that they can get in to a loss site swiftly and start the assessment process to get insureds back on their feet, but this can be a bottleneck point where access is prevented and that halts forward momentum (Thomson, 2016). In the Fort McMurray wildfire of 2016, due to the shifting fires insurers were not allowed onsite until day 26 (Edmonton Sun, 2016). This access issue saw a number of stakeholders, not just insurers, investigating innovative satellite technology to capture imagery to be used for remote damage assessment (Mogg, 2016).

This effect – also known as the duration effect – where insurers and other stakeholders cannot access loss sites is one of the key issues to solve, and can be more effectively explored in the "expediting the recovery pathway" (*see the main report "Future Cities: building infrastructure resilience", Section 5.2, p48*). The use of remote damage assessment technology, either via satellite or drone aided, is an innovation space that is rapidly developing, and is an opportunity for action, not only for insurers but all those involved in and responsible for the recovery of cities and communities.

Establishing a demonstrator city

Emergency response and disaster relief agencies often hold live exercises to test their plans, and adopting a shared scenario process and risk models could be used to develop a broader systems model for all parties to coordinate and plan their responses. Local offices should explore partnerships in their cities that run these exercises to ensure insurers' views are heard, and can demonstrate the tools and expertise that could be used to develop contingency and operations plans with agreed standards and guidelines, and expected responses by stakeholders with assigned ownership and responsibilities (African Risk Capacity, 2017).

Assigning responsibility for actions at the lowest key stakeholder level – e.g. defining who exactly is responsible for what in a city Department, such as planning teams distributing building information – during multi-stakeholder scenario and response planning could cut red tape and confusion in the wake of events. Partnerships are the only way this will happen.

Establishing answers to the following basic questions could help processes flow to get cities up and running – something that all stakeholders are working towards:

- What is needed?
- Who is responsible for what?
- Who gets access when?
- Where resources and data can be shared between stakeholders with common goals?

A single demonstrator city could be chosen to explore this framework so a template approach can be applied to cities around the world. This kind of scenario approach could also be adopted and expanded to cover other pathway responses. All parties – government, private sector, communities, etc – should be involved to see what is possible under each pathway, and through the process of building common understanding and building relationships in advance identify what would help during of the first critical hours of disaster response.

This common understanding could also enhance the development and value of coupled modelsd to understand the flow of impacts and reactions, such as what and where the costs are for cities, and how systems respond to changes, to test the impacts and effects. This could facilitate better pricing for investors and more informed decisions by policymakers, and ensure a smoother journey to a more resilient future.

[d] State-of-the-art computer simulations of past, present, and future states.

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