

BUROHAPPOLD  
ENGINEERING

## RESILIENCE INSIGHT



## 12 CITIES ASSESSMENT



FEBRUARY 2016

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# 1 FOREWORD

Foreword by Guy Hammersley, Executive Director, BRE

There is a growing realisation in both government and private sectors that cities across the globe are facing unprecedented challenges from social, technological, environmental, economic and political changes. As a consequence there is an urgent need to help cities implement policies, systems and solutions to build resilience for the future. This involves being able to better resist stress from both short term shocks and long term change, as well as improving the city's capacity to bounce back rapidly from impacts. The consequences of climate change are recognised world-wide and have been highlighted in the UK by recent extreme weather and flooding events, putting it high on the political agenda. However, there are many other facets to resilience such as population growth, urbanisation, energy security, resource depletion, crime and security, all with complex interdependencies.

The importance of the resilience agenda led to the creation of the BRE Centre for Resilience to act as a national and ultimately global resource for government, local authorities, industry, universities and the public to support the goal of creating a resilient built environment. This has been underpinned by the BRE Trust establishing a thematic research programme on a "resilient built environment" to support exciting and relevant research and innovation built on good science. In this capacity the BRE Trust was delighted to be able to make an award to BuroHappold, in partnership with the Worshipful Company of Constructors, to support their much needed work on a city resilience diagnostic framework. Beneficial change requires a robust understanding of the issues, metrics based on sound science and engagement with stakeholders, all things that the BuroHappold framework sets out to achieve. The BRE Trust and Worshipful Company of Constructors is now pleased to be able to publish the outcome of this valuable work through the BRE Centre for Resilience.

## 2 EXECUTIVE SUMMARY

### CONTEXT

Cities have become the prevalent living environment for the world's population. Since the beginning of civilisation the freedom, opportunity, society, stability and security provided by cities have drawn ever greater numbers of people. In 2007 this growth reached the point where over half the world's population was living in cities rather than rural communities and this is anticipated to grow by an extra 2 billion people (70% of the World's population) by 2050.

The impacts of climate change pose a disproportionate threat to our cities because of their location, (generally near the coast (sea level rise) or on river crossings and deltas), high resource demands particularly in term of fresh water and the concentration of people and assets. Other strategic challenges such as aging demographics; the growth of the middle class; a growth in obesity and diabetes; anti-microbial resistance and others are all adding stress to our city systems and could cause some cities to fail with significant harm to their populations and world stability. These factors will also increase the impact and severity of factors that can significantly shock our city systems; such as flooding, drought, desertification, disease migration, mass migration, armed conflict and terrorism.

### PURPOSE

In response to this unprecedented level of crises affecting the world's urban population, BuroHappold has developed a comprehensive framework for measuring the resilience of cities to a broad spectrum of shocks and stresses; from the sudden impact of flooding to the longer term process of urbanisation. BuroHappold were the recipient of the Royal Charter International Research Award from the BRE Trust and the Worshipful Company of Constructors which contributed funding to validate and test the framework on 12 global cities.

The objective of the framework is to support international disaster reduction priorities such as the Sendai Framework for Disaster Risk Reduction by providing a simple framework and tool to understand, measure and manage resilience. This will;

- (1) assist municipal authorities and other key private/public sector stakeholders in assessing their current and future resilience demands and capacities, allowing the development of business cases for investment in resilience building;
- (2) gain a holistic understanding of each city component's resilience and their interrelationships and;
- (3) prioritise and measure the performance of policies and interventions that would improve the city's resilience.

### METHODOLOGY

As part of the validation process BuroHappold assessed 12 global cities as case studies (Bristol, Detroit, Dhaka, Glasgow, Hong Kong, London, Manchester, Miami, Mumbai, New York, Riyadh and Sao Paulo). The framework was used to evaluate three of these cities (Bristol, London and Sao Paulo) in further depth at a component level. The results of these in depth studies were validated in stakeholder workshops with experts from each city. The feedback from each workshop then informed the development of the framework.

BuroHappold's resilience framework is unique in that, unlike many other assessment tools, the methodology is risk-based and considers long term trends. Furthermore, interrelationships between shocks and stresses are mapped; for example, the affect of stresses such as globalisation or climate change on the current and future intensity of shocks are captured. The methodology also measures the capability of a city to counteract these shocks and stresses through a combination of protective mitigations as well as adaptive, response and recovery measures (adaptive capacity).

This diagnostic methodology identifies and prioritises those parts of a city facing gaps in resilience and predicts how this will change in the future based on trend data. By being able to measure resilience, city authorities can understand and manage their city's resilience and build business cases to meet future resilience challenges.

### FINDINGS

From interviews and previous experience working with cities we found there is a tendency for cities to approach resilience in a siloed way without prioritising initiatives systematically. Often the major focus is the last disaster, for example flooding, when in fact, the city may be less prepared for a more urgent risk such as an epidemic. All parts of a city are dependent on one another and any shock to a city, even if it only directly impact one aspect, will have ripple effects throughout. It is for this reason that resilience needs to be viewed holistically, breaking down silos and understanding interdependencies. Traditionally there has not been one entity that has an overview of all these areas and that is cited as the reason for this lack of joined up thinking. However, in the UK with more powers moving to city mayors (e.g. London, Bristol), this is changing. The Rockefeller 100 Resilient Cities Program has introduced the concept of Chief Resilience Officers (CROs) – a person responsible for delivering resilience strategies for the city - there is now an opportunity to think differently and truly understand and prioritise the many issues facing our cities and develop holistic solutions that benefit more than one issue or group.

One of the key benefits noted when implementing this approach with city leaders is that stakeholders are unified around a common vision. A comprehensive resilience strategy will touch all aspects of a city and is therefore a great way to integrate a city and break down these silos. We have found that successful resilience strategies address multiple vulnerabilities and deliver benefits across a wide range of areas. They also require interventions that cross departmental barriers; strategy workshops being invaluable in successfully aligning interests. This provides the co-benefits of better collaboration and better understanding between departments which results in resilient solutions that maximise benefits across multiple agencies.

Exploiting the capability of the Resilience Diagnostic to model future trends, we are able to test possible scenarios against the current baseline, to assess the comparative impact and benefits of different strategic options.

Our baseline assessment also enables us to take insight into the cost and benefit of different options and compare them with the cost of inaction of doing nothing. This informs the creation of business cases around possible programmes of activity.

Clients investing millions if not billions into a development need to know their investment is protected and the business case supporting that investment will remain pertinent for the necessary period of repayment or for the development's lifetime. The risk management model that sets the scene for our resilience approach is focused on creating and protecting value; looking at the underlying assumptions upon which business models are based and understanding how strategic risk factors can both challenge these assumptions but also reveal previously unidentified opportunities. In order to simplify the process, BuroHappold has subsequently developed an online resilience diagnostic tool that can be used by a variety of stakeholders to understand their perspective on their city's resilience.

## KEYWORDS

Resilience, Built environment, Framework, City, Diagnostic, Prioritisation



Figure 2.1: Sao Paulo, Brazil.

### 3 ACKNOWLEDGEMENTS

BuroHappold were the recipient of the Royal Charter International Research Award from the BRE and the Worshipful Company of Constructors which contributed funding to validate and test the framework developed by BuroHappold on 12 global cities .

We would like to thank the BRE Trust and the Worshipful Company of Constructors for supporting this report.

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London Councils

University College London (UCL)

Environment Agency, UK

Greater London Authority (GLA), UK

University of Leeds, UK

Municipality of Sorocaba/Technological Park of Sorocaba

Municipality of Recife, Brazil

Municipality of Fortaleza, Brazil

Municipality of São Bernardo dos Campos

International Council for Local Environment Initiatives, Secretariat for South America (ICLEI SAMS)

British Consulate General, Brazil

Office of the President of Brazil

Bristol City Council

London Local Resilience Forum



Figure 3.1: London, UK.

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Richard is an Associate Resilience Consultant within the Risk and Resilience Team. With a background in emergency planning, business continuity and the military, he brings a practical, integrated approach to resilience and has spent the last 15 years practicing in this area with significant experience both mitigating community risks and responding to emergencies. Richard was an officer in the British Army for 7 years. He underwent officer training and received specialist training in logistics, secure telecommunications and all aspects of ammunition and explosives and served as both a Regimental Signals Officer and an Ammunition Technical Officer (ATO (EOD)). He led troops on operations in Oman, Afghanistan, Kuwait, Iraq, and the Balkans.



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Thomas has a background in architecture. He obtained his Master of Philosophy in Architecture and Urban Design from the University of Cambridge. While there he acted as a Supervisor and briefly taught as a Visiting Fellow in Nanjing, China. At BuroHappold he focuses on assessing resilience as well as the creation of city scale resilience and sustainability masterplans. Before joining, Thomas specialised in the relationship between infectious disease and the built environment at the London School of Hygiene & Tropical Medicine. His papers have since been published in several scientific peer reviewed journals.

## 4 INTRODUCTION

BuroHappold has developed the Resilience Insight, a framework for measuring the resilience of cities against a broad spectrum of shocks and stresses; from the sudden impact of flooding to the longer term process of urbanisation. This comprehensive approach has been created in response to growing challenges affecting the world's urban population. The aim of the framework is to act as a tool;

(1) to assist municipal authorities and other key private/public sector stakeholders in assessing their current and future resilience demands and capacities;

(2) to gain a holistic understanding of each city sector's resilience and their interrelationships and;

(3) for prioritizing and measuring the performance of policies and physical interventions that will improve the city's resilience. By making resilience quantifiable, the framework makes it measurable, comparable and manageable.

BuroHappold were joint winners of the 2014 Royal Charter International Research Award presented by the BRE Trust and Worshipful Company of Constructors. Our team of experts have spent the past year researching and developing our resilience framework and applying this approach to 12 cities around the world. Through our research we wanted to meet the urgent need to make city resilience measurable; with a useful level of detail to reflect each city's specific circumstance, whilst still providing a consistent set of metrics against which cost/benefit cases for resilience building can be made.

The 12 global cities considered as case studies are Bristol, Detroit, Dhaka, Glasgow, Hong Kong, London, Manchester, Miami, Mumbai, New York, Riyadh and Sao Paulo. We assessed three of these cities (Bristol, London and Sao Paulo) in further depth by dividing cities into 12 functional areas or "components". Each component was then individually assessed and validated with stakeholders from each city in stakeholder workshops.



Figure 4.1: Edinburgh, UK.

## 5 A BACKGROUND TO RESILIENCE

### 5.1 WHAT IS RESILIENCE?

At BuroHappold we have defined resilience as:

*The ability to anticipate and adapt to shocks and stresses; implementing lessons learned to leverage emerging opportunities, and effectively reduce vulnerabilities.*

This definition emphasizes the critical concepts of anticipation, adaptation, considering shocks and stresses and reducing vulnerability. The definition also recognizes the strong potential for opportunities that exist and must be identified and exploited if our cities are to thrive.

Our approach to resilience is holistic and includes risk management and future proofing. It is broad; combining disaster reduction, risk management, business continuity and emergency planning. It includes governmental, societal, economic and environmental solutions and encompasses all parts of a city system, bringing together these key groups to build resilience, promote a successful city and drive successful outcomes to disruptive events.

### 5.2 SHOCKS AND STRESSES

Shock factors are those one off events that cause disruption, harm or damage on such a scale that specific action needs to be taken to respond and resources need to be diverted. The shock factors that are most commonly considered include accidents, flooding, disease or utility failure but can include terrorist attacks, land movement and seismic events, cyber-attack and many others. An example of these have been outlined in Figure 5.2.

Stresses are factors that continually change our environment and systems over time, they exacerbate existing shocks or become shocks themselves. The current environment is forming into a perfect storm of stress factors with ever increasing demand for resources from a growing and ageing population; an increased scarcity of supply in a wide range of key resources including fresh water and energy; and a rapidly changing environment as a result of climate change.

Coupled to these severe strategic challenges are other pervasive stress factors that will impact every level of society such as growing obesity and diabetes levels, rapidly changing technology, a widening gap between rich and poor, anti-microbial resistance, a rise in international terrorism, and increased globalisation where greater reliance is placed on elongated supply chains.

HAZARD TYPE	SHOCK DESCRIPTIONS						
 <b>HEALTH</b>	 Existing disease outbreak - Epidemic	 Human disease - Disease pandemic (e.g. influenza)	 Human disease - New and emerging infectious	 Animal disease - Zoonotic notifiable	 Obesity & Type 2 diabetes	 Aging population & increased life expectancy	
 <b>INFRASTRUCTURE</b>	 Financial failure/ Crisis	 Structural failure/ movement/instability	 Power Outage	 Critical component failure	 Vehicle strike on structure	 Automation of labour/structural unemployment	
 <b>NATURAL</b>	 Flooding - Surface water - Pluvial	 Heat wave	 Climate change	 Flooding - Fluvial	 Earthquake, Land movement, Landslip & Subsidence	 Desertification	
 <b>SECURITY</b>	 Corporate/ Organisational Governance/ Ethics Failure	 Increased criminal technical sophistication	 Sovereign default	 Security of Global Supply Chains	 Corruption/Bribery	 Accidental or Deliberate Release of Confidential Information	
 <b>SOCIETAL</b>	 Explosion or explosive risk (gas leak, explosive device, etc.)	 Changes in economic power and geo-political stability	 Major fire/ Incendiary accident/ Incident	 Civic disorder - Riots	 Population growth (location & quantity)	 Terrorism	
 <b>TECHNOLOGY</b>	 Cyber crime	 Malicious Software	 Significant Cyber Attack	 Loss of control of key assets	 Identity theft	 Intellectual Property Theft	

Figure 5.1: Example of Shocks and Stress Factors by Category.

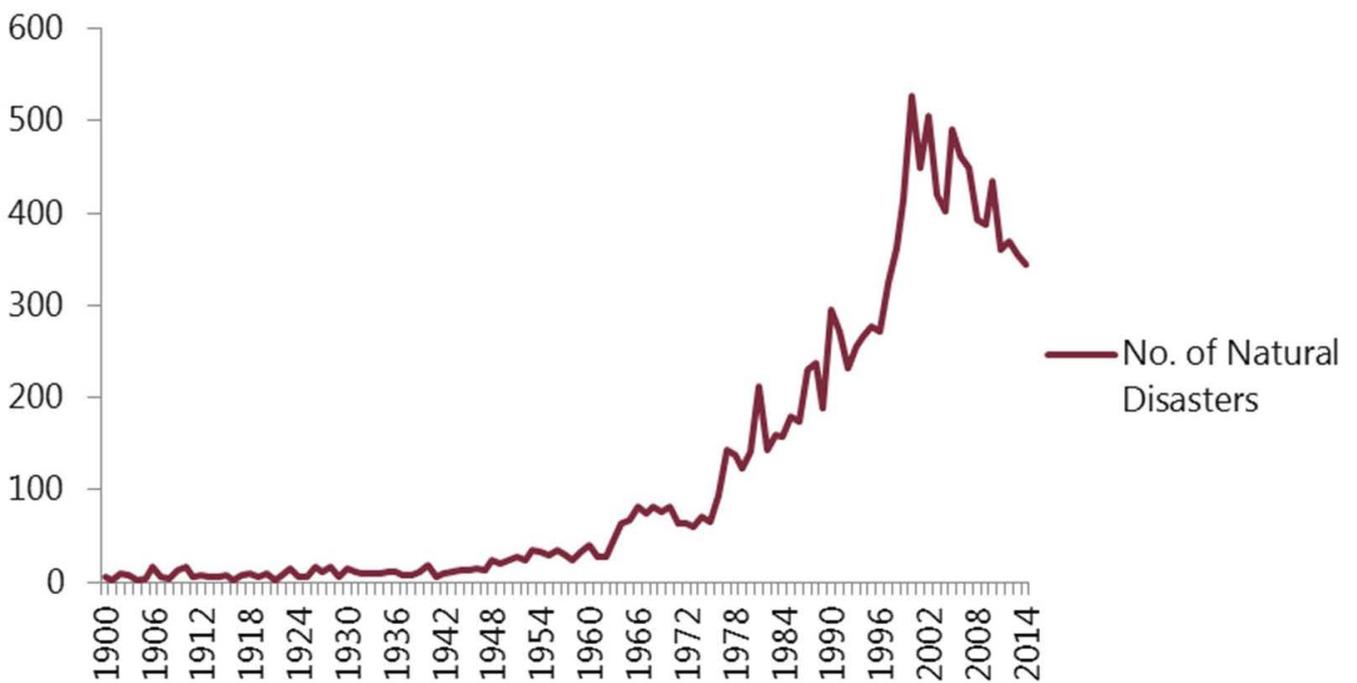


Figure 5.2: Number of Natural Disasters 1900 - 2014 (Source: EM-DAT).

### 5.3 WHY CONSIDER CITY RESILIENCE?

The rate of climate change, economic progress, the rapid pace of urbanisation and population growth have combined to concentrate people, jobs and property in areas exposed to high risk from shocks and stresses resulting in a growth in the number of recorded natural disasters as shown in Figure 5.3. This has been witnessed in recent years where the economic losses due to shocks alone have exceeded £60 billion/year as illustrated in Figure 5.4. Over the past 14 years, the earth has seen record-breaking temperatures and rainfall; economic losses alone reached £1 trillion.

Cities are a key concern with a growing trend towards urbanisation as shown in Figure 5.5; there are more of us living in cities than not. In the 1950s  $\frac{2}{3}$  of the world's population were rural and  $\frac{1}{3}$  urban. By 2050 that ratio is set to reverse. 'The Urban Turn', when world's population turned from a predominantly rural to an urban population, was passed in 2007.

With continued population growth there are more of us than ever before. Today (2015) there are a total of 7.25 billion people with just over 55% living in cities. By 2050 we will see 70% of people living in urban areas, an increase of approximately 2 billion people, this growth will lead to the spread of megacities. There are likely to be winners and losers within this scenario, with some cities becoming very large indeed (megacities), whilst other may struggle to remain relevant and competitive.

Cities tend to be built on trade routes which are traditionally associated with river crossings, ports, estuaries and river deltas. With sea level rise and other effects of global warming this will mean that cities will concentrate societal vulnerability like never before. This changing environment requires cities to work proactively to prepare for the future by understanding the factors that could cause disruption and harm.

Strategies need to be developed to mitigate the threats and increase the adaptive capacity within each aspect of the city sector so the challenges posed by long term stresses and a greater frequency and severity of shocks can be met. The economic, social, governmental cost of not doing so is substantial. The world, and in particular its cities, are undergoing unprecedented change and increasing threats that are turning previously rare events into an everyday occurrence. The world's rapidly increasing urban population and the growth in the number and severity of disaster (Figure 5.3 to Figure 5.7) have meant that cities' capacity to cope with this increase is being sorely tested.

#### **The Business Case for investment**

The case for resilience is clear; the UNISDR Sendai Framework notes, "Addressing underlying disaster risk factors through disaster risk-informed public and private investment is more cost effective than primary reliance on post-disaster response and recovery, and contributes to sustainable development". Part of the BuroHappold approach is to quantify the cost of "doing nothing", based on an annualised cost of impact. This can then be compared to the potential cost of mitigation so that the cost-benefit of investment is clear.

Clients investing in a development need to know their investment is protected and the business case supporting that investment will remain pertinent for the lifetime of their involvement or for the development's lifetime. The risk management model that sets the scene for the resilience approach is focused on creating and protecting value; looking at the underlying assumptions upon which business models are based and understanding how strategic risk factors can both challenge these assumptions but also reveal previously unidentified opportunities.

Overall losses and insured losses 1980-2014 (in US\$ bn)

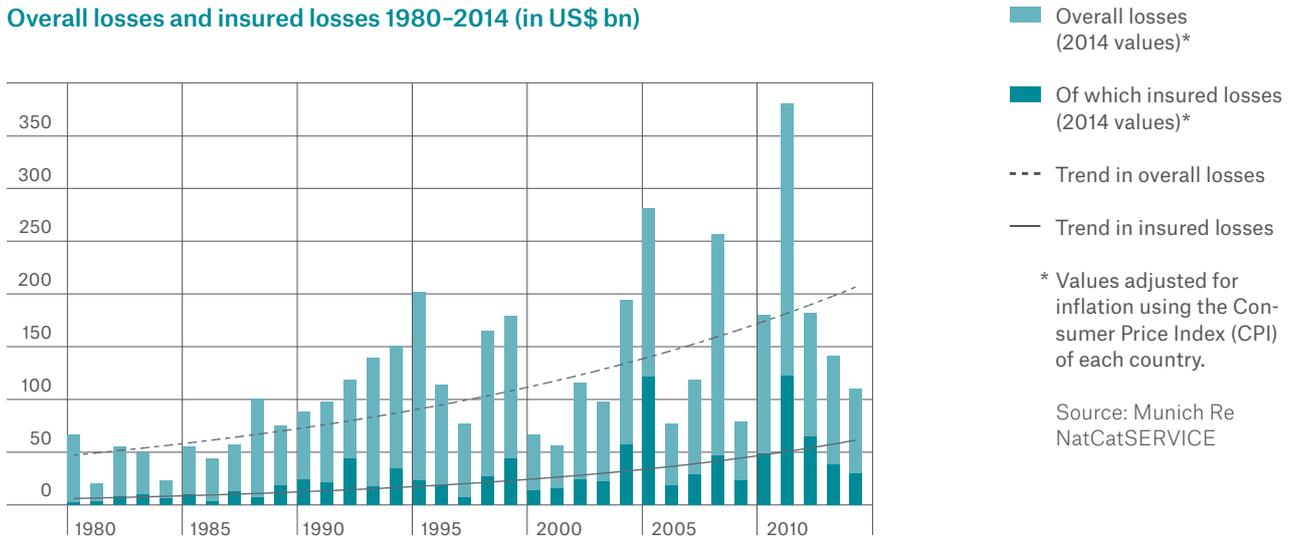


Figure 5.3: Overall losses and insured losses 1980 – 2013 (in US\$bn).

Urban and rural population of the world, 1950–2050

A majority of the world’s population lives in urban areas

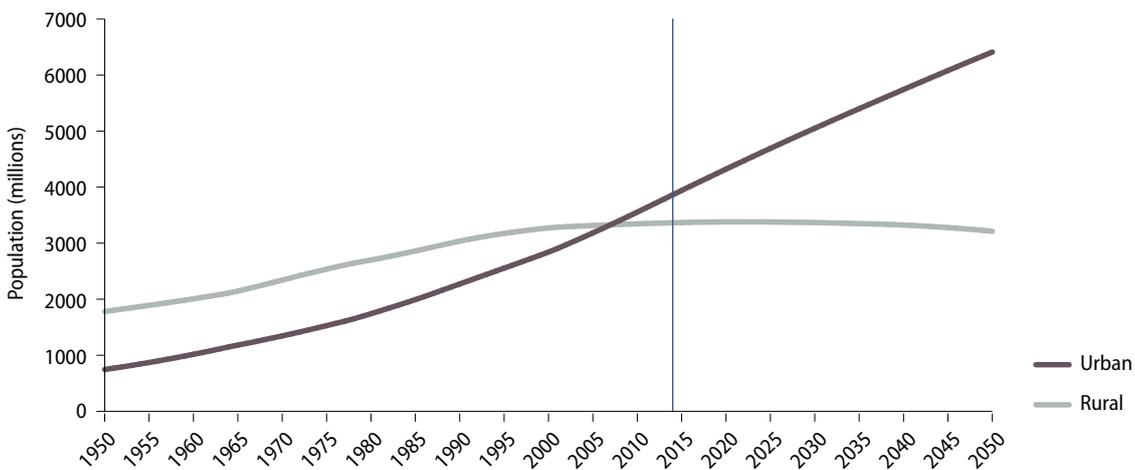


Figure 5.4: Urban and rural population of the world, 1950 – 2050 (UN).

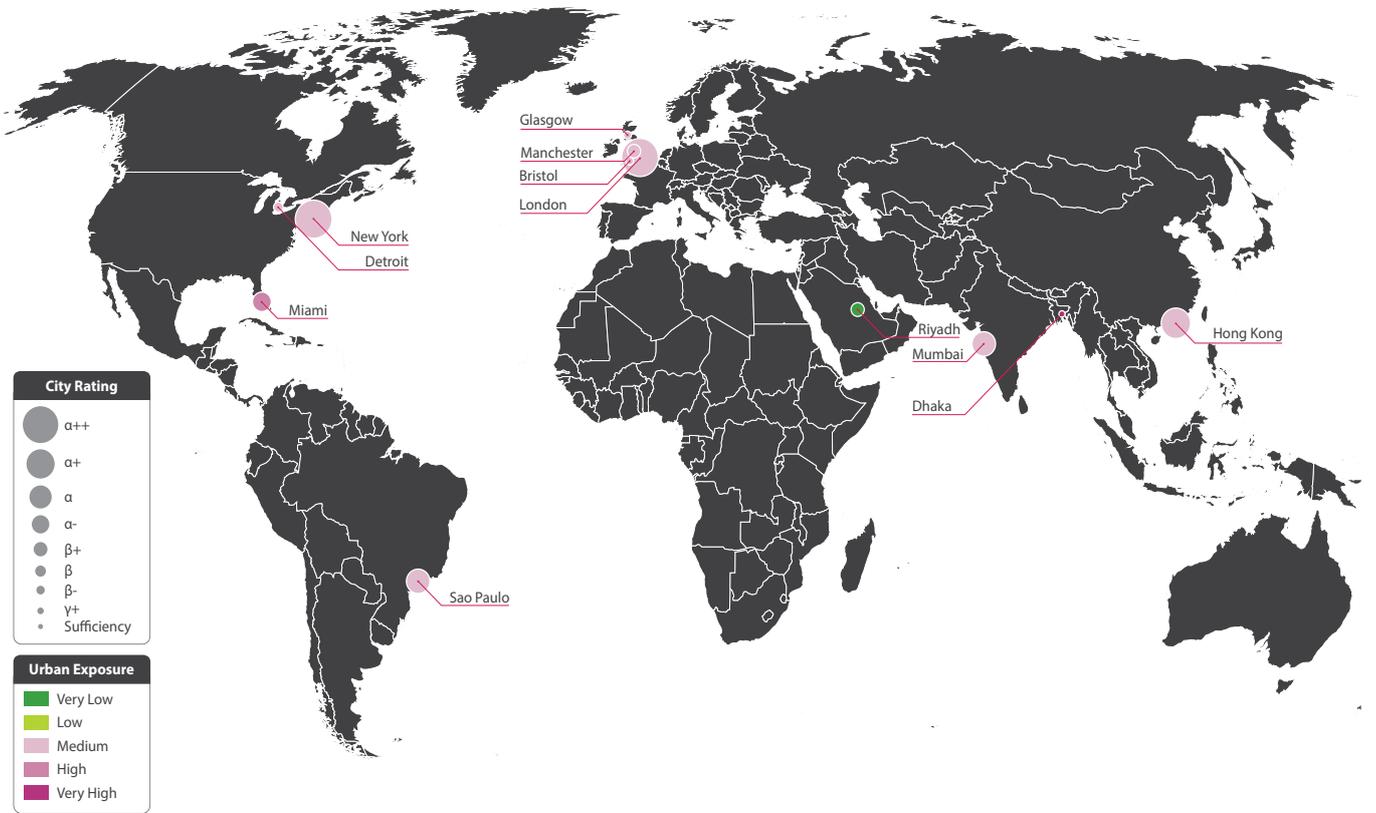


Figure 5.5: Urban Exposure Map showing the 12 case study cities and the relative exposure of their population to natural disasters. City Rating scores are taken from the Globalization and World Cities (GaWC) Research Network's ranking of cities' international connectedness 2012. Urban Exposure tiers are taken from the United Nation's WorldRiskReport 2014.



Figure 5.6: Growth Rate Map. World Risk Report 2014.

## 6 BUROHAPPOLD RESILIENCE PROCESS OVERVIEW



Figure 6.1: The Overall Approach to Resilience.

The 3-stage methodology shown in Figure 6.1 provides a consistent framework through which existing and future measures can be coherently managed to deliver a city that is more resilient today and can evolve to meet the challenges of tomorrow.

It ensures cities are able to develop their understanding of the shocks and stresses they face; allowing adaptive solutions of be implemented pre-emptively. This in turn ensures better planning and coordination; allowing benefits across stakeholder groups to be maximised, breaking down silos and integrating a wide range of expertise.

However, this study is primarily focused on the resilience diagnostic phase of the process.

This approach is outlined in the following sections.

### 6.1 RESILIENCE DIAGNOSTIC

A risk-based Resilience Diagnostic has been created to gain a thorough understanding of a city’s unique vulnerabilities in generic terms. This framework assesses long-term stresses, as well as shocks, (examples of which can be found in section 5.2) and assesses the capabilities of the city to manage them. See section 7 for more information on our Diagnostic Framework.

The process starts by collecting base data to understand the current state of the city from a range of perspectives; social, economic, environmental, the infrastructure and systems, and how the city is organised, governed and funded. The city’s future vision, goals and plans are also examined.

A broad cross section of stakeholders are then engaged to develop a rich understanding of the key shock and stress factors that can disrupt or harm the city and those within it; or in some cases, provide real opportunities for growth and competitive advantage. This analysis allows resilience demand to be calculated providing a baseline against which resilience capacity can be balanced.

In consultation with cities authorities and relevant experts, shocks and stress factors are prioritised and the resilience focus defined.

### 6.2 RESILIENCE STRATEGIES

The process uses a number of tools to help take a fresh look at all the key vulnerabilities. The diagnostic assesses resilience demand and capacity around the following three themes: Society & Community; Governance & Economy and Environment & Infrastructure. To complement the insight that this delivers, vulnerabilities can be mapped spatially to better understand the city’s overall situation.

Working with a range of key city stakeholders and drawing on input from our experts in strategic planning, economics, and other relevant technical disciplines (e.g. water management, transport planning), we run a series of stakeholder workshops to define strategies that will best address the identified key vulnerabilities. The diagnostic tool is used to measure the potential impact of suggested strategies in order to articulate the cost-benefit case.

It is important to resist the temptation to create individual strategies for the different hazards, since this often results in silo'd thinking, duplication, lack of coordination and investments that do not deliver maximum benefit. Successful resilience strategies address multiple vulnerabilities and deliver benefits across a wide range of areas. They also require interventions that cross departmental barriers. Strategy workshops have proved invaluable in successfully aligning interests and uniting diverse stakeholders around a common vision.

Exploiting the capability of the Diagnostic Framework to model future trends, the resilience process is able to test possible scenarios against the current baseline, to assess the comparative impact and benefits of different strategic options. The baseline assessment also enables insight into the cost and benefit of different options and compare them with the cost of inaction.

This informs the creation of business cases around possible strategies for increasing resilience capacity.

### 6.3 RESILIENCE PROGRAMME

Many cities have hundreds of improvement projects underway at any one time. Success of these programmes is driven by clarity on core strategies, aligned to an overarching programme and with appropriate levels of funding. Governance failings can result in projects lacking alignment with the core vision and this creates duplication and wasted effort.

In-depth quantitative analysis is performed to develop and implement robust and fit for purpose strategies that support city resilience. These strategies include detailed design and procurement of identified infrastructure upgrades, the implementation of a community resilience plan and/or the development of emergency response plans supported by training, exercise and learning. During this process we ensure these deliverables are in alignment with the resilience strategy and other key city objectives to maximise the return on investment. The Diagnostic Framework is updated to illustrate the measurable resilience benefit obtained through the implementation of these solutions.

## 7 RESILIENCE DIAGNOSTIC APPROACH

The methodology is risk-based; providing a comparative risk score for each of the shocks and stresses identified as well as the effect on each of the components of the framework. The risk-based approach follows the traditional methodology where risk is defined as the product of the likelihood of an event occurring and the severity of the impact. The analysis attempts to consider the full spectrum of hazards so as to build a complete picture of resilience demand and to then understand gaps in the city's capacity. It also incorporates trend analysis to simulate that cities are constantly changing and that underlying stresses such as climate change, globalisation and urbanisation shift a city's risk and ability to cope. Stresses and shocks are mapped against each other to understand the effect the former has on the latter allowing trend analysis for shocks based on the best possible evidence on stresses. This is fundamental in understanding the shifting risk profile over time. The tool ultimately helps investors and key public/private stakeholders prioritise decisions by making the impact of resilience strategies measurable and comparable.

### 7.1 RESILIENCE FRAMEWORK

Our resilience approach is based on the framework shown in Figure 7.1 which helps to ensure that complex and interconnected design challenges are captured, evaluated and managed in a holistic, integrated manner. Separated into three themes with four components each, it encapsulates aspects and interconnectivities of a city. The themes and components break down as follows:

#### 1. Society & Community

- Community & Inclusion
- Health & Wellbeing
- Mobility & Communication
- Sense of Place

#### 2. Governance & Economy

- Leadership & Government
- Security & Safety
- Business & Trade
- Skills & Innovation

#### 3. Environment & Infrastructure

- Structures & Infrastructure
- Systems & Technology
- Resources
- Environment

These components are further described in Appendix A.

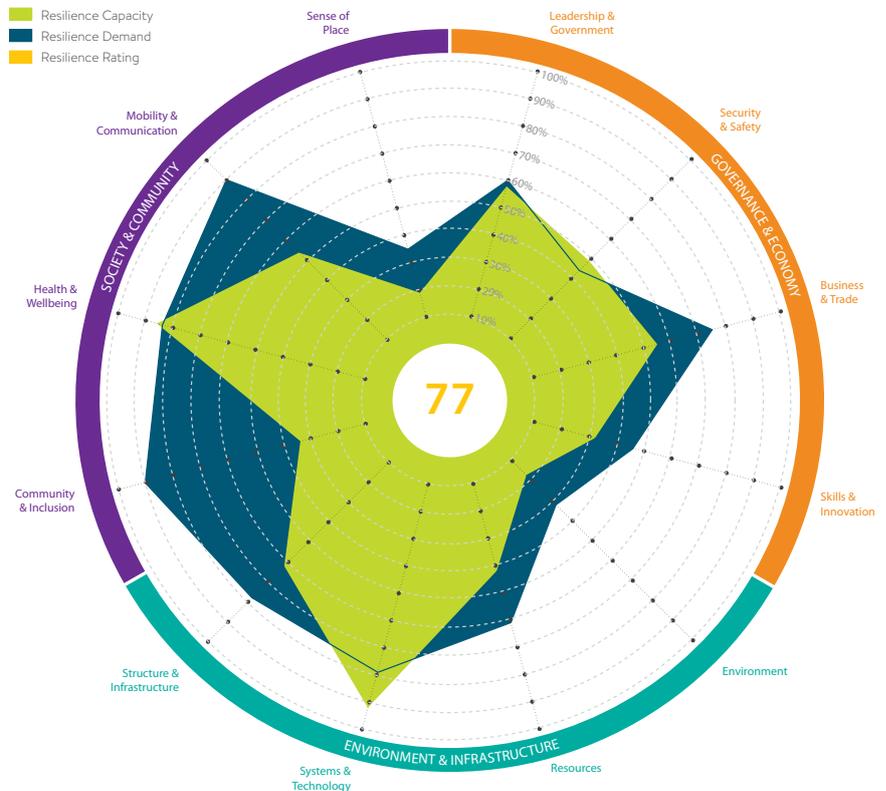


Figure 7.1: BuroHappold's Resilience Wheel. This diagram is part of an information dashboard detailing London's challenges and opportunities.

## 7.2 ALTERNATIVE METHODOLOGIES

A number of contemporary indicator systems were reviewed and compared against the BuroHappold Resilience Framework as shown in Table 7.1. A separation can be made between those systems used as tools and those which are indices. The latter may identify hazards and resilience but the former prioritises suitable action to increase resilience. The second key feature of a tool is its ability to create a baseline measure with which future policies can be measured for their effectiveness or ineffectiveness at increasing resilience.

**Table 7.1** Comparison with existing indicator systems.

Name	Author	Tool/ Index	Baseline Tool	Multi-sector	Multi-hazard	Exposure	Capacity	Risk-based	Trend-based	Mapped inter-relationships
Hyogo Framework	UNISDR	Index	N	Y	Y	Y	Y	N	N	N
Urban Risk-Index	World Bank	Index	N	Y	N	Y	Y	Y	N	N
Mind the Risk	Swiss Re	Index	N	N	N	Y	N	Y	N	N
Resilient Cities Research Report	Grosvenor	Index	N	N	Y	Y	Y	Y	Y	N
Resilience Framework	BuroHappold	Tool	Y	Y	Y	Y	Y	Y	Y	Y

### 7.3 THE RESILIENCE DIAGNOSTIC PROCESS

The resilience rating process is shown in Figure 7.2 below and further detailed in the sections below.

As shown in Figure 7.3, the resilience assessment process can be broken down into six main steps. The following is a description of how these steps are formulated and the sub-components from which they are constructed.

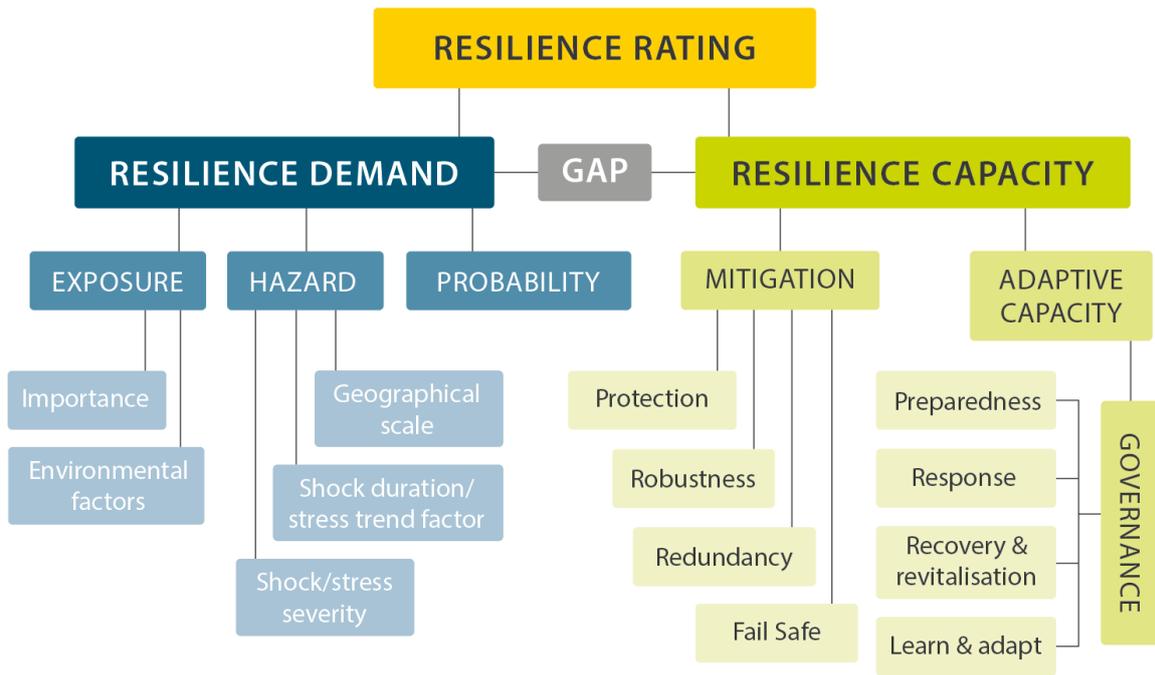


Figure 7.2: Resilience Rating Flowchart.

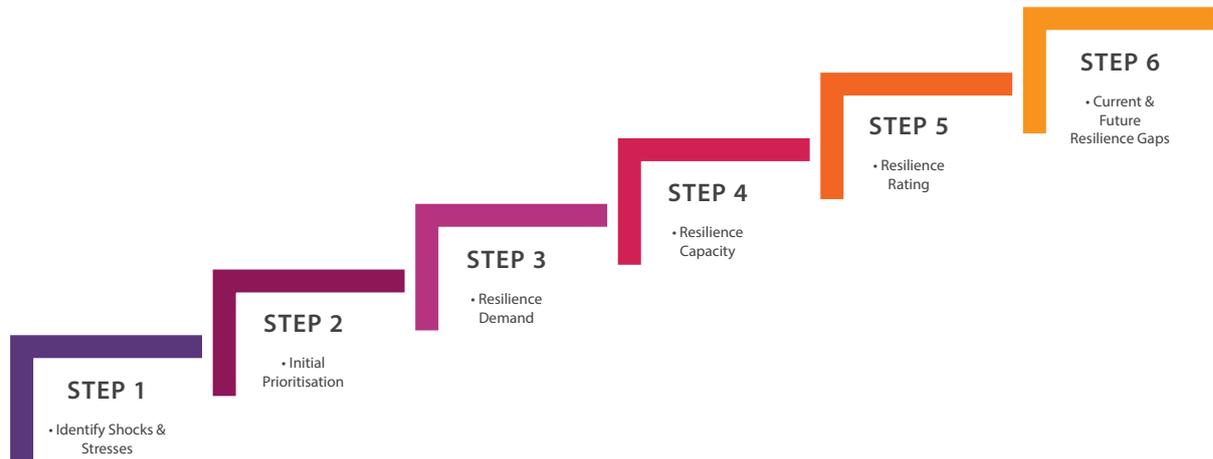


Figure 7.3: The resilience assessment process.

### 7.4 STEP 1: IDENTIFY SHOCKS & STRESSES

At its core resilience is based on the development of a very thorough understanding of the operational environment taking into account a broad range of factors both internal and external. BuroHappold has and continues to develop a comprehensive shock and stress factor data set and this is used as a starting point for stakeholder engagement. These are subsequently narrowed down and prioritised. Examples of shock and stress factors are shown in Figure 5.2.

### 7.5 STEP 2: INITIAL PRIORITISATION

It is likely that the initial broad scope shock and stress factor identification process will result in a list with potentially hundreds of hazards. The initial prioritisation process refines the list of hazards into those that are most important to consider using a quick methodology known as MoSCoW. MoSCoW asks the user to categorise the shocks and stresses by the following criteria:

- **Must consider** - Shocks and stresses that must be considered or can be considered critical.
- **Should consider** - Shocks and stresses that should be considered and are second in priority for the resilience of the city or the client’s needs.
- **Could consider** - These are shocks and stresses that, capacity of the client permitting, could be considered.
- **Won’t consider** - These shocks and stresses are either outside of the client’s scope or not pertinent to the city e.g. snow storms in Dakar. The won’t consider options allows the shock or stress to be reconsidered at a later date if the situation changes.

### 7.6 STEP 3: RESILIENCE DEMAND

The framework calculates resilience demand as a combination of; (i) multi-hazard events and (ii) the city’s exposure to these and (iii) the probability of their occurrence or, in the case of stresses, the rate of growth of that trend.

#### Calculate Exposure

Cities consist of layers of complex integrated systems that are mutually supporting and dependant. Assessing a city’s resilience needs to take into account the baseline parameters of these systems as well as the complexity of interrelationships that exist.

The assessment establishes two baselines; Baseline 1: the relative importance of each of the 12 components in terms of value and systemic importance.

Baseline 2: the exposure (i.e. the total potential for harm or disruption). Each component of the framework is assessed on financial exposure as well as other factors relevant to each component e.g. residents for community and inclusion or transport systems for mobility and communication.

Exposure factors are further discussed in Appendix B.

### 7.7 STEP 4: RESILIENCE CAPACITY

Resilience capacity is the city’s capacity to deal with shocks and stresses and is broken down into two aspects; mitigation and adaptive capacity. These aspects reduce the impact or probability; or deal with the consequences, as shown in Figure 7.4. Mitigations can remove or reduce exposure, provide immunity, implement protective measures, increase robustness, provide redundancy and design in fail safes. Contingencies are a key component of adaptive capacity providing response systems with specific prepared response capabilities such as warning & informing, deployable preventative and protective measures, emergency shelter, evacuation, public safety measures, business continuity, resolving the source hazards e.g. firefighting, recovery and the ability to learn and adapt.

The overarching themes are important properties that a good resilience strategy should include;

1. A good balance of both mitigation and adaptive capacity measures across all components of the city;
2. Well coordinated and integrated to provide the maximum benefits and;
3. The output will be sustainable and future focussed.

A comprehensive resilience strategy will touch all aspects of a city. It is therefore a useful strategy for integrating a city and breaking down silos. Providing an overview for resilience means that the city is integrated around this goal which provides the co-benefit of better collaboration and better understanding between departments which results in resilient solutions that maximise benefits across multiple areas and agencies.

The following are measurable strategies for resilience captured within our framework:



Figure 7.4: The core aspects of adaptive capacity (prepare, respond, recover, learn & improve) and mitigation (protect, robust, redundant, fail-safe) as well as the desirable approaches to each (balanced, co-ordinated, sustainable and integrated).

### 7.7.1 EXPOSURE PREVENTION MEASURES

A shared situational awareness, risk analysis and vulnerability assessment allows a holistic understanding to the types of measures needed to prevent exposure from the outset and reduce resilience demand. Exposure prevention measures are those external to the city or project (i.e. off-site measures). Specific examples may include stores and spares in a global supply chain, regulation to ensure safe and secure operation of key infrastructure, or coastal defences outside the city.

### 7.7.2 MITIGATION MEASURES

Mitigation measures mitigate exposure and reduce vulnerability. The effectiveness of existing mitigation measures is evaluated for the identified shocks and stresses on a 5 point scale which are categorised into the following mitigation strategies:

#### 7.7.2.1 PROTECTION

Protective measures can be physical or procedural. They usually form a protective barrier between an identified hazard and areas that are vulnerable. Famous examples include the Thames Barrier and the Great Wall of China; but on a small scale protective measures would include property level flood protection.

#### 7.7.2.2 ROBUSTNESS

A system's ability to resist an impact without changing its form. An example would be a structure that has been enhanced to withstand specific extreme shock factors such as wind, flooding, blast, heat, dust, collision, et al; where a threat has been identified. The assessment of robustness is based on the likelihood of failure if the entity is impacted by the specific shock or stress.

#### 7.7.2.3 REDUNDANCY

The addition of components or capacity which are not necessary to functioning but are included in case of component failure. An example of this is designing utilities in loops and with extra capacity so that if there is a break or interruption at any point, supplies can be re-routed to ensure continuity. Redundancy is assessed against the ability to continue to operate despite partial loss of systems or infrastructure.

#### 7.7.2.4 FAIL-SAFES

In the event of a failure, the failure is proportionate and does not propagate within the system or to other connected systems resulting in disproportional failure or loss. An example of this would be to understand the failure modes of a structure and making sure that loss of one member does not cause disproportionate or progressive collapse.

### 7.7.3 ADAPTIVE CAPACITY MEASURES

Adaptive capacity is the capacity of people, organisations, cities, regions, nations and trans-national organisations to anticipate, respond, learn and adapt to the changing environment. Measurable strategies for adaptive capacity include an effective response system that provides good preparation, response capability, recovery and the ability to learn and improve as discussed below.

#### 7.7.3.1 EFFECTIVE COMMAND AND CONTROL (C2)

During an incident command & control refers to the people, facilities and systems that ensure the overall management of an incident including situational awareness, leadership & governance, controls, coordination, communication, and appropriate escalation. During normal business these activities would be delivered through good governance and management systems. C2 is terminology taken from the military and can be expanded to include all computer, communication and information systems.

#### 7.7.3.2 PREPARE

An entities ability to adapt to a situation is greatly improved with planning, understanding (modelling), testing, exercising, pre-positioning of resources/ capabilities and preparing facilities. These activities can be coordinated through states of readiness where there is an ability to anticipate a shock. These preparations greatly improve the chance that, when triggered, the response to the hazard is swift, effective and coordinated. The level of preparation needs to be in line with the level & nature of the threat, the complexity and the necessary speed of the response.

**7.7.4 RESPOND**

Emergency response is the organizing, coordinating, and directing of available resources in order to respond to the event and bring the emergency under control. Primarily, the goals of an emergency response is the protection of life and property, however, in recent time the minimisation of mental and physical impacts and reducing disruption are equally important. Key to a successful response is the gathering and management of information; to detect the problem; generate situational awareness which in turn allows the right decision to be made; coordination of resources; and the development of learning to ensure systems continually improve.

**7.7.5 RECOVER**

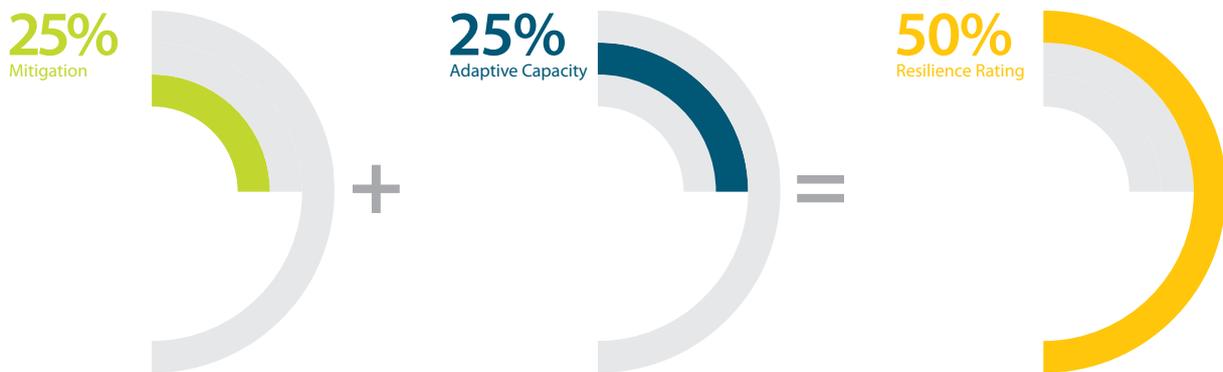
Recovery strategies formulate the recommended ways and means through which an entity recovers from adverse impacts. The principle of bounce back better is key, and to understand what better means takes effective engagement with those effected. Recovery is aided by well-designed mitigation measures and in particular fail safe's, redundancy and robustness which will have reduced negative impacts and made remediation action cheaper and quicker.

**7.7.6 LEARN, IMPROVE & ADAPT**

Resilience is greatly aided by a culture of continuous learning and the learning organisation (Senge, 1990). At every stage, opportunities to learn and adapt need to be taken; allowing a more complete understanding of the city/ organisations and the environment within which it resides (environment used in the broadest sense). Learning, improving and adapting can be challenging as they result in change, which can cause some to be fearful, disconcerted and threatened resulting in change resistance. The ability of a city or organisation to understand, acknowledge and overcome or take account of these concerns is key to continued resilience.

**7.8 STEP 5: RESILIENCE RATING**

Resilience rating is the resilience capacity divided by resilience demand. So effectively is the percentage of the demand that is met either through mitigation measures or adaptive capacity measures. This breakdown is illustrated in Figure 7.5.



\* Figures rounded

Figure 7.5: .Example calculating mitigation, adaptive capacity and resilience rating.

## 7.9 STEP 6: CURRENT & FUTURE RESILIENCE GAPS

The resilience gap is simply the resilience demand minus the resilience capacity.

When designing resilient systems it is not sufficient to gauge the resilience demand for the here and now. The information gathered by the framework can be used to project onto the future and understand how shocks and stresses are likely to change over time.

The report has already indicated that the exposure assessments are used to project shock and stress factor growth or reduction. Within the tool there is also a map of shocks and stress, how they relate and how their interrelationships are likely to cause associated growth or reduction. An example of this is climate change which, depending on location (UK example), is likely to increase the risk of flooding, drought, heatwave, invasive species, new diseases etc., but reduce the

risk of heavy snow or prolonged freezing temperatures. These assessments are used to measure the changing resilience demand over a set time period. For the purposes of this study, the time period has been set at 15 years, 2015 to 2030, and it is well understood that the further into the future the projection is made, the less confidence can be placed in the results. Projections are based in various models provided by governmental and intergovernmental bodies such as the IPCC, IMF, WHO, United Nations, OECD, HM ONS etc. Figure 7.6 illustrates how the resilience gap now and in 2030 can be mapped against components of the city.

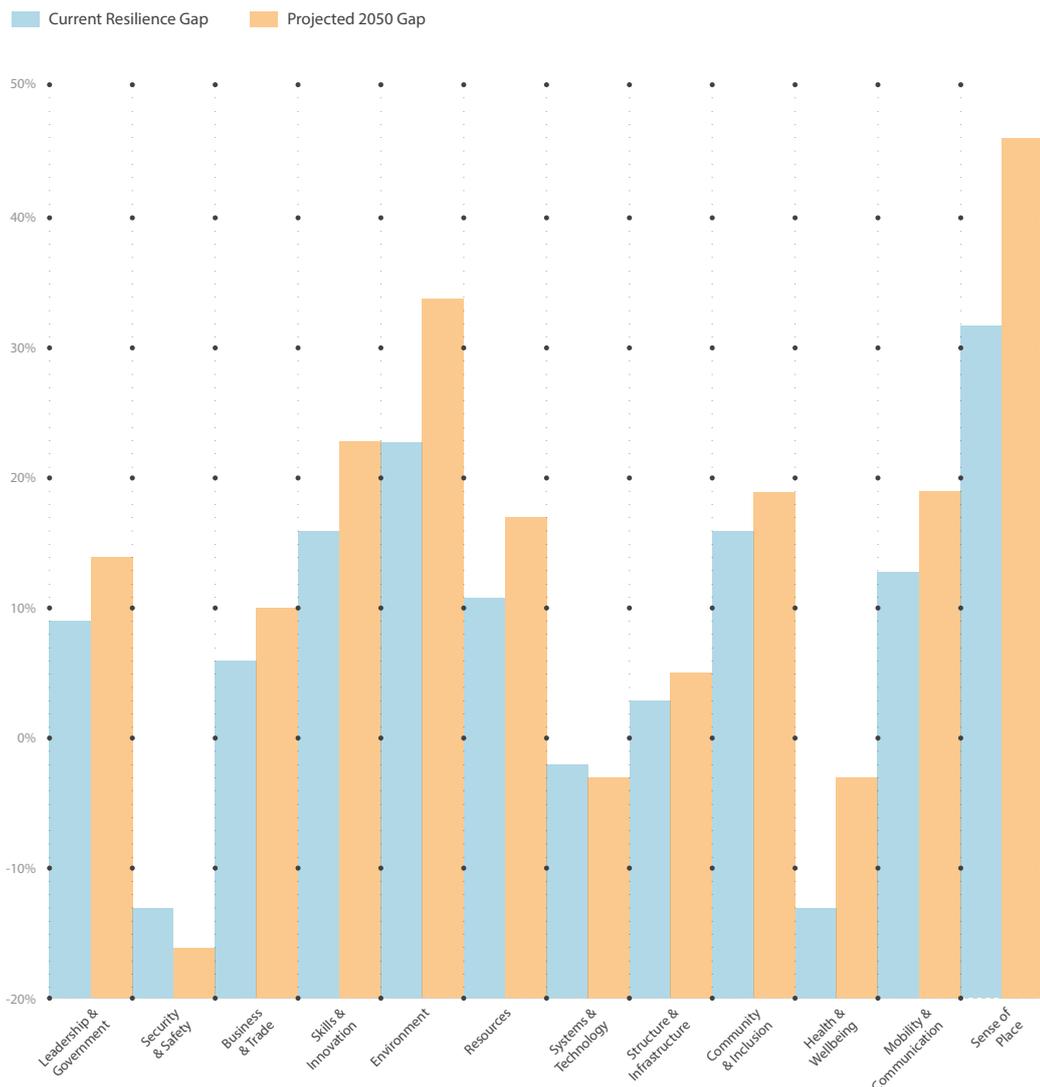


Figure 7.6: Current resilience gap (blue) versus future (2050) resilience gap (Yellow) per framework component.

### 7.10 ANNUALISED FINANCIAL IMPACTS

Clients investing millions if not billions into a development need to know their investment is protected and the business case supporting that investment will remain pertinent for the necessary period of repayment or for the development's lifetime. If investors are also looking to invest in building resilience as a means of protecting the value of a development, the annualised value of financial impacts become key to building the business case. The risk management model that sets the scene for our resilience approach is focused on creating and protecting value; looking at the underlying assumptions upon which business models are based and understanding how strategic risk factors can both challenge these assumptions but also reveal previously unidentified opportunities.

Figure 7.7 below shows the 15 hazards with the greatest annualised cost of impact for London. This is calculated by dividing the estimated cost of impact by the return period (based on the 95th percentile scenario). The probability and cost of impact are assessed using a five point scale as shown in Table 7.2 and Table 7.3.

This provides the baseline for developing the business case for action and investment. The next step is to develop strategies and evaluate their effectiveness and cost compared to doing nothing.

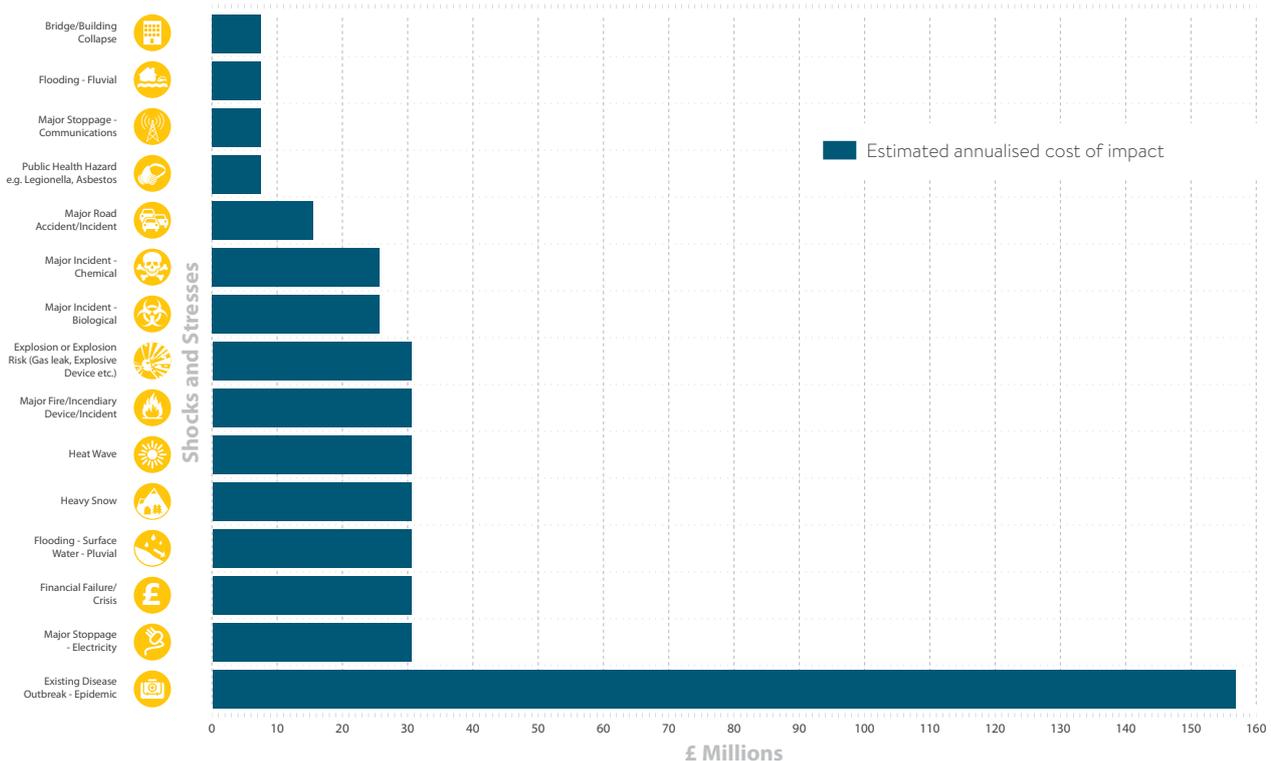


Figure 7.7: Example Top Estimated Financial Impacts.

**Table 7.2** Probability Scale.

Scale	Qualitative Measure	Quantitative Measure	
		Chance of Occurrence every 5 years	Annual Probability of Occurrence
5	Extremely Likely	1:1	33%
4	Likely	1:5	6%
3	Unlikely	1:20	2%
2	Very Unlikely	1:50	1%
1	Exceptionally unlikely	1:200	0.16%

**Table 7.3** Cost of Occurrence Scale.

Scale	Qualitative Measure	Quantitative Measure
5	£100 million +	500,000,000
4	Between £10 & £100 Million	55,000,000
3	Between £1 & £10 Million	5,500,000
2	Between £100 thousand & £1 million	550,000
1	Less than £100 thousand	50,000

### 7.11 MAIN OUTCOMES OF THE APPROACH

The key benefits and outcomes of the approach we have developed are as follows:

**A multi-factor environmental analysis that identifies opportunities and threats.** Systems thinking is an essential part of the resilience approach and not just the system itself but also the environment within which it resides. This allows for effective horizon scanning and a truer understanding of the operational risks that the future can pose.

**Quantifies the need for action and indicates what action should be taken.** If you can't measure it, you can manage it, and you certainly can't improve it. If we are to build resilience within our cities, we will need an approach that can measure what we are trying to improve. A journey needs a start and a finish, without a means of measuring resilience, how do we know where to start and when our goal has been achieved?

**Baselining tool.** The tool provides a baseline against which progress can be measured. It then allows hypotheses and scenarios to be tested against this baseline level of resilience to ascertain the effects on a city's resilience.

**Provides a means for stakeholder engagement in order to build capital:**

- a. Political capital – makes evidenced case to politicians to back investment and support programmes of resilience capacity development.
- b. Social capital – provides a common basis for broad engagement and developing resilience networks. It can provide a community unity of purpose. Engagement to build the communities resilience capacity.
- c. Human capital – provides the basis for investment in skills and capabilities.
- d. Manufactured capital – business cases to support capital investment in engineered solutions.
- e. Financial capital – key to developing business cases for resilience building investment using tools and techniques recognised by investors.

**Provides a basis for engaging the insurance industry.** The framework helps to answer the question “what is the cost of not considering resilience?” and what are the potential future losses to a broad range of hazards (perils).

**A means to future-proof.** By understanding the key trends shaping the city, a stakeholder can understand the future needs for resilience and prospects for the city.

The key issues of complexity and uncertainty and their interrelationships are illustrated in Table 7.4.

**Table 7.4** The importance of mapping interrelationships. The Resilience Framework's methodology (non-bold) and the issues of resilience that they address (bold).

	Mapped Interrelationship	
Mapped Interrelationship	<b>Complexity</b>	
	Hazard (Impact)	City (Impacted)
	Multi-hazard Analysis	Multi-sector Analysis
	<b>Uncertainty</b>	
	Shocks (short-term)	Stresses (long-term)
	Risk Analysis	Trend Analysis

## 7.12 CONFIDENCE LEVELS

The validity of the data provided by the tool is greatly influenced by the data input. The following five point scale as show in Table 7.5 indicates the confidence level that can be applied to the output of the diagnostic tool.

**Table 7.5** Confidence Level Scale.

Scale	Qualitative Measure	Description
5	Very High	Multiple corroborating data sets including key stakeholder groups, modelled and independent peer reviewed
4	High	Multiple corroborated data sets including key stakeholder groups supported by independent peer review
3	Medium	Multiple corroborating data sets including key stakeholder groups
2	Low	Assessment corroborated by informed stakeholder engagement
1	Very Low	Uncorroborated assessment supported by open source data

Decisions based on the output of the tool should have an appropriate confidence level applied. Small, low risk decisions can be made with information of a lower confidence; however, significant, high risk decisions should be based on information with a high confidence level.

## 7.13 SENSITIVITY ANALYSIS

A sensitivity analysis was carried out to assess the interrelationships between different variables across the 12 sectors. Analysis was based on a generic city model where all 5-point scales were set at 3 to gain an 'average' score. Variables were then set to 'High' (a rating of 5) or 'Low' (a rating of 1). Other than the probability sensitivity analysis, the variables tested did not include those relating to hazards. Instead they focused on the notional city's resilience demand and capacity. Initially the analysis did produce some areas of improvement that were corrected in an iterative process coupled with the testing of results with stakeholder groups.

Ultimately, the result of the analysis showed that the tool behaved as anticipated with all the key elements such as exposure, impact, probability, vulnerability all having a proportionate but significant impact on the tool's outputs.

## 8 12 CITIES COMPARISON ASSESSMENT

### 8.1 INTRODUCTION

12 cities were chosen from a variety of countries in order to test the methodology on cities with a broad range of differing capacities and demands. A more simplified, high-level assessment was completed resulting in a single score attributed to each city rather than for each city component. At this level of analysis the output is primarily used to compare cities, as shown in Figure 8.1, rather than assess a city's resilience demands and capacities in depth.

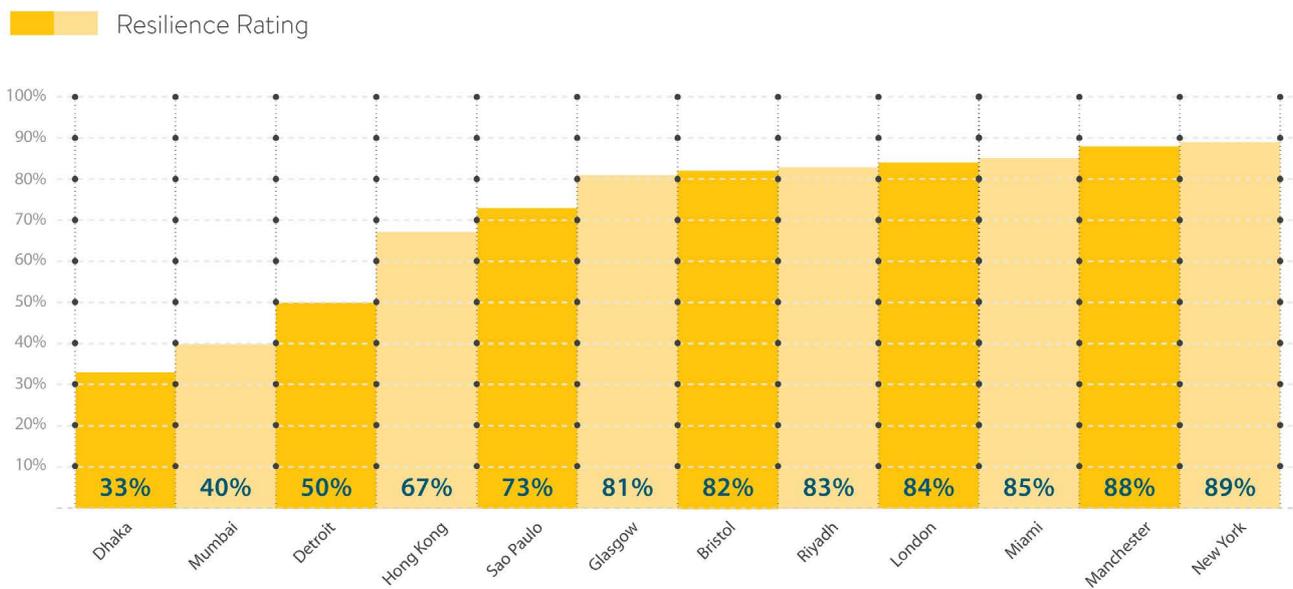


Figure 8.1: 12 Cities Comparison Graph of Resilience Ratings.

## 8.2 RISK IDENTIFICATION & PRIORITISATION

Shocks and stresses were chosen to be as generic as possible to allow comparison between the 12 cities. Shocks were therefore compiled into their base categories (i.e. Health, Infrastructure, Natural, Security and Societal\*) while stresses were chosen based on their universal nature.

\*At the time of the assessment, Technological Hazards were not included as a separate category but were instead incorporated into Security Hazards).

**Table 8.1** 12 Cities Shocks & Stresses.

Shocks	Health Hazards
	Infrastructure Hazards
	Natural Hazards
	Societal Hazards
	Security Hazards
Stresses	Climate change
	Urbanisation
	Migration
	Peak oil & other fossil fuel depletion
	Globalisation
	Terrorism
	Obesity & Type 2 Diabetes
	Anti-microbial resistance
	Criminal Sophistication
	Workforce replacement
Mental Degenerative Disease	

### 8.3 RESILIENCE DEMAND

Figure 8.2 illustrates the resilience demand of the 12 cities ordered by resilience rating from left to right. This shows that the most resilient are not necessarily the ones facing the most serious effects of shocks and stresses. New York and Miami, for example, are prone to severe flooding but their high adaptive capacity and mitigation scores (see Figure 8.3) reduce the demand for resilience. This shows the importance of considering the resilience capacity in the context of the demands it faces.

### 8.4 RESILIENCE RATING, MITIGATION AND ADAPTIVE CAPACITY

Figure 8.3 illustrates a general pattern; the top six resilient cities have a strong score in both mitigation and adaptive capacity. In the less resilient cities the ratio begins to slip with varying relationships between the two scores. Hong Kong, for example, constrained by its geographical location and with little flexibility to expand or renew its ultra-dense urban form has a low mitigation score but a significantly higher adaptive capacity score recognising the ability of the Hong Kong government to manage the city effectively. Conversely, Sao Paulo's mitigation score is higher than its adaptive capacity due to many of its problems being rooted in its relatively ineffective political system to manage and adapt to change. Riyadh is another example where the mitigation score is higher than its adaptive capacity largely due to the high level of investment put into the city (improving its mitigation score).

Mitigating the impact before the event is highly beneficial as this prevents adverse impacts as far as possible, but can have high capital cost implications. Conversely, over-reliance on mitigation measures can result in complacency and ill-preparedness making the impacts of the one off extreme event that breaches protections all the more severe. Even if the known threats are mitigated, there is always the need for situational awareness and contingencies to deal with operational and logistics requirements, along with those unforeseen events that may occur. These ratings do highlight the importance of cities to consider both aspects of resilience in order to make themselves fully prepared and protected and it is clear that most cities put less effort into mitigation and more into response capabilities, which may not be the most cost effective strategy and could also mean disruption and harm are more likely even if the response is effective.

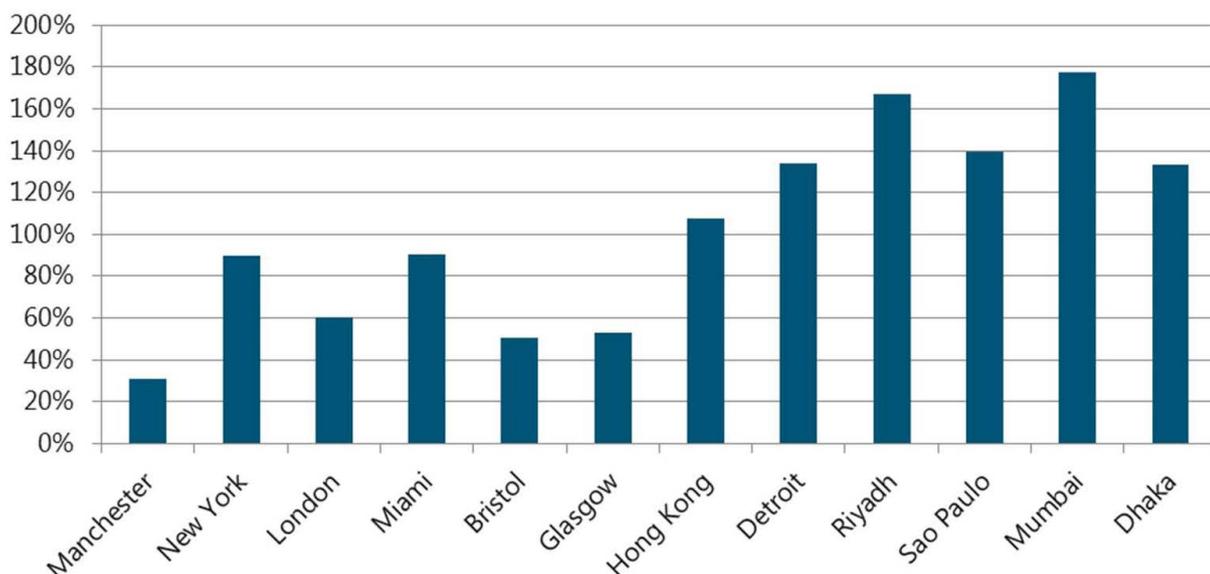


Figure 8.2: Resilience demand for 12 cities.

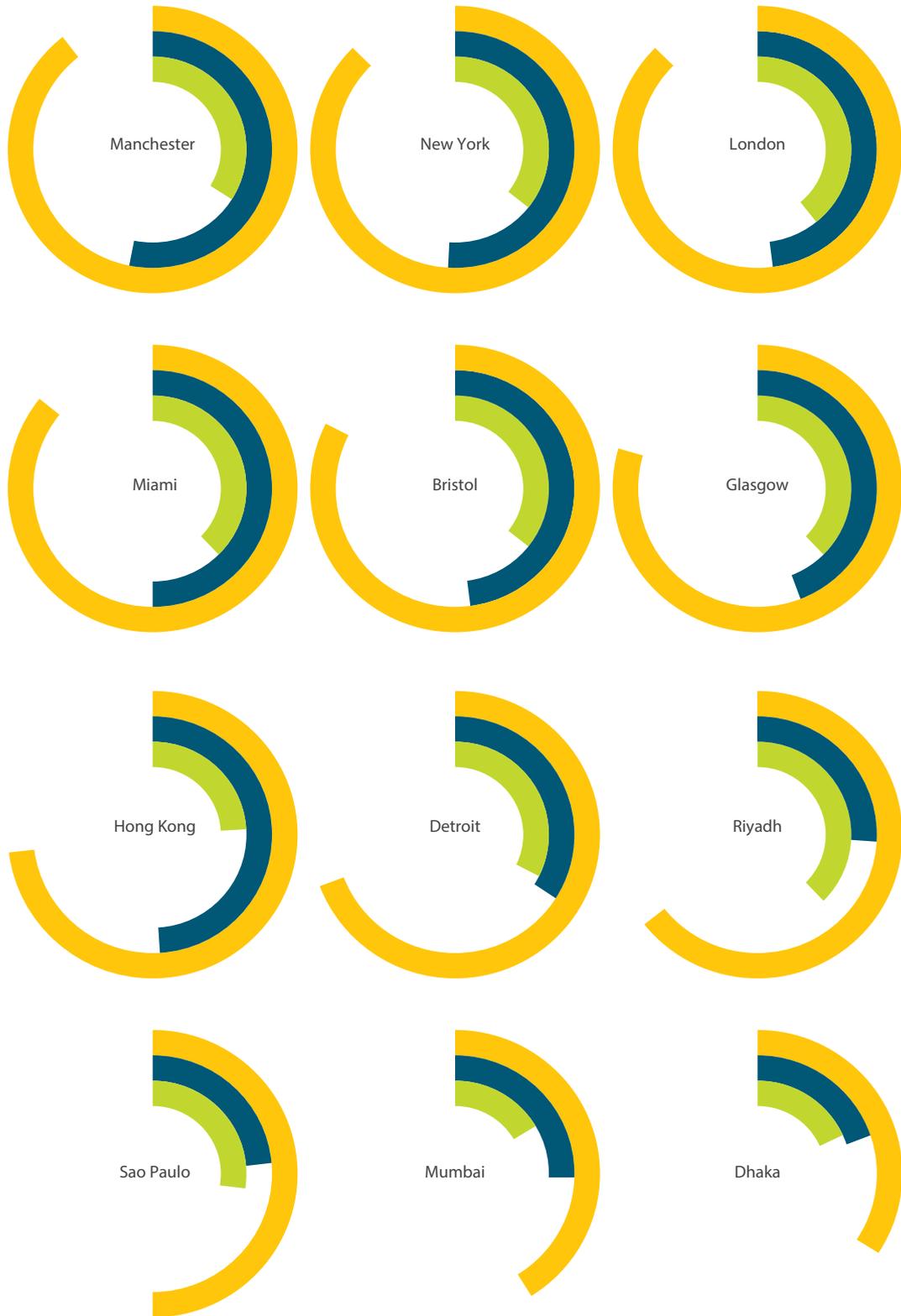


Figure 8.3: Mitigation (green), Adaptive Capacity (blue) and Resilience Capacity (yellow) scores for 12 cities from most to least resilient.

### 8.5 CURRENT AND FUTURE RESILIENCE GAPS

While Figure 8.3's information allows us to plot the current resilience, of greater importance when prioritising decisions affecting the resilience of a city are the future resilience needs. Figure 8.4 indicates the gaps between resilience demands and capacities for each city. This shows that the top eight most resilient cities are predicted to have only moderate growth in their resilience gap; whereas the bottom four cities are likely to experience significant growth in the gap between resilience demand and capacity. It is important to note that this is based on the assumption that the current resilience capacity remains static; which in reality is unlikely to be true.

Looking at a specific example, Dhaka's population increase of 60% (a figure far higher than any of the other city growth projections) will expose even greater numbers of people to shocks and stresses facing the city. For Sao Paulo, the poor governance structure makes it difficult to adapt and implement mitigation strategies.

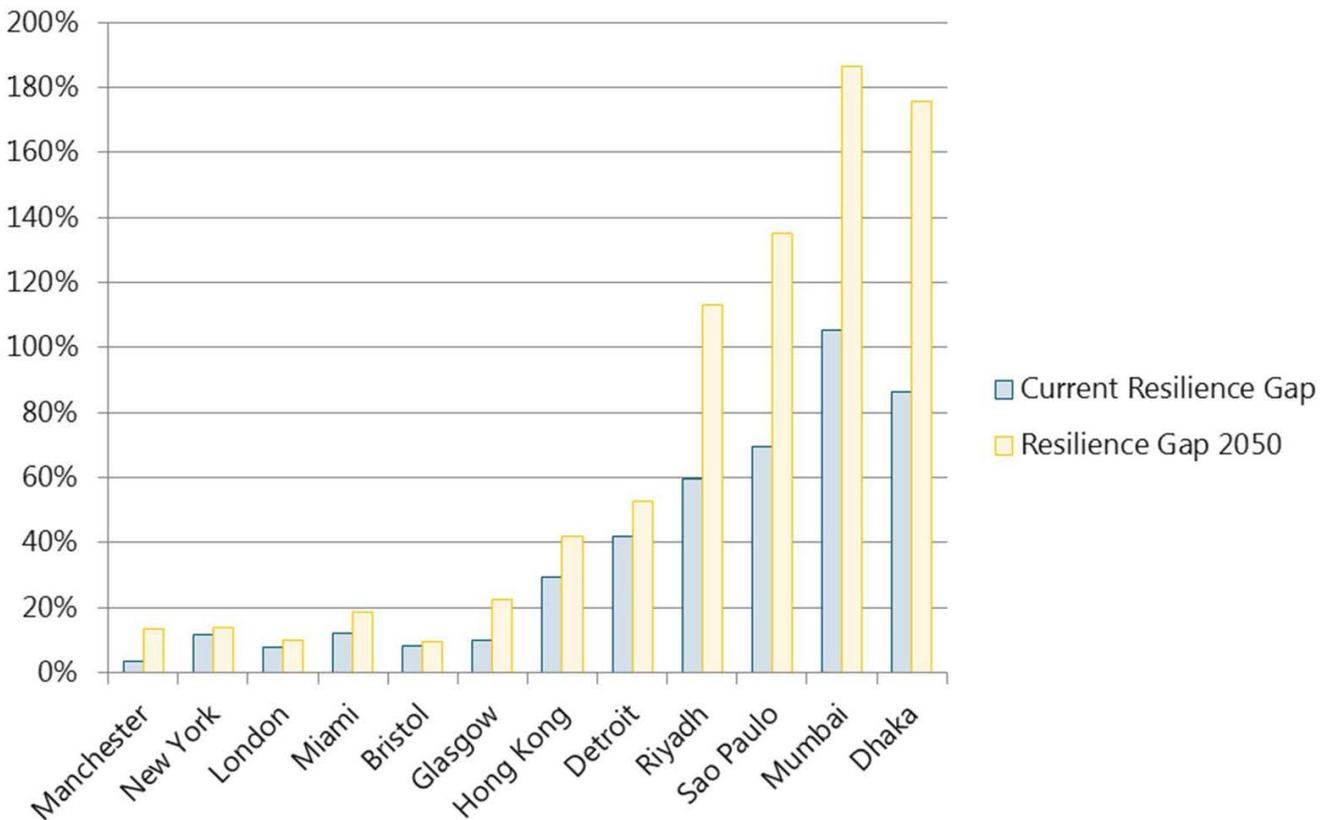


Figure 8.4: Current and future resilience gaps for 12 Cities.

## 9 THREE CITIES CASE STUDIES

### 9.1 INTRODUCTION

The following three cities were assessed at component level for a more in depth assessment of the individual components' capacities and demands. Each assessment was then discussed in a workshop with informed stakeholders from each city. The workshop's aim was to review the framework methodology and its outputs to assess validity and value. After each city's assessment the framework's methodology was developed to incorporate learning.

NOTE: Due to the assessments for the three cities being more in depth i.e. at a component level, their scoring also changes and are no longer comparable with the high level review of the 12 cities.



Figure 9.1: Bristol, UK.



Figure 9.2: London, UK.



Figure 9.3: Sao Paulo, Brazil.

## 9.2 BRISTOL COMPONENT ASSESSMENT

### 9.2.1 INTRODUCTION

Bristol is a unitary authority covering 110 km<sup>2</sup> which is located in the southwest of England. The city itself is developed along the River Avon and up to the coastline on the Severn Estuary which in turn flows into the Bristol Channel. It is England's sixth most populous city, with a population of 437,500 in 2014 and a projected increase to 528,200 by 2037. Bristol is one of the fastest growing cities in the UK.

### 9.2.2 RESILIENCE DEMAND AND CAPACITY

Due in part to its own success and underlying global trends, Bristol is undergoing an increasing amount of chronic stresses testing the city's capacity to cope and adapt in changing times. Bristol City Council has taken the initiative in a move towards future proofing the city and its citizens. 2014 saw the appointment of Bristol's Strategic (Chief) Resilience Officer as part of a wider strategy set out and funded by Rockefeller Foundation's 100 Resilient Cities initiative. In 2015 Bristol became the UK's first ever European Green Capital, setting the standard for other cities and councils within Europe.

Bristol has the worst car congestion of any core UK city and the worst congestion of any English city (DOT, 2015). Between 2001 and 2011 the number of cars in the city increased by 25,200 cars. As car ownership increases, peak time vehicle speeds are set to decrease to 15.7mph. By 2016 traffic congestion could cost the local economy £600 million a year. Even with an increase in cars, a disparity remains between households as 29% do not own or have access to a car. However, Bristol citizens do employ sustainable alternatives such as commuting by foot and by bicycle. Bristol has the highest rate of commuting by foot or bicycle of any Local Authority in England or Wales. This is illustrated in Figure 9.4 with a high demand in "Mobility and Communication" as well as a high "Environmental" demand due to poor air quality.

Supermarkets account for 75% of all food brought in Bristol, causing an overreliance on global supply chains that are out of Bristol City Council's jurisdiction and therefore control. Additionally, a lack of infrastructure for local distribution to the estimated 70% of retailers that are independent makes it difficult to reduce the risk of a highly centralised supply system. This is captured under "Resources" in Figure 9.4 with a high demand and gap in this area.

Bristol is a rapidly growing and relatively affluent city but continues to have deprivation 'hot spots' which are amongst some of the most deprived areas in the country yet are adjacent to some of the most wealthy. This is illustrated in the large demands under "Sense of Place" and "Community & Inclusion" and the corresponding large gaps between demand and capacity in these areas as shown in Figure 9.4.



Figure 9.4: Bristol's Resilience Wheel.

Bristol's total resilience rating is reasonably high with 82% of demands met through either mitigations (38%) or adaptive capacity measures (44%), as illustrated in Figure 9.5.

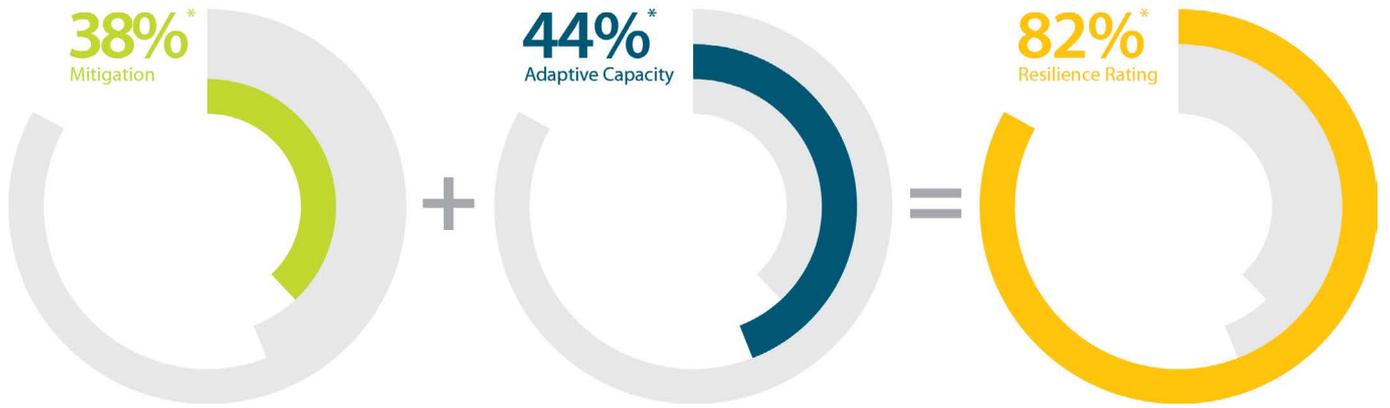


Figure 9.5: Mitigation, Adaptive Capacity and Resilience Rating Scores.

As shown in Figure 9.6, the top three resilience ratings are not particularly surprising. Security and Safety is a top priority in cities with large investment and excellent adaptive capabilities. Likewise, healthcare is a high priority with universal access to citizens.

Systems and Technology scores high for Bristol because of its burgeoning high-tech business sector and innovative culture. It supports and encourages new and local business.

Figure 9.7 shows that Bristol has a low Environment rating. This is due to the city's exposure to flooding, as well as poor air quality due to congestion. Its low Community & Inclusion rating is due to its high health and wealth inequalities associated with deprivation 'hot spots' which are amongst some of the most deprived areas in the country yet are adjacent to some of the most affluent.

These disparities in wealth and health outcomes can be a cause for social unrest as well as having an impact on health outcomes and the overall resilience of the city. The city also has limited community resilience and that which there is, is largely associated with high risk flood areas such as Brislington.

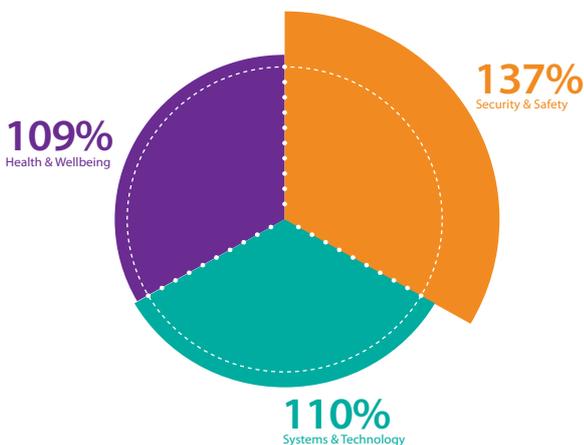


Figure 9.6: Top 3 Resilience ratings.

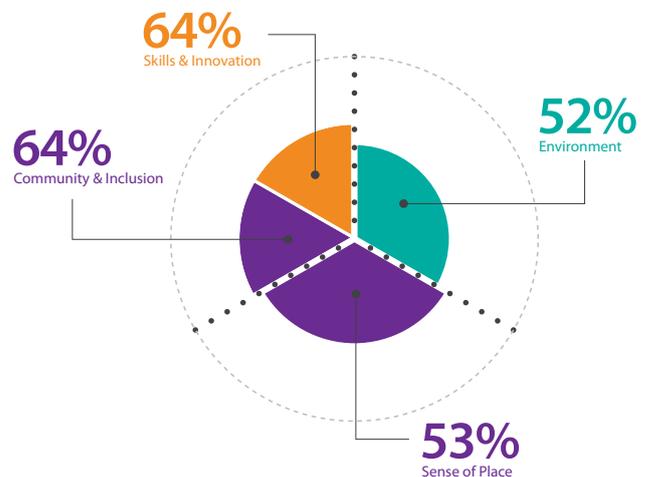


Figure 9.7: Bottom 3 resilience ratings

### 9.2.3 ANNUALISED FINANCIAL IMPACTS

Figure 9.8 indicates the annualised financial impact of key shocks and stresses on the city. This can then be compared to the cost of mitigation strategies to build the business case for capacity building in Bristol and therefore attracting the necessary investment. As can be seen the cost of epidemics is substantial due to loss of productivity and the cost of medical treatment.

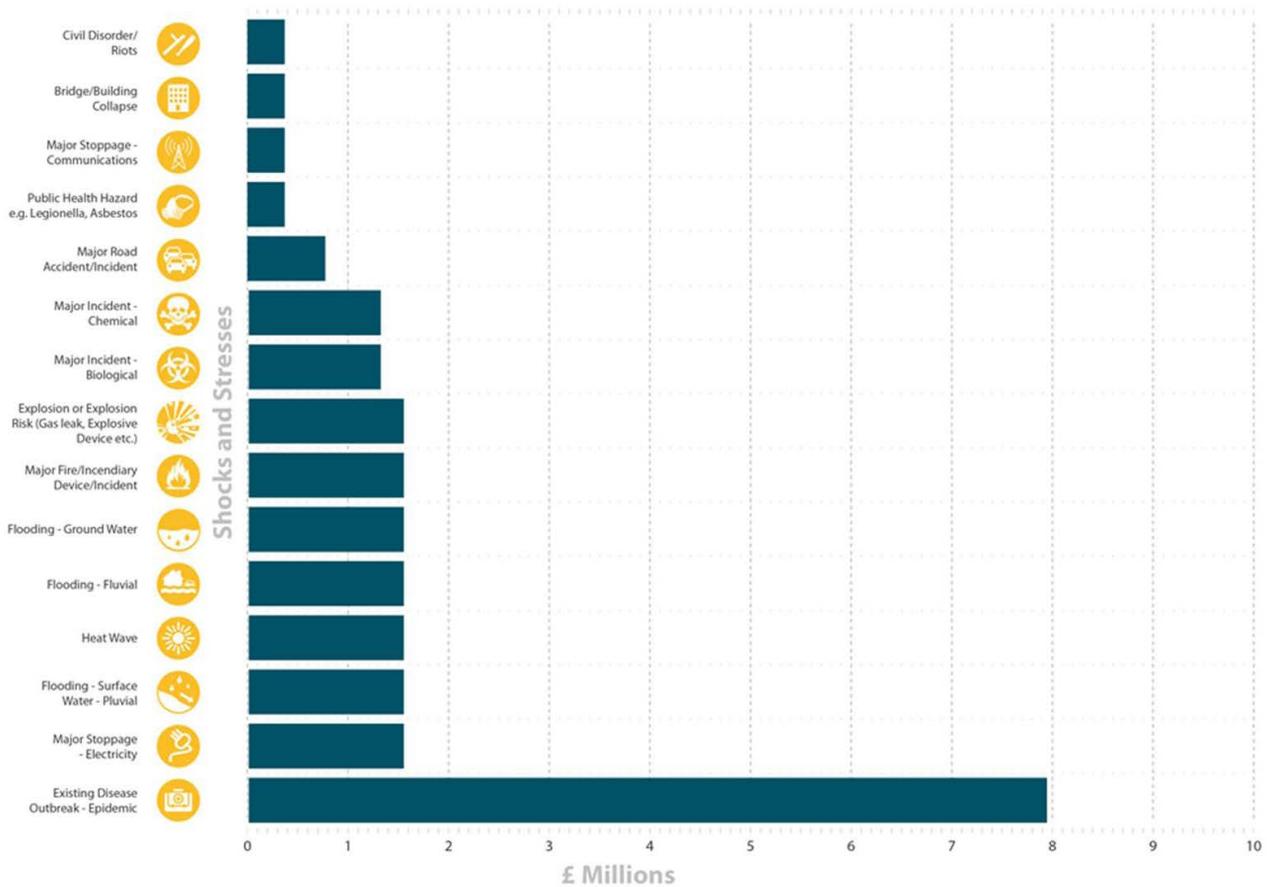


Figure 9.8: Top estimated financial impacts.

### 9.2.4 CURRENT AND FUTURE RESILIENCE GAPS

The current and future predicted resilience gaps for Bristol are shown by component in Figure 9.9. Environment, Health & Wellbeing and Sense of Place are all expected to have substantial future demands due to stresses such as population growth, inequality, congestion and air quality. The data illustrated in Figure 9.9 does not reflect the anticipated cut to local government and policing announced following the completion of this assessment. This could impact on Security & Safety and Leadership & Government in particular and result in the future gap being greater than shown below if the assessment was to reflect subsequent policy decisions.

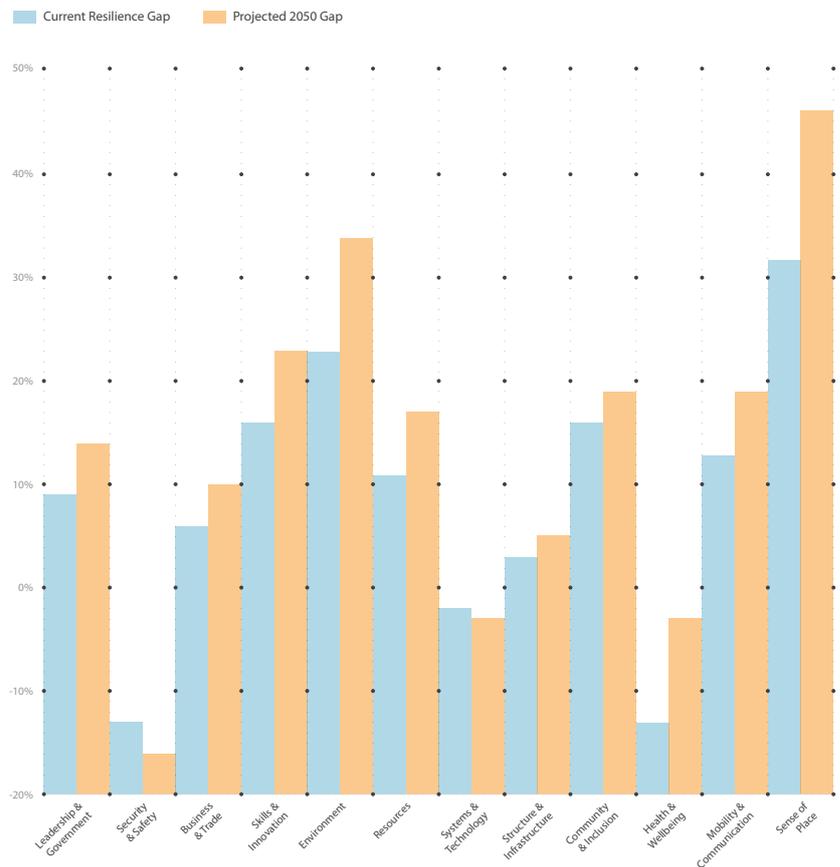


Figure 9.9: Bristol's current and 2030 resilience gap.

### 9.2.5 WORKSHOP FEEDBACK

#### Framework refinement suggestions and general comments

The workshop group agreed that three sectors were easier to comprehend than four. The addition of Sense of Place as a theme was also seen as an important component as it meant the framework encapsulated the human element of cities.

It was suggested that not all shocks and stresses necessarily had negative effects on Bristol's resilience and there would need to be some way for the framework to recognise this. Additionally, the participants recognised that while the risk based approach was pertinent, it may be useful to include a confidence rating per shock or stress so that a user of the framework would recognise how accurate their assessment was. In a similar vein, it was suggested that in order for the framework to be a successful method of prioritising hazards there should be a distinction made between the acceptable outcome from each of the shocks and stresses, since this may be different for each. When discussing the successfulness of the three themes and 12 categories of creating a holistic view of the city, participants largely agreed they were suitable categories. They did, however, query the use of the term 'Health & Wellbeing', suggesting 'Health Services' may be more accurate as health & wellbeing was incorporated into Community & Inclusion and arguably Sense of Place. Furthermore, a suggestion was made to separate Skills & Innovation into two separate themes as the two were very different. For example, Bristol City has arguably a good level of innovative practices but has a considerable skills gap. A higher score in only one area i.e. Skills or Education could therefore skew the overall score for that sector.

On the subject of the merging of scores hiding low (or high) scoring areas, the workshop suggested it was of high importance for separate communities, neighbourhoods or districts to be assessed independently. The rationale behind this was that, using income inequality as an example, a city level assessment of income inequality could give an acceptable score. This would not reflect that Bristol has an acute problem with income inequality between adjacent wards. A high level assessment would not identify these specific areas but assessing each neighbourhood would. This would then allow actions to be targeted at the correct neighbourhoods to improve those that are least resilient. This would be our preferred approach for city assessment.

### 9.2.6 FRAMEWORK DEVELOPMENT

- The framework was developed to incorporate a more detailed assessment of exposure that would differentiate between shocks and stresses that had a negative or positive impact on exposure.
- Health inequality has been added into model to affect exposure and vulnerability.
- "Skills & Innovation" has changed to "Skills & Education"

## 9.3 LONDON COMPONENT ASSESSMENT

### 9.3.1 INTRODUCTION

London is the largest city in Europe and the UK's capital city. Inner London is by far the most economically productive region of the country. More than one third of new jobs created in Britain since the recession have been based in the capital. It makes a significant contribution to the wealth and prosperity of the country.

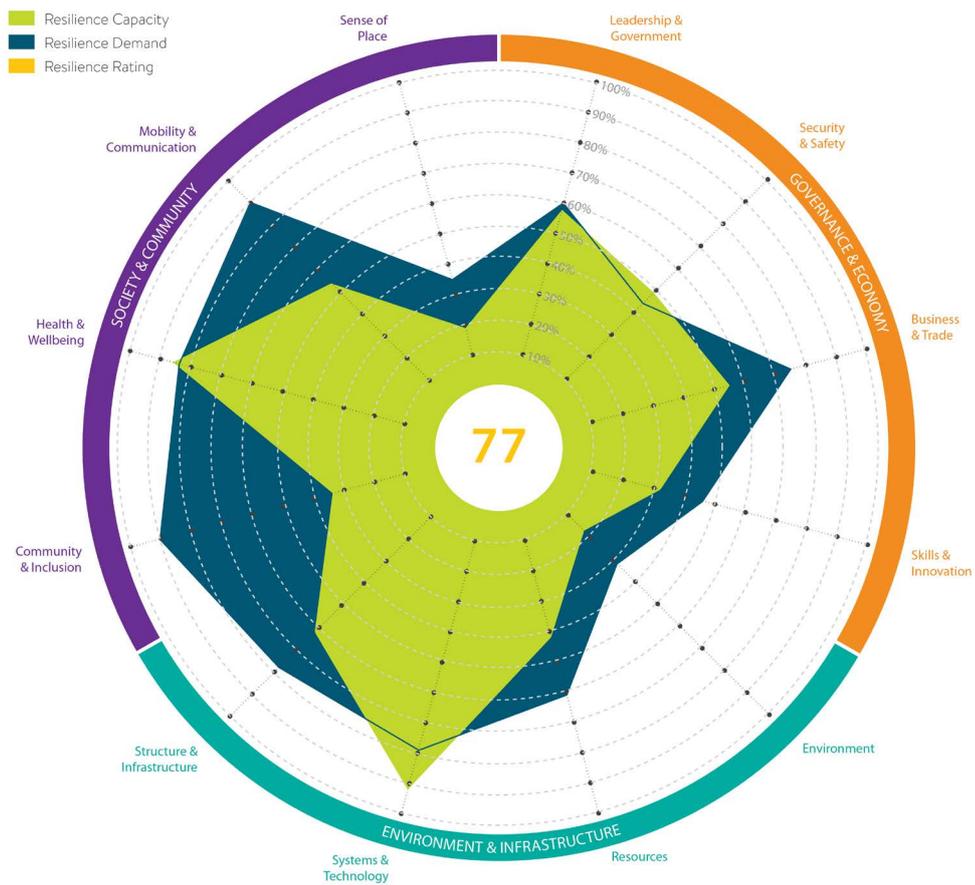


Figure 9.10: London's resilience wheel.

### 9.3.2 RESILIENCE DEMAND AND CAPACITIES

London's current population is 8.6 million, but an estimated 11.3 million people will call London home by 2050. In the past decade the number of homes in London has grown by just 8%. High house prices are pushing people in lower paid work out of London causing a potential structure employment problem in the future, with the city needing workers to complete low paid work but with no one on low pay able to afford to live in or travel to London. From 2005 to 2014 the number of people commuting into London rose by 32%. There will be a 80% increase in demand on London's rail network by 2050, while airports are already reaching capacity. Transport capacity will need to grow by 70% to cope with increasing population. London's red buses are now dealing with 6.25m passenger journeys every day, the highest demand since the late 1950s according to Transport for London. This is illustrated in Figure 9.10 with the large demand in the "Mobility & Communication" component, along with the large shortfall in capacity in this area.

Climate change is perhaps London's most serious stress factor. It not only creates direct challenges to the city, such as overheating, water stress and flooding, but also indirect challenges which increase the severity and/or likelihood of other shocks and stresses. The impact of flooding on London, for example, is likely to be further exacerbated by poor housing quality and aging infrastructure. The housing issue is a large factor in the large demand and shortfall in the "Community & Inclusion" category, shown in Figure 9.10. Climate change is also likely to exacerbate migration and compound the rate of population growth.

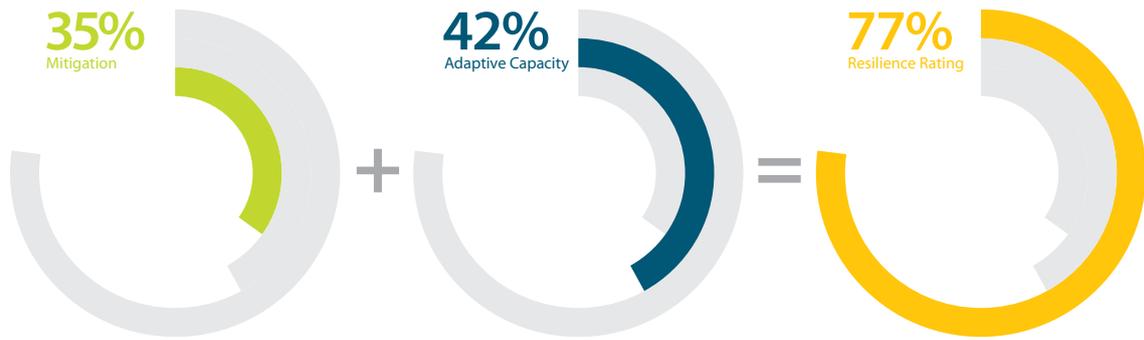
Around 40,000 properties in London are likely to flood in part due to their density and placement on floodplains. London is also vulnerable to surface water flooding. After intense storms, the impervious urban surfaces prevent water from being absorbed into the ground and the drainage system can be overwhelmed by the additional volume. The area of garden vegetation in London has declined from 25,000 ha to 22,000 ha since 1998-99, as lawns and flowerbeds are replaced with hard surfaces, such as patio and parking areas.

London is particularly vulnerable to high temperatures – most existing homes, workplaces, public buildings, public realm and transport infrastructure were not designed for high temperatures. Hot weather places additional stress on the body, raising health risks for the vulnerable. It is estimated that the 2003 heatwave caused 3000 extra deaths in the UK and 30,000 across Europe. Climate change is likely to increase the frequency and intensity of such events.

London's total resilience rating is reasonable with 77% of demands met through either mitigations (35%) or adaptive capacity measures (42%), as illustrated in Figure 9.11.

As the UK's capital city London is relatively well prepared in order to protect such a crucial city to the country's prosperity. It has in the past experienced security threats and expects more in the future which is why its security services have been well drilled to expect the worst. Additionally, as a hub for innovation and a relatively technologically advanced city, it realises and prepares for technological hazards. The factors contribute to strong resilience ratings in the areas Systems & Technology, Security & Safety and Health & Wellbeing as shown in Figure 9.12.

Figure 9.13 identified the lowest performing component of the city. Sense of Place and the Environment include all those areas of the city where people can come together or are under community ownership. It is for this reason that these areas are often at the margins and have greater exposure, for example, they are often seen as sacrificial areas for flood. Community & Inclusion also has lower resilience ratings. This illustrates the strong need for community resilience programmes to build capacity.



\* Figures rounded

Figure 9.11: Mitigation, adaptive capacity and resilience rating scores.

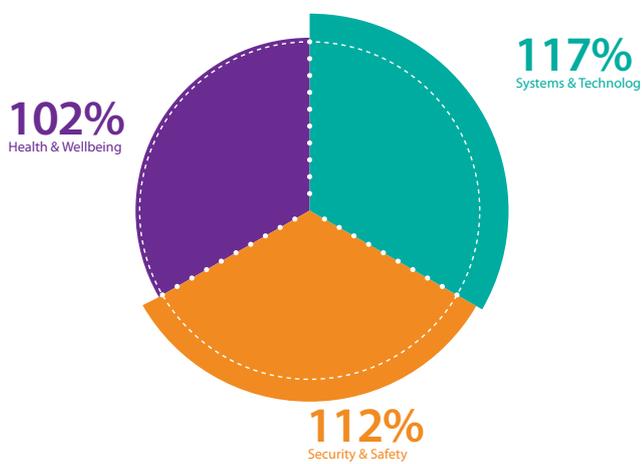


Figure 9.12: Top 3 resilience ratings.

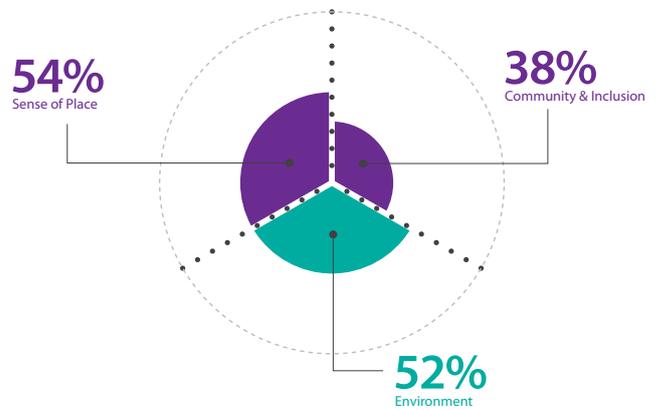


Figure 9.13: Bottom 3 resilience ratings

### 9.3.3 ANNUALISED FINANCIAL COSTS

Figure 9.14 indicates the cost of unmitigated inaction; the annualised financial impact of key shocks and stresses on the city. This can then be compared to the cost of mitigation strategies to build the business case for capacity building in London and therefore attracting the necessary investment. As can be seen, the cost of epidemics is substantial due to loss of productivity and the cost of medical treatment.

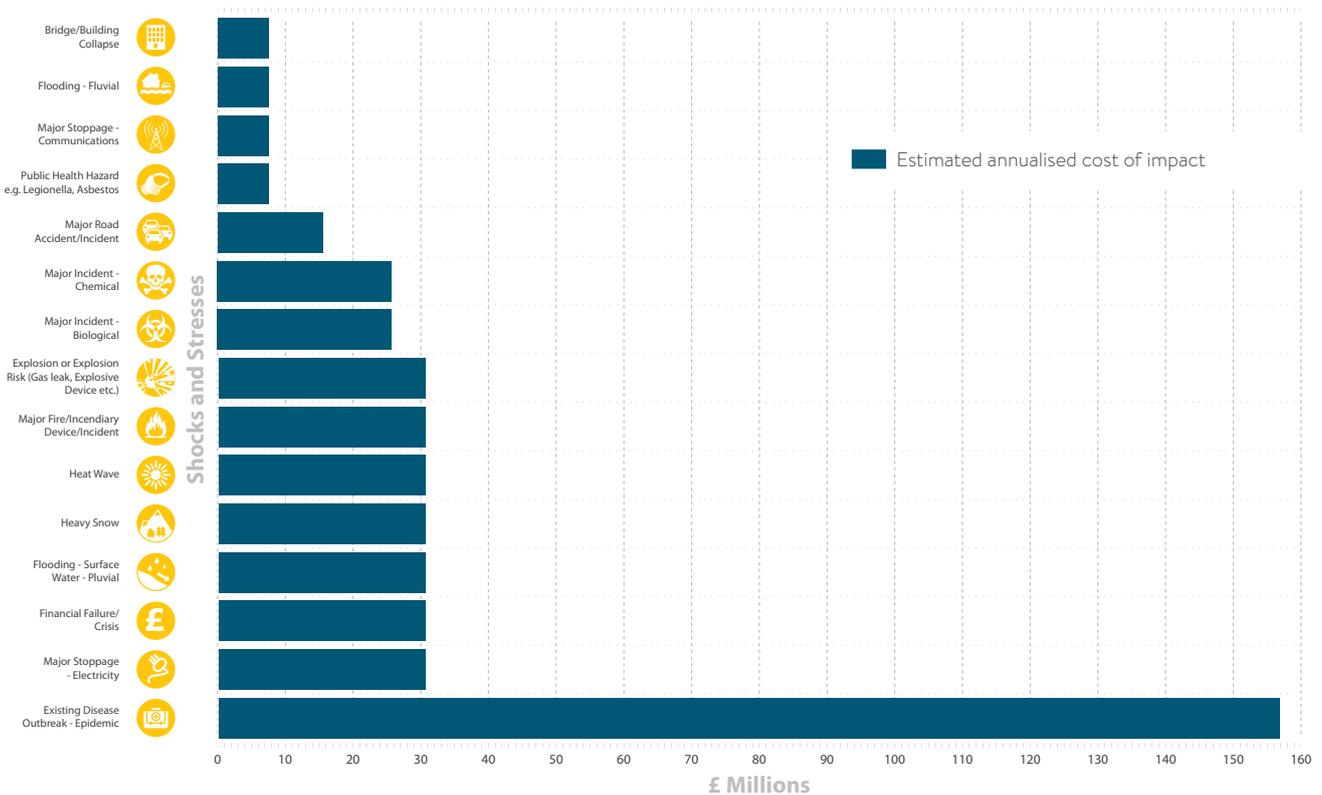


Figure 9.14: Top estimated financial impacts.

### 9.3.4 CURRENT AND FUTURE RESILIENCE GAPS

The current and future predicted resilience gaps for London are shown by component in Figure 9.15. Community & Inclusion is expected to have substantial future demands due to stresses such as population growth, inequality and the growing lack of affordable housing. This supports the case for greater effort in developing community resilience.

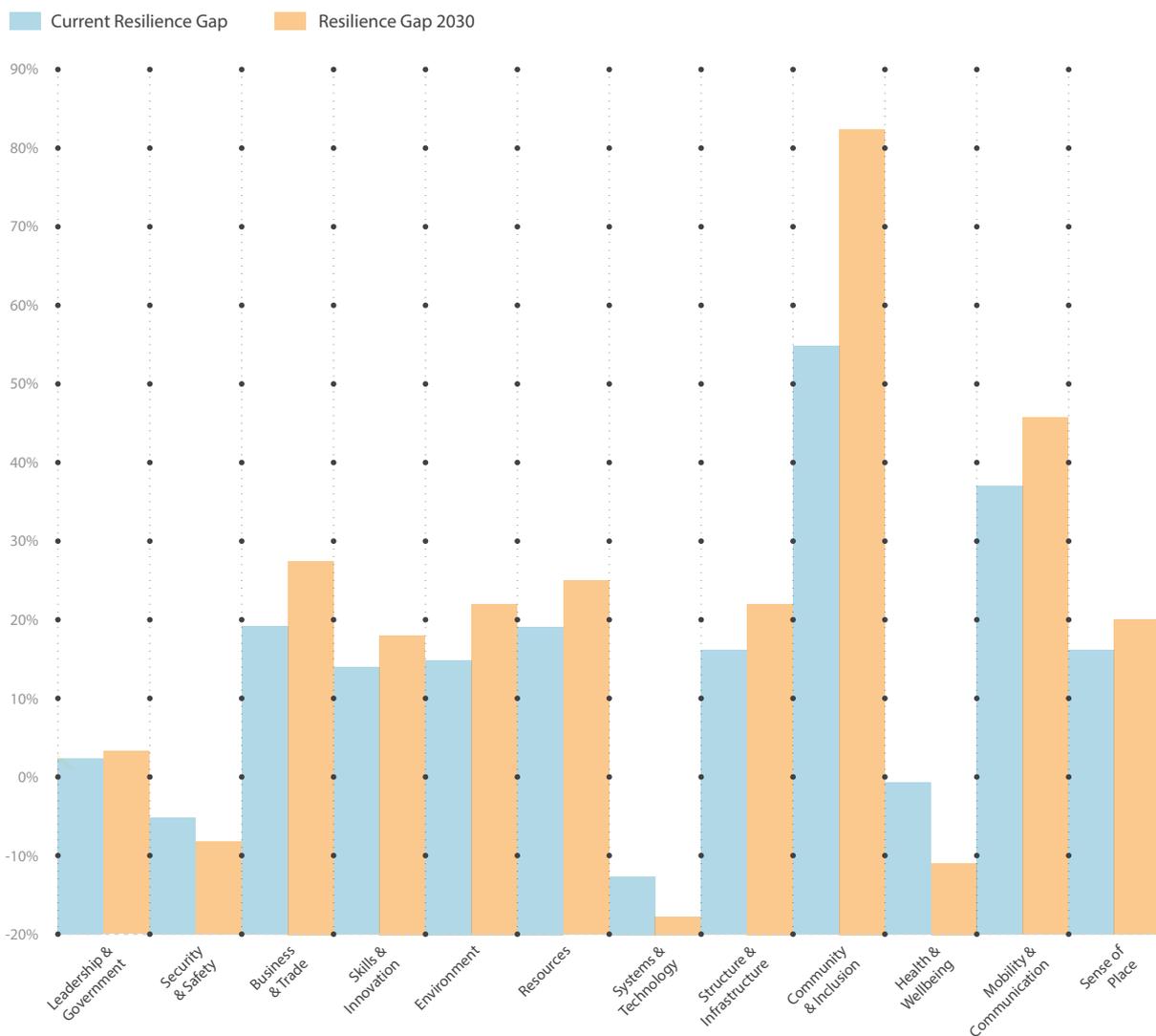


Figure 9.15: London's current and 2030 resilience gap.

### 9.3.5 LONDON WORKSHOP FEEDBACK

#### **Framework refinement suggestions and general comments**

Participants included several members of London's Climate Change Partnership (LCCP).

The workshop began with a discussion on how the framework chose to define some of its terminology. No significant issues were raised, however, simply that clear definitions were important aids. For example, participants were keen to highlight that the framework's definition for 'mitigation' may be eclipsed or assumed to be the same as 'climate mitigation'; a currently more widely used term. Again, participants agreed that the three themes and 12 components were an accurate breakdown of a city with some suggestions on how to refine the naming or indicators of certain components. For example, the participants were keen that the Business & Trade sector should measure economic diversity and how interconnected prime economies in London were connected to other economies.

Interconnectedness and interdependencies of systems and sectors seemed to be a key area of discussion and interest for the participants. They noted the tool was allowing users greater exploration of interdependencies as well as making users aware of risks outside their typical departmental scope. The latter point was suggested as of particular importance considering government department's tendency to act in a 'silo' fashion.

A number of participants queried if certain initiatives enacted to combat risk e.g. flood defences and their effectiveness would be clearly presented using the tool. An important and proactive initiative, they reasoned, should be clearly shown in relation to the overall resilience of the city so that it would be obvious how the initiative contributed to the resilience of different sectors. The workshop facilitators explained that it was possible to assess the city with and without the intervention in order to quantify its impact on citywide resilience.

Finally, the discussion ended on the topic of the framework's applicability in other cities and the importance of context. It was questioned as to how the framework included national resilience strategies to which it was explained this was considered in the exposure measure (a factor of the resilience demand rating). Furthermore, it was agreed by participants and facilitators that certain indicators would have to change depending on the city being assessed. For example, to properly assess Health & Wellbeing, the range of indicators would have to change as countries and cities' health issues change dramatically (e.g. between developed and developing countries where psychological health issues are of greater concern in the former). The facilitators explained that the indicators would be chosen based on the shocks and stresses that users prioritised in the initial stages of the assessment.

Overall participants saw it as useful to validate data, for mayoral strategies and producing scoping documents for the future mayoral candidates. They also saw the value in allowing users to think outside of their typical perception of risks and the ability for greater exploration of interdependencies inherent in a city.

## 9.4 SAO PAULO

### 9.4.1 INTRODUCTION

Sao Paulo is a state, metropolis and global city located in the southeast of Brazil. It is the 7th most populous city in the world and the 21st largest urban agglomeration at 2,849 km<sup>2</sup>. Sao Paulo's population is 19 million inhabitants if including the 38 cities which make up its metropolitan area. Its city proper population alone is 11 million.

### 9.4.2 RESILIENCE DEMAND AND CAPACITIES

Internal rural to urban migration is mainly from the poor Brazil's northeast region. These migrants are arriving in a city already struggling to cope. 20% of inhabitants live in shanty towns (favelas) and as such suffer from inadequate and aging housing, infrastructure, services; and the city receives a further 2,000 migrants per week. This is evidenced by the high demands and shortfalls in all aspects of the "Society & Community" components shown in Figure 9.16.

Climate change is having a significant effect on the demands and coping capacity of the city. Since the 1950s the average temperature in the city has risen by 1.5°C. During the summer months it is common to have thunderstorms at least four days per week. Sao Paulo has seven lightning strikes per square kilometre per year.

The city is also undergoing severe water shortages. For example, the five reservoirs in the Cantareira system provide almost half the Sao Paulo's drinking water but are only at 13% capacity. Considering the strain that the 2016 Olympics will have on this limited resource the city is working to find solutions. It has been estimated that the drought could shave 2% off of Brazil's GDP. The unresolved situation is being further exacerbated by inhabitants and businesses growing fear of a lack of water. Unregulated drilling to access groundwater threatens to pollute and deplete difficult to replace underground supplies which in turn is swiftly becoming

a public health risk. The stress of water scarcity is also exposing the problems in the system which would otherwise be tolerated. The city's aging water distribution network is contributing to more than 30% of São Paulo's drinking water being lost (the rest of the 30% is due to theft). This is shown in the high demands and shortfalls in the "Resources" and "Structure & Infrastructure" components in Figure 9.16.

**Transport & infrastructure**

São Paulo also suffers from severe traffic congestion with the average traffic jams on Friday evenings being from 180km to 295km long. Despite the traffic congestion, São Paulo is experiencing increasing numbers of vehicles. Pollution of air, land and water are resulting issues. The wealthy within the city have opted to use helicopters to avoid the jams giving Sao Paulo the largest helicopter fleet in the world.

**Societal issues**

The protests in Brazil that have caused Dilma Rousseff’s (Preident), approval rate to drop hugely. These started as a local protest against public transport fare increases in Sao Paulo. The city has continued to be at the epicentre of many of Brazil’s protests.

**Energy scarcity**

Sao Paulo relies heavily on hydropower. At least six other cities have been hit by blackouts due to weak hydroelectricity generation and high demand for air conditioning as temperatures soar. In response to the demand, utilities are burning more fossil fuels, adding to the cost of energy (and pollution). The Brazilian government has previously had to import power from Argentina to try to cover the shortfall.

**Income inequality**

In 2001, São Paulo’s richest 10% earned around 15 times more than the poorest 40%; The unemployment rate is 10.9%. The poor citizens of the city are situated on the outskirts and hence face long commutes. Consequently, air pollution from idling buses and cars takes a toll on environmental and human health.

**Technology**

São Paulo nurtures one of Brazil’s top tech hubs. Leading the country in GDP, it is the nation’s financial capital and the base of many Latin American corporations.

Sao Paulo’s resilience wheel shows consistence issues across all components. This typically illustrates a problem with the city’s governance.

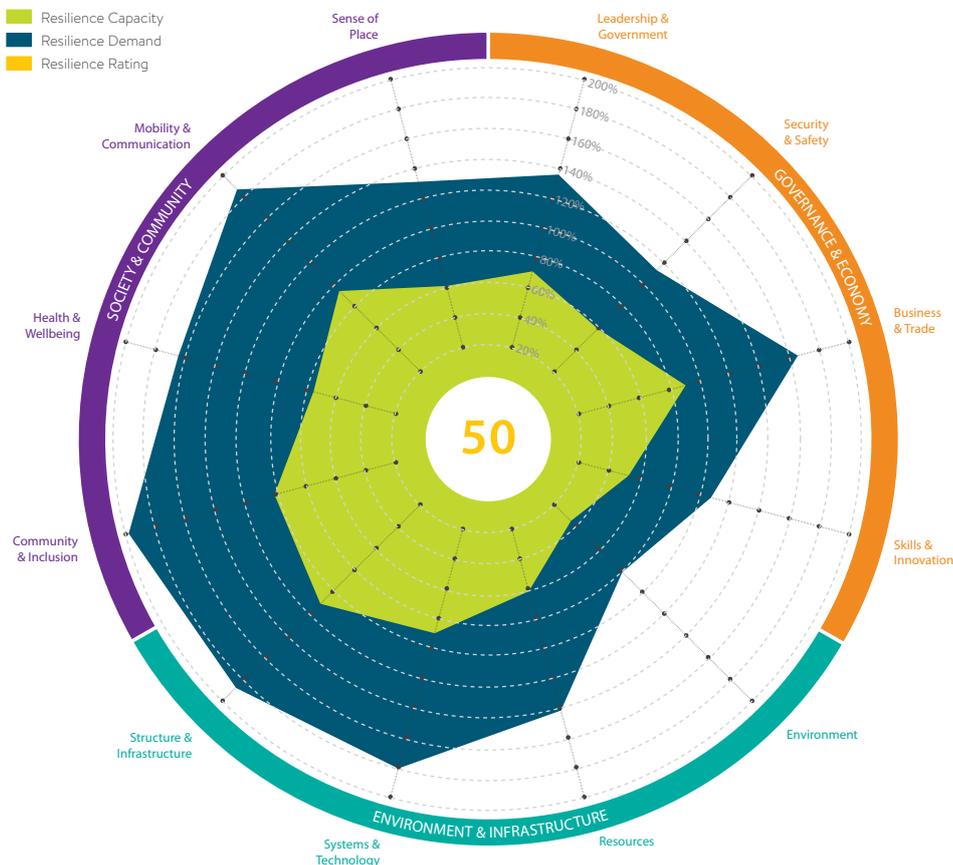


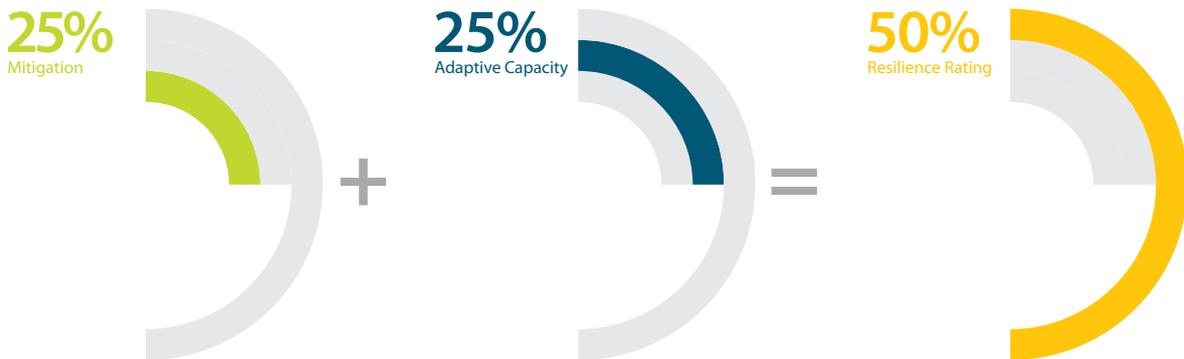
Figure 9.16: Sao Paulo’s resilience wheel.

Sao Paulo's total resilience rating is low with just 50% of demands met through an even split between mitigation and adaptive capacity measures, as illustrated in Figure 9.17 below.

Figure 9.18 shows the three most resilience components of the city. Since the results are rather even, it is difficult to pick out specific components as strengths or weaknesses. However, it is clear that Sao Paulo is prominent as a business hub and that entrepreneurship in the communities was strong.

Figure 9.19 shows the three least resilience components of the city. Given the consistent low score over most components and corresponding feedback from Sao Paulo stakeholders, it is clear that there are issues with the city's governance structure that are hampering efforts to improve the city's resilience.

Sao Paulo's problems are interconnected and due to several trends; climate change, the growing population and urbanisation severe strain is placed on the city's Environment, Resources and fundamentally the Health & Wellbeing of its citizens. The continued inability to cope in these areas will exacerbate problems in other components e.g. in the form of social unrest, consequently reducing Sao Paulo's overall resilience.



\* Figures rounded

Figure 9.17: Mitigation, adaptive capacity and resilience rating scores.

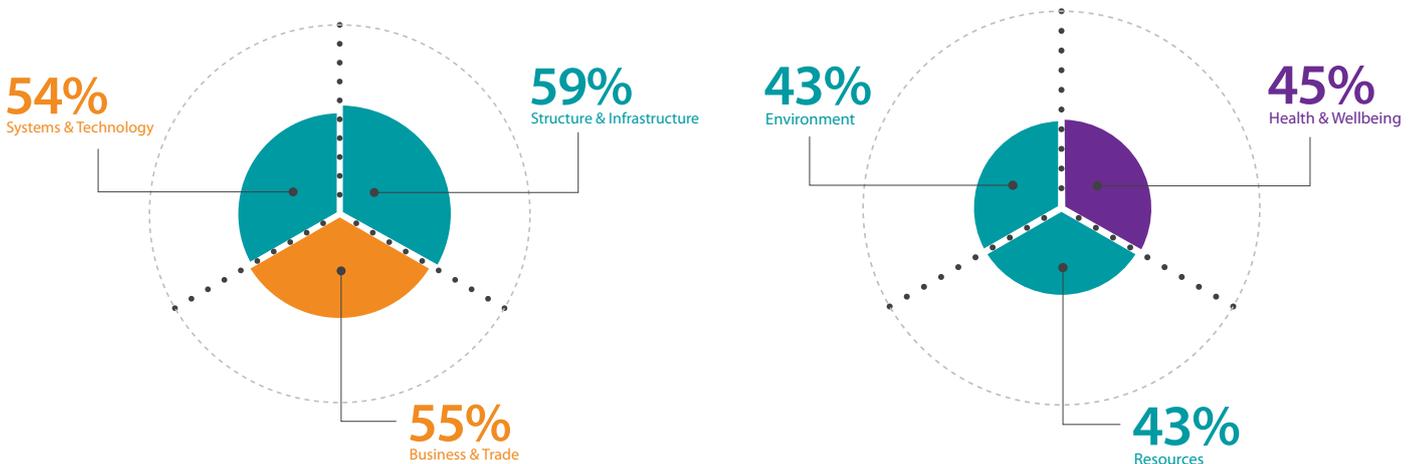


Figure 9.18: Top 3 resilience ratings.

Figure 9.19: Bottom 3 resilience ratings.

### 9.4.3 ANNUALISED FINANCIAL COSTS

Figure 9.20 indicates the annualised financial impact of key shocks and stresses on the city. This can then be compared to the cost of mitigation strategies to build the business case for capacity building in Sao Paulo and therefore attracting the necessary investment. Considering Sao Paulo’s status as a financial hub of Brazil, it is no surprise that a financial failure would be significantly costly. Other shocks features include major stoppages – highly likely in a city where services and infrastructure are stretched to capacity.

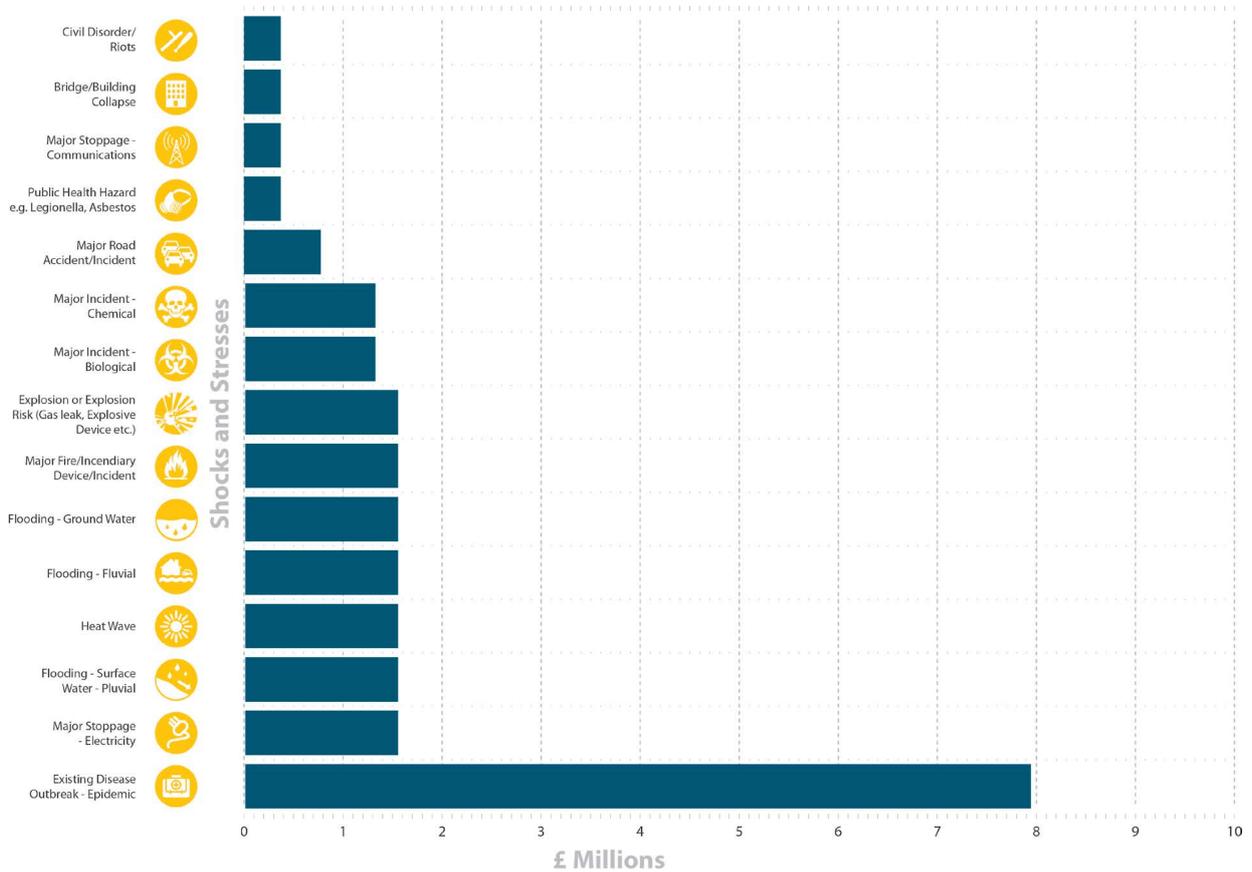


Figure 9.20: Top estimated financial impacts.

### 9.4.4 CURRENT AND FUTURE RESILIENCE GAPS

The current and future predicted resilience gaps for Sao Paulo are shown by component in Figure 9.21. Community & Inclusion is expected to have the highest increase in future demands due to stresses such as population growth, inequality and the lack of affordable housing. These stress factors will exacerbate the increasing threat of natural disasters such as flooding.

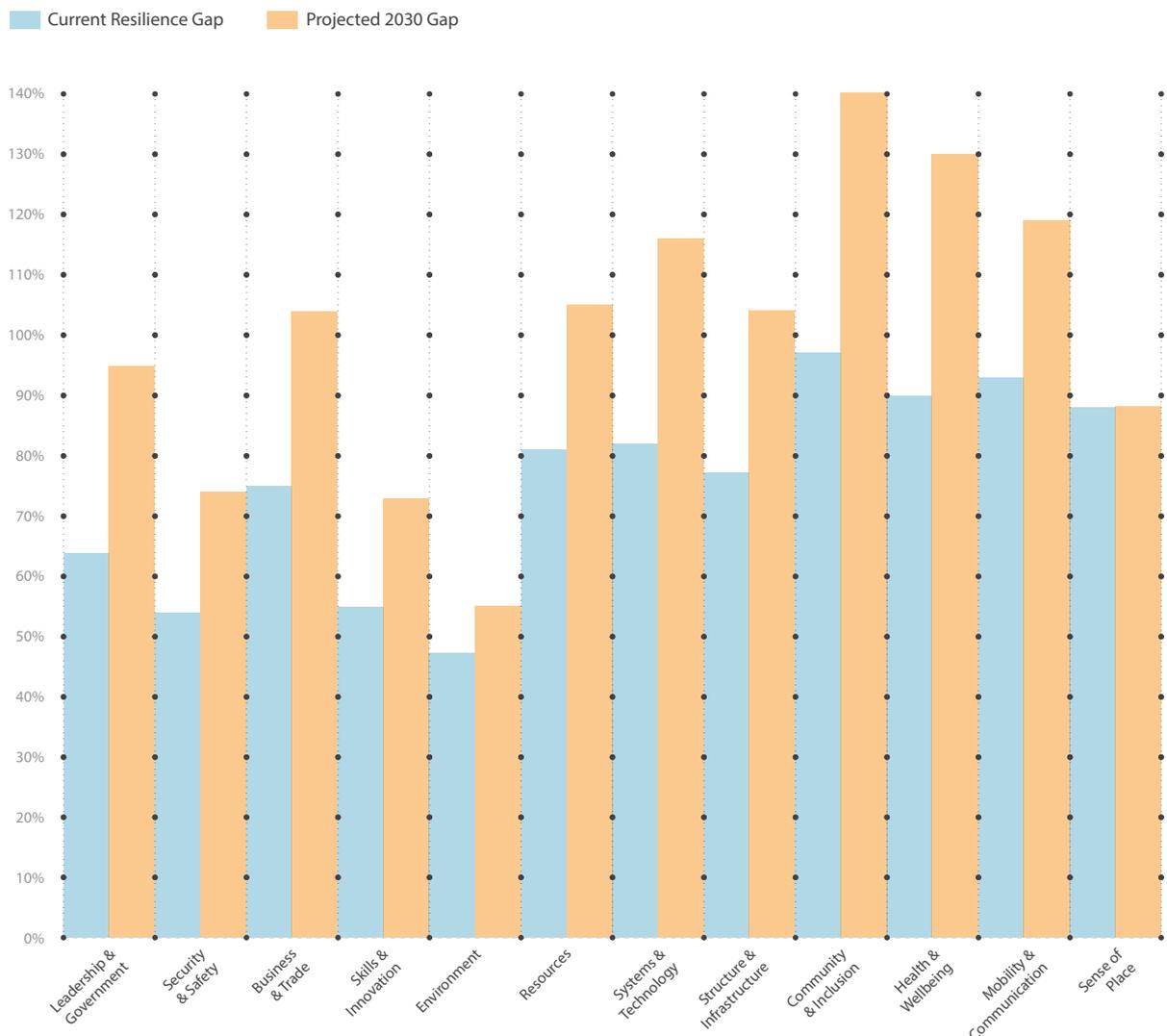


Figure 9.21: Sao Paulo's current and 2030 resilience gap.

#### 9.4.5 SAO PAULO WORKSHOP FEEDBACK

##### Framework refinement suggestions and general comments

Participants from various institutions and municipal departments in Sao Paulo as well as other cities in Brazil were invited to discuss the impact of several shocks and stresses. These shocks and stresses were prioritised by the participants themselves. The top two stresses (urbanisation and congestion) and top two shocks (financial crisis and flooding & droughts) were then discussed in two separate groups. The discussions centred on how each shock and stress impacted the city, what was the response and what was learnt.

##### Group 1 – financial crisis discussion

The financial crisis in the early 2000s effected federal and municipal government. The latter, it was noted, had to adapt to a worsening financial situation which severely limited many municipalities ability to provide basic services. In St. Bernardo, a metropolitan area in the south of Sao Paulo, vehicle industry, manufacturing, infrastructure and many municipal services relied on federal government funding. Many programmes were therefore interrupted leading to high unemployment. As banks had no guarantees that the construction companies could pay the whole sector faced collapse. It was mentioned during the workshop that spending on maintaining the environment was seen as an afterthought in tough economic times.

One of the factors that exacerbated problems was that public policies were decentralised but funds were not. Federal government provides funding while municipal governments enact policies and were seen to get the blame for poor decisions which arguably were partially the fault of federal level decisions. This increased public distrust of municipal governments ability to cope and provide effective recovery solutions. Additionally, government initiatives were too slow to be effective, often creating results a year after implementation. Cities such as Sao Paulo are now looking for alternative initiatives. With population growth, people are demanding better public services which municipal governments are struggling to provide.

Local people were seen to be frustrated at the lack of pace and progress from their municipal governments and were seen to take matters into their own hands, showing a high degree of personal & community resilience. They were even praised and acknowledged for their 'creativity'. A loss of jobs due to the financial crisis meant a growth in the informal sector. Sao Paulo municipal governments (and universities) were able to capitalise on this phenomenon by encouraging entrepreneurship and creating places for innovation such as technological parks. Many of the informal businesses, it was noted, eventually became formalised through such initiatives and became solutions on Sao Paulo's path to recovery. The workshop found no easy solutions or ways to completely prepare for further future financial crises and suggested reforms at state level were needed in order to make any effective preparations.

##### Group 2 – floods & droughts

The discussion opened up the interesting idea that flooding was treated very differently among Brazilian cities. The representative from Fortaleza, the capital city of the North East Brazilian state of Ceará, argued that the city did not recognise floods as rare events and instead were expected and to some extent tolerated by its citizens. Flooding, he suggested, was no longer considered a shock but instead a stress on the city. In contrast, Sao Paulo was considered to lack the infrastructure to collect rainfall and was coping poorly with what it saw as a sudden escalation in the number of floods (and droughts) in recent years.

Sao Paulo's struggle with managing floods and droughts is partly attributed to the majority of the responsibility of water management being at state rather than municipal level. In the last 20 years there has been competition between the governor and mayor due to this. Partly as a consequence investment in Sao Paulo's water management has not been sufficient. Where it cannot be proactive it has been reactive; its municipal government did produce an emergency plan (the wet season also helped combat the problem of droughts) which it disseminated to the populace through educational plans.

Again, the root problems were seen as political with a lack of coordination between state, municipality and public seen as a particularly pressing issue. When asked if participants saw a political solution or at least a manageable 'normalisation' of the situation, participants were doubtful. They did, however, mention that, like the citizens of Fortaleza, the population were beginning to change their habits to manage such as reducing their daily water intake.

### Group 3 – Urbanisation

Sao Paulo's population growth was seen to be steady while the expansion of the city is high (in the surrounding conurbation). Most of the people entering the city are from other parts of Brazil. Even though its metropolitan region is growing at a higher rate than its Central Business District, it is not as developed or well connected. The current transport system is overcapacity, unreliable and unsafe. These conditions are forcing more people to buy cars to commute. This is further exacerbated by the way cities are planned to encourage car use.

Unlike the issue of water management, local authorities have a huge say in what goes on as opposed to regional regulatory bodies. Coordination, however, between the city centre and the suburban areas is not as good as expected. This is suggested as partly being due to mayors having different interests and therefore everyone prioritises different issues. It was stressed that it is not that officials did not want to agree but due to the huge inequalities between city areas each faced different priorities at different times making consensus very difficult.

When asked about major issues connected with urbanisation, participants saw security and sewage as two main issues. Participants also highlighted the fact that Sao Paulo's huge inequality among its populace meant that the poorer citizens were far more affected by the disadvantages of urbanisation.

### Group 4 - Congestion

As a major issue for Sao Paulo's government, congestion is tackled through several initiatives including cycling lanes, priority lanes and greater investment in public transportation. There has been some resistance, however, from those that are used to commuting by car. Participants recognised this as not a simple issue as there are cultural, historical and economic issues involved not to mention strong lobbying from the car industry. Owning a car is seen as a status symbol; Brazilians are seen as idealising and aspiring to what they see as the American way of life. Often the first thing they buy when they save enough money is a car.

Overall participants were complementary and positive about the initiatives instigated by the government but were critical of the lack of integration. They pointed out that the strain on the central transport network would be slightly alleviated were the metro lines extended into the outer conurbation. San Bernardo will be the first city to have the metro extend into it from the centre.

### Feedback

In regards to Sao Paulo and its shocks and stresses, participants felt that the political issues needed to be addressed before anything else could be. For example, water management was found to be of top priority but a solution could not be found because of the politics involved.

The feedback on the framework was very positive. The participants identified it as a useful method for identifying different solutions to their problems. The following are some comments made by the delegates:

- The framework forces the user to consider different solutions
- The methodology was found to be clear and objective
- In order for this tool to be useful for a city, participants suggested Mayors and all Department Secretaries should be gathered and a workshop similar to this should be held
- The participants felt that an online version of the tool would be useful but that using the framework as part of workshops with key stakeholders was vital.

## 10 CONCLUSION

From interviews and experience we found there is a tendency for cities to approach resilience in a siloed way without prioritising initiatives systematically. Often the major focus is the last disaster, for example flooding, when in fact, the city may be less prepared for a more urgent risk such as an epidemic. All parts of a city are dependent on one another and any shock to a city, even if it only directly impact one aspect, will have ripple effects throughout. It is for this reason that resilience needs to be viewed holistically, breaking down silos and understanding interdependencies. Traditionally there has not been one entity that has an overview of all these areas and that is cited as the reason for this lack of joined up thinking. However, in the UK with more powers moving to city mayors (e.g. London, Bristol), this is changing. The Rockefeller 100 Resilient Cities Program has introduced the concept of Chief Resilience Officers (CROs) – a person responsible for delivering resilience strategies for the city - there is now an opportunity to think differently and truly understand and prioritise the many issues facing our cities and develop holistic solutions that benefit more than one issue or group.

One of the key benefits noted when implementing this approach with city leaders is that stakeholders are unified around a common vision. A comprehensive resilience strategy will touch all aspects of a city and is therefore a great way to integrate a city and break down these silos. We have found that successful resilience strategies address multiple vulnerabilities and deliver benefits across a wide range of areas. They also require interventions that cross departmental boundaries; strategy workshops being invaluable in successfully aligning interests. This provides better collaboration and understanding between departments which results in resilient solutions that maximise benefits across multiple agencies and groups.

Exploiting the capability of the Resilience Diagnostic to model future trends, we are able to test possible scenarios against the current baseline, to assess the comparative impact and benefits of different strategic options. Our baseline assessment also enables us to get insight into the cost and benefit of different options and compare them with the cost of inaction – of doing nothing. This informs the creation of business cases around possible programmes of activity.

### 10.1 FURTHER DEVELOPMENT

In order to refine the process, BuroHappold has subsequently developed an online resilience diagnostic tool that can be used by a variety of stakeholders to understand their city's resilience from their perspective. This is a powerful stakeholder engagement tool that can easily acquire the insights of key stakeholders within a couple of hours. It is available for free via our website.

<http://www.burohappold.com/think-again/specialism/risk-resilience/>

Future plans include adapting the process for businesses and buildings.

## APPENDIX A DEFINITION OF 12 COMPONENTS OF RESILIENCE FRAMEWORK

Title	Description
Community & Inclusion	Communities are the living heart of a city made up of all the citizens, businesses and regular visitors; people who consider the city to be theirs and themselves to be part of the city. Some communities are very strongly bound to their city and each other; with a united and inclusive sense of belonging and collective ownership.
Mobility & Communication	Movement and communication are essential parts of human society and commerce. Concepts such as Sustainable Urban Mobility and the "Human Scale" indicate a move away from traditional transport planning to people focused mobility strategies. This needs to be coupled with effectively integrated communication and technology to reduce demands on transport infrastructure even further.
Health & Wellbeing	Health is the level of functional or metabolic efficiency of a living organism. In humans, it is the general condition of a person's mind and body, usually meaning to be free from illness, injury or pain (as in "good health" or "healthy"). Health can also refer to the systematic activities to prevent or cure health problems and promote good health in humans. In addition to health care interventions and a person's surroundings, a number of other factors are known to influence the health status of individuals, including their background, lifestyle, and economic, social conditions, and spirituality; these are referred to as "determinants of health."
Sense of Place	Designing, building and coordinating the communities assets and public spaces to promote people's health, happiness and wellbeing as well as providing opportunities and inspiration for economic growth. Capitalising on the communities shared sense of place to create innovative and unique spaces.
Leadership & Governance	Governance is the system by which a state ,community or organisation is structured and governed. Government normally consists of legislators, administrators, and arbitrators. Government is the means by which state policy is enforced, as well as the mechanism for determining the policy of the state. Governance Within a city context all three are necessary to prevent anarchy and promote fairness. Governance is the process of decision-making and the process by which decisions are implemented (or not implemented). It refers to all processes of governing and regulations are used to control conduct in line with desired behaviour. Governance is implemented by the management apex of an organisation and as such, needs to be underpinned by robust leadership to ensure the right standards of behaviour are enforces as well as providing impetus to see difficult decisions and programmes through.
Security & Safety	Safe from the threat of criminal activity such as terrorism, theft or espionage. Security is the degree of resistance to, or protection from, harm. It applies to any vulnerable and valuable asset, such as a person, dwelling, community, nation, or organization. It is a form of protection where a separation is created between the assets and the threat. These separations are generically called "controls," and sometimes include changes to the asset or the threat.
Business & Trade	Commerce is the entire environment for business. The system includes legal, economic, political, social, cultural and technological systems that are in operation. Thus, commerce is a system that affects business and economic prospects. It can also be defined as a component of business which includes all activities, functions and institutions involved in transferring goods from producers to consumers.
Skills & Innovation	The aspects of human activity involved in the acquisition, maintenance and transfer of knowledge as well as the development of skills, new discoveries, the generation of new ideas and the development of engineered solutions.
Environment	The term environment is the universe that lies outside the boundaries of the system. It is also known as the surroundings, and in thermodynamics, as the reservoir. The environment encompasses all living and non-living things occurring naturally on Earth or some region thereof. It is an environment that encompasses the interaction of all living species. Climate, weather, and natural resources that affect human survival and economic activity.

Title	Description
Resources	A resource is a source or supply from which benefit is produced. Typically resources are materials, energy, services, staff, knowledge, or other assets that are transformed to produce benefit and in the process may be consumed or made unavailable. Benefits of resource utilization may include increased wealth, meeting needs or wants, proper functioning of a system, or enhanced well-being. In this context, resources are all the city system inputs from a macro perspective.
Systems & Technology	Technology is the product and determiner of engineering and science, bringing both benefit and risk to natural and built environments, influenced by and influencing the creativity of the world's cultures. A modern example is the rise of communication technology, which has lessened barriers to human interaction and, as a result, has helped spawn new subcultures; the rise of cyber culture has, at its basis, the development of the Internet and the computer. Not all technology enhances culture in a creative way; technology can also help facilitate political oppression and war via tools such as weapons, indeed, times of war are often when there is the greatest technological advancement.
Structure & Infrastructure	Infrastructure is the basic physical and organizational structure needed for the operation of a society or enterprise, or the services and facilities necessary for an economy to function. It can be generally defined as the set of interconnected structural elements that provide a framework supporting an entire structure of development.

## APPENDIX B EXPOSURE FACTORS

Layered on top of the baseline exposure assessment are a number of factors that can reduce or exacerbate exposure depending on an assessment of the city's effectiveness. These factors are as follows:

### Community & Inclusion

- Large population size
- High population density
- Low income inequality
- Very little poor condition housing stock
- No ghettoization
- Good social mobility
- Good community cohesion
- Good Community Coordination & Governance

### Mobility & Communication

- Little Congestion
- High sustainability
- Increasing Automation

### Health & Wellbeing

- Very little Health Inequality
- Good Nutrition
- Extended Life Expectancy
- Excellent Quality of Life
- Effective Health & Social Care infrastructure
- Effective Health Improvement Policies
- Effective Mental Health Care Provision
- Very little Substance Misuse
- Very little domestic violence

### Sense of Place

- Group Held Unique City Concept
- Good Sense of belonging (Civic pride)
- Strong Sense of ownership
- Strong Sense of history (Heritage)
- Strong Sense of future

### Security & Safety

- Effective Law Enforcement
- Independence from Political Interference
- Effective Security Services
- Effective Health & Safety Enforcement
- Very Low Priority Terrorism Target

### Leadership & Government

- Good Adherence to Human Rights
- Good Transparency & Anti-corruption
- Effective Leadership
- Good Public Representation
- Effective Checks and Balances
- Effective Financial Security
- Effective Regulation & Legislation
- Very Capable State

### Business & Trade

- Effective Governance
- Growing corporate influence
- Stringent Market Regulation
- Good Workforce relations
- Effective Security
- Appropriate levels of Investment
- High Productivity
- Strong customer base
- Effective Trading Standards

### Skills & Education

- Low Educational Inequalities
- Competitive in the global marketplace
- Strong Skills base
- Low Skills inequality

### Structure & Infrastructure

- Designed Infrastructure Over-capacity
- Effective Maintenance Regimes
- Appropriate levels of Investment
- Looped or cellular networks
- Effective Flood Defences

### Systems & Technology

- Rapid uptake of technological advances
- Effective Systems Integration
- Effective Cyber security
- High Automation
- Effective information infrastructure
- Resources
- Sustainable Resource Management
- Self sufficient
- Resource Security
- Robust Supply Chains
- Diverse Sources & Distribution Networks

### Environment

- Effective Environmental Protection
- Robust planning regulation

## GLOSSARY

Term	Definition
Resilience	The ability to anticipate and adapt to shocks & stresses; implementing lessons learned to leverage emerging opportunities, and effectively reduce vulnerabilities.
Risk	Risk is a product of a hazard's severity and its probability.
Shocks	Any event or circumstance (happening with or without warning) or combination of events that cause or threaten immediate death or injury, disruption to the community, or damage to property or to the environment on such a scale that the effects cannot be dealt with as part of normal, day-to-day activities of the affected community. Shocks are short term and end when the underlying cause stops.
Stresses	A trend that over time change the circumstances and environment under which cities and buildings operate. Incrementally, these factors will challenge the base assumptions upon which many business models are founded; and challenge the norms, values and standards underpinning communities.
Demand	Numerical measurement of the strain placed on city's systems and components due to various shocks and stresses. This is based on a risk calculations and is the product of 1) a city's exposure to a risk and 2) the severity and (3) the probability of occurrence. This value is rather arbitrary since the important measure is the percentage that is mitigated i.e. rating.
Vulnerability	Vulnerability is the susceptibility of a body (building, people, environments, assets, etc) to a hazard.
Mitigation	Mitigations can remove or reduce exposure, provide immunity, implement protective measures, increase robustness, provide redundancy and design in fail safes. This are implemented prior to a shock occurring.
	<b>Measures</b>
	<b>Protect</b> The action of protecting and often preserving the status quo.
	<b>Robust</b> A system's ability to resist an impact without changing its initial stable form.
	<b>Redundant</b> The addition of components which are not necessary to functioning but are included in case of failure in other components.
Adaptive Capacity	<b>Fail-Safe</b> In the event of a failure, the component fails in a way that prevents or mitigates the impact on the wider system.
	Adaptive capacity is the capacity of people, organisations, cities, regions, nations and trans-national organisations to adapt to the changing environment. Adaptive capacity can be characterised by the ability to observe the environment, detect changes, research and understand those changes, formulate options on how to deal with those changes, decide on a course of action and its implementation. Furthermore, these actions must also be understood for their impact and effectiveness. To ensure the situation develops and progress is achieved in the future, lessons must be learnt in order that behaviours do not revert back to the original set of circumstances.
	<b>Measures</b>
	<b>Prepare</b> Proactive measures that reduce the risk of a hazard.
	<b>Respond</b> The ability to respond in a timely manner.
<b>Recover</b> Measures to ensure a recovery period is planned for.	
<b>Learn &amp; Improve</b> Measures to make sure the city reviews, learns and adapts its measures in order to improve their resilience in time for the next event.	
Resilience Rating	The percentage of the resilience demand that is met through mitigation and adaptive capacity measures. Rating = resilience capacity / resilience demand.

**RELILIENCE INSIGHT**  
12 CITIES ASSESMENT

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