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LIQUEFACT

Assessment and mitigation of liquefaction potential across Europe: a holistic approach to protect structures/infrastructure for improved resilience to earthquake-induced liquefaction disasters.

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DELIVERABLE 5.1

Report on Individual Stakeholder and Urban Community Performance Metrics

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GLOSSARY

Acronym	Description
EILD	Earthquake Induced Liquefaction Disaster
RAIF	Resilience Assessment and Improvement Framework
DRR	Disaster Risk Reduction
FCM	Fuzzy Cognitive Map
SH	Stakeholder
CI	Critical Infrastructure
UNISDR	United Nations Strategy for Disaster Risk Reduction
AHP	Analytic Hierarchy Process
ANP	Analytic Network Process

CONTENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 700748

LIST OF FIGURES

LIST OF TABLES

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 700748

EXECUTIVE SUMMARY

Recent events have demonstrated that Earthquake Induced Liquefaction Disasters (EILDs) are responsible for significant structural damage and casualties with, in some cases, EILDs accounting for half of the economic loss caused by earthquakes. With the causes of Liquefaction being substantially acknowledged, it is important to recognise the factors that contribute to its occurrence; to estimate the impacts of EILD hazards; and to identify and implement the most appropriate mitigation strategies that improve both building/infrastructure and community resilience to an EILD event. The LIQUEFACT project adopts a holistic approach to address the mitigation of risks to EILD events. The LIQUEFACT project sets out to achieve a more comprehensive understanding of EILDs, the applications of the mitigation techniques, and the development of more appropriate mitigation techniques tailored to each specific scenario, for both European and worldwide situations.

INTRODUCTION, GOAL AND PURPOSE OF THIS DOCUMENT

This report presents the results of a desk based study that critically reviews existing indicators and metrics used to assess the resilience of communities and critical infrastructure (CI) stakeholders to disaster events and to identify those most appropriate for use in the Resilience Assessment and Improvement Framework (RAIF). The report builds on the previous resilience literature reviewed in LIQUEFACT Deliverable D1.1; the disaster risk reduction frameworks reviewed in LIQUEFACT Deliverable D1.3; and the theoretical background to the RAIF outlined in LIQUEFACT Deliverable D1.4. In addition the report reviews various (EU Funded) disaster risk reduction frameworks currently in development and identifies the range of indicators used to assess the resilience of CI systems. The report also critically appraises the modelling approaches used by these frameworks to assess the impact of CI resilience and overall community resilience. The report maps the indicators against the needs of the RAIF and provides the rationale behind the selection of those indicators included in the RAIF. The report also provides a first draft of the top level metrics which will be developed as part of the RAIF (LIQUEFACT Work package 5) and tested through the Emilia Romagna Case Study (LIQUEFACT Work Package 7).

To this end this report will:

- Present an overview of the RAIF and summarise the theory of community resilience to disaster events;
- Review the principles underpinning disaster risk reduction frameworks and present a review of current EU projects that address CI and community resilience;
- Present an overview of the UNISDR Sendai Framework for Disaster Risk Reduction and critically review the UNISDR Disaster Resilience Scorecard for Cities; and
- Present a first draft of the indicators and metrics that will be used in the RAIF to assess the impact of EILD events on both CI and Community resilience.

Goal: The primary aim of this report is to provide the LIQUEFACT project partners and researchers with an introduction to the indicators and metrics that will be developed as part of the RAIF to assess the potential of EILD mitigation interventions to improve the resilience of buildings and CI to EILD events and as such contribute to improved community resilience to EILD events.

SCOPE OF THIS DOCUMENT

The review presented in this report should be considered a work in progress which will be reviewed and modified throughout the duration of the LIQUEFACT project to reflect emerging issues identified by the research team, project partners; location specific characteristics of the case study sites; external stakeholders; and advice received from the expert advisory groups.

TARGET AUDIENCE

Although the report is publically available it is principally an internal working document intended for the LIQUEFACT project partners and researchers.

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Report on Individual Stakeholder and Urban Community Performance Metrics

1 INTRODUCTION

1.1 This report presents the results of a desk based study that critically reviews existing indicators and metrics used to assess the resilience of communities and critical infrastructure (CI) to disaster events and to identify those most appropriate for use in the Resilience Assessment and Improvement Framework (RAIF). The report builds on the previous resilience literature reviewed in LIQUEFACT Deliverable D1.1; the disaster risk reduction frameworks reviewed in LIQUEFACT Deliverable D1.3; and the theoretical background to the RAIF outlined in LIQUEFACT Deliverable D1.4. In addition the report reviews various (EU Funded and UNISDR) disaster risk reduction frameworks currently under development and identifies the range of indicators used to assess the resilience of community and CI systems. The report also critically appraises the modelling approaches used by these frameworks to assess the impact of CI resilience and overall community resilience. The report maps the indicators against the needs of the RAIF and provides the rationale behind the selection of those indicators included in the RAIF. The report also provides a first draft of the top level metrics which will be further developed as part of the RAIF (LIQUEFACT Work package 5) and tested through the Emilia Romagna Case Study (LIQUEFACT Work Package 7).

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- Present a first draft of the indicators and metrics that will be used in the RAIF to assess the impact of EILD events on both CI and Community resilience.

1.2 The primary aim of this report is to provide the LIQUEFACT project partners and researchers with an introduction to the indicators and metrics that will be developed as part of the RAIF to assess the potential of Earthquake Induced Liquefaction Disaster (EILD) mitigation interventions to improve the resilience of buildings and CI to EILD events and, as such, contribute to improved community resilience to EILD events. As such the report should be considered a work in progress which will be reviewed and modified throughout the duration of the LIQUEFACT project to reflect emerging issues identified by the research team, project partners, external stakeholders and advisors.

2.0 BACKGROUND TO THE RESILIENCE ASSESSMENT AND IMPROVEMENT FRAMEWORK (RAIF)

2.1 The RAIF is a decision support tool that can be used by built assets owners and/or managers to assess the antecedent vulnerability, resilience and adaptive capacity of their built assets (buildings and infrastructure) to disaster events; particularly EILD events, and develop and evaluate alternative mitigation measures to reduce vulnerability and/or improve resilience at the built asset and community level. The RAIF is an enhancement of the risk/resilience framework developed by Jones et al (CREW, 2012) to extreme weather events. In particular the risk/resilience framework has been enhanced and refined to reflect the latest disaster risk reduction guidance provided through the Sendai Framework and best practice extracted from other disaster risk reduction frameworks. By extension the framework can also be used by EU, national, regional and local decision makers to assess vulnerability, resilience and adaptive capacity of urban communities to EILD events. Full details of the RAIF can be found in LIQUEFACT Deliverables D1.3 and D1.4.

2.1 Vulnerability, Resilience, Adaptive Capacity and Risk

2.1.1 Vulnerability, resilience, and adaptive capacity are concepts from the biophysical and social realms that are increasingly being applied to the understanding of the complex relationships between communities, the built environment, and the drivers that may affect change. Whilst there is considerable debate over the precise definitions of the terminology, the LIQUEFACT project has adopted the UNISDR (2009) definitions:

- **Vulnerability** as *"the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard"*. Vulnerability is considered as the principal component of risk (Hewitt, 1983) which encompasses physical, social, economic, and environmental factors and the effect that these have across geographical, social and temporal scale.
- **Resilience** as *"the ability of a system, community or society exposed to hazards to resist, absorb, accommodate and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions"*. Resilience is both the capacity of a system to react appropriately to moments of crises that have not been entirely anticipated, and its ability to anticipate these crises and to enact, through planning and recovery, changes in the systems that will mitigate their effects (Aguirre, 2006). Therefore, the resilience of a community is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need.

- **Adaptive Capacity** as *"the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.*[1] Adaptation can occur in an autonomous fashion, for example through market changes, or as a result of intentional adaptation policies and plans. Thus adaptive capacity can be considered as the capacity of a system to adopt mitigation measures (physical, social, economic, environmental etc.) to potential disaster events.

2.1.2 The UNISDR (ibid) defines:

- **Risk** as *"The combination of the probability of an event and its negative consequences"*.

In this context the term risk extends beyond a single measure of the impact of an event to encompass a range of *"… potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period*". Thus disaster risk reflects the concept of disaster as the outcome of continuously present conditions of risk and comprises different types of potential losses which are often difficult to identify and quantify. Thus, whilst in its simplest form risk may be expressed as:

$$R = H\ V\ E$$

Where:

Risk (R): the combination of the probability of an event and its negative consequences

Hazard (H): the probability of an event occurring

Vulnerability (V): the characteristics of a system that make it susceptible to the damaging effects of a hazard

Exposure (E): all the elements of the system that are subject to potential loss

2.1.3 The indicators and metrics required to measure vulnerability and exposure are complex and need to reflect the inter-relationships between the characteristics of the system (or indeed systems) and multiple potential losses, and as such a single measurement of risk is not meaningful in a disaster risk context. Establishing a measure of risk is further complicated

[1] This definition addresses the concerns of climate change and is sourced from the secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). The broader concept of adaptation also applies to non-climatic factors such as soil erosion or surface subsidence.

when one considers the relationship between vulnerability and resilience. Resilience is related to vulnerability; the more resilient a system the less vulnerable it is to the impacts of a hazard. Given the relationship between resilience and vulnerability the risk formula may therefore also be expressed as:

$$R = H \frac{V}{Re} E$$

Where (in addition to the definitions above):

> Resilience (Re): The ability of a system, community or society exposed to hazards to resist, absorb, accommodate and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

2.1.4 Given the above, when considering the theoretical requirements of the RAIF the LIQUEFACT project perceives risk as a multi-dimensional (e.g. vulnerability, coping capacity, exposure of persons and assets etc.) construct that needs to be assessed across a range of scales rather than as a single measure at a single scale. In essence the RAIF must accommodate all the impacts that a disaster event may have on the performance of built assets (buildings and CI) from both the physical and business perspective as it is the combination of these that effect the wider resilience of the system (economic, political, social and business effects) and the community. Further details of the theoretical principals underpinning the RAIF can be found in LIQUEFACT Deliverable D1.1.

2.2 Factors Affecting Community Resilience to Disaster Events

2.2.1 Whilst there is a broad understanding of the factors that affect community resilience to disaster events at the national and regional level, there is less understanding of the factors that affect local community resilience (CREW, 2012). Whilst it is generally accepted that a community's resilience and adaptive capacity is a complex association of behavioural characteristics between: households; businesses (particularly small and medium sized enterprises - SMEs); and local decision makers (politicians), the precise nature of these relationships is less well understood (Smit & Wandel, 2006, CREW, 2012). What is generally agreed is the need for each community to identify its own determinants of vulnerability and adaptive capacity rather than rely on generic assessments and 'preferred solutions' and to understand the sensitivities of these determinants to the wider political, social, economic and technological forces (Smit & Wandel, 2006, Ali & Jones, 2013). Thus, whilst measuring community resilience to disaster events relies on generic factors the precise relationship between the factors will vary depending on the local circumstances.

2.2.2 Attempts to develop practical measures of community resilience have resulted in a number of explanatory models that seek to qualify the relationships between the various determinants of community resilience for different disaster event scenarios. Tierney & Bruneau (2007) developed a working definition of disaster resilience *"… the ability of social units (e.g. organisations, communities) to mitigate hazards, contain the effects of disasters when they occur, and carry out recovery activities in ways that minimise social disruption and mitigate the effects of future disasters."* in which they identified four attributes/determinants of a resilient system framework:

- **Robustness** - the ability of systems to withstand disaster forces without significant degradation or loss of performance;
- **Redundancy** - the extent to which systems are substitutable (by other systems);
- **Resourcefulness** - the ability to diagnose and prioritise problems and initiate solutions (by identifying and mobilising material, monetary, informational, technological and human resources);
- **Rapidity** - the capacity to restore functionality in a timely way.

Tierney & Bruneau (ibid) also identified 4 dimensions/domains of resilience:

- **Technical Domain** - the physical properties of systems;
- **Organisational Domain** - the organisations that manage the physical components of the system (including emergency responders);
- **Social Domain** - population and community characteristics that render social groups either more vulnerable or more adaptable to hazards;
- **Local and Regional Economies** - ability to identify and access a range of options for coping with a disaster – the more limited the options, the lower the community resilience.

In considering these attributes/dimensions Tierney & Bruneau (ibid) highlighted the complex nature of resilience and emphasised the need to adopt a holistic approach to assessing community resilience that considers organisational and community capacity alongside household's and business's ability to cope with disaster events.

2.2.3 Another review of the theory of community resilience was undertaken by Paton (2007) who examined resilience to disaster events from a societal perspective and identified four general components that he believed made a community resilient to disaster events:

- Communities, their members, businesses and societal organisations must possess the resources (e.g. household emergency plans, business continuity plans etc.) to ensure their safety and continued core function during an event;
- Communities must possess the competences (e.g. action coping, community competence, trained staff, disaster management procedures) required to

mobilise, organise and use the resources to confront problems encountered and adapt to the reality created by the event;
- The planning and development strategies used to facilitate resilience must include mechanisms designed to integrate the resources available at each level to ensure the existence of a coherent societal capacity, and one capable of realising the potential to capitalise on opportunities for change, growth and the enhancement of Quality of Life;
- These resources need to be available over an extended time period and be sympathetic to the changing (adapting/emerging) community.

Paton (ibid) also concluded that resilience to a disaster event was a combination of personal, community and institutional factors:

- **Personal factors included**: critical awareness; self-efficacy; sense of community; outcome expectancy; action coping; and resource availability;
- **Community factors included**: collective efficacy; participation; commitment; information exchange; social support; decision making; and resources availability;
- **Institutional factors included**: empowerment; trust; resources; mechanisms for community problem solving.

2.2.4 By expressing these factors as a range of variables and undertaking a questionnaire survey of the Auckland community, Paton (ibid) identified three personal indicators (action coping, positive outcome expectancy and negative outcome expectancy), two community level indicators (community participation and ability to communicate community problems) and two institution level indicators (empowerment and trust) as having direct influence on community resilience. Further, in an attempt to provide local decision makers with a mechanism to evaluate potential interventions, Paton used the base-line data collected through the questionnaire survey to develop a resilience indicator that represented a composite measure of resilience (on a 1-10 scale). For the scenario examined, Auckland scored 5.53, which, whilst of academic interest, has no absolute meaning since it cannot be calibrated until a disaster event occurs. This is a recurrent problem with the use of generic models to predict community resilience.

2.2.5 Paton et al (2013) reviewed the theory of community resilience in the light of the 2011 Christchurch earthquakes and re-examined the factors that affected community resilience, reinterpreting the original model to reflect the lessons learnt from these events. From this review Paton et al (ibid) identified the key role that adaptive capacity played in supporting community recovery over time. Immediately following a disaster event, people need the capacity to respond to the impact of the event. In the case of the Christchurch earthquake event this involved the capacity to safeguard the structural integrity of their house, fixtures and fittings and having plans and resources in place that increased their self-reliance and capacity to confront/adapt to the unfolding impacts of the earthquake. Once the immediate disaster event had passed, people's adaptive capacity was more focused around addressing local needs and community integration to support community recovery. During rebuilding, adaptive capacity required effective leadership and engagement with civic agencies. Based on this review Paton reconfigured his model of community resilience to that shown in Figure 1.

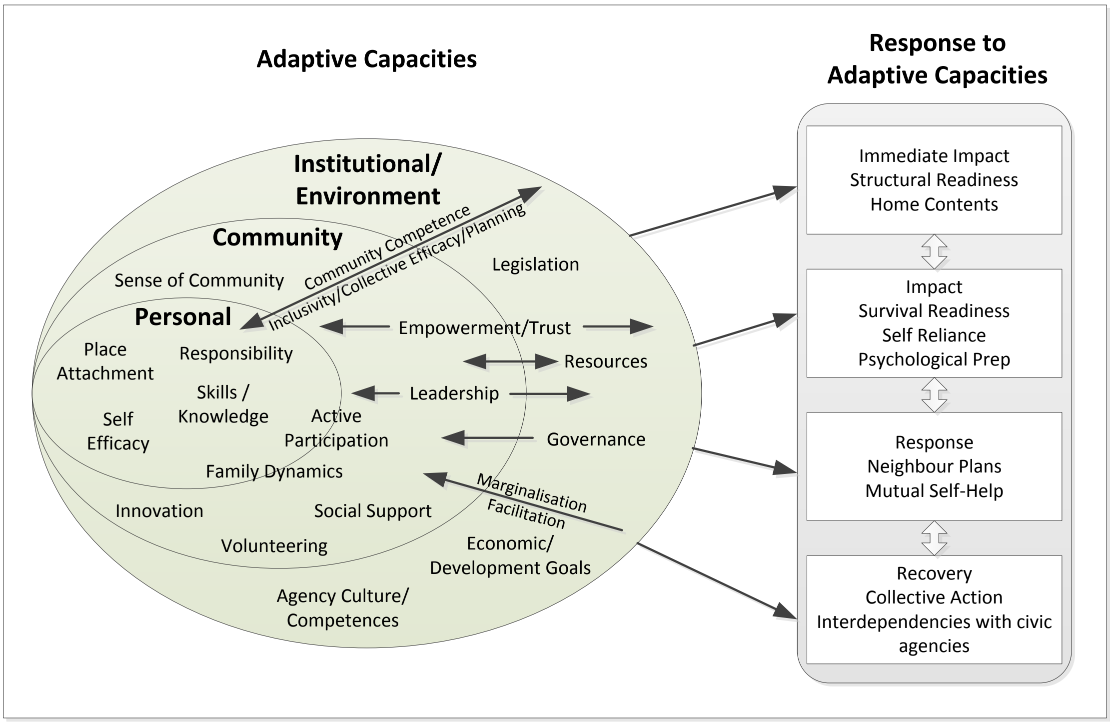

Figure 1: Summary of a) Responses to Adaptive Demands (over time), and b) the adaptive capacities and interdependencies at personal, community, cultural and Institutional / environmental level identified. (Source: Paton et al, 2013)

2.2.6 A third view of community resilience to natural disasters was proposed by Cutter et al (2008). Cutter drew attention to the fact that, whilst there is a growing body of research focussing on defining the dimensions of community resilience, little attention has hitherto been paid to the development of consistent factors or standard metrics that can be used to quantify community resilience. Cutter addressed this shortcoming by outlining a conceptual model of natural disaster resilience supported by a set of candidate variables for measuring community resilience.

2.2.7 The basis for Cutter's (ibid) conceptual model is the relationship between vulnerability and resilience. From a hazard perspective resilience is the ability of a system to survive and cope with a disaster event whilst from a global environmental change perspective resilience focuses on the ability of a system to absorb the disturbance and re-organise itself into a functioning system that may be the same as existed before the disturbance or may have evolved to a new state through learning and adaptation. Whilst such differences may seem esoteric to built environment researchers, they are important because of the implications that the relationships between vulnerability, resilience and adaptive capacity (see Cutter et al, 2008 for further details) have on the perspective, and hence the body of literature, that underpin the models. Cutter's model is based on a hazards perspective which views vulnerability and resilience as separate but linked components.

2.2.8 Cutter's (ibid) DROP (Disaster Resilience of Place) model (Figure 2) considers the inherent (antecedent conditions) vulnerability and resilience of existing communities (combination of natural systems, social system and the built environment) to a disaster event. The antecedent conditions interact with the hazard event characteristics to produce immediate effects. The event characteristics include frequency, duration, intensity, magnitude and rate of onset of the event. These vary depending on the type of hazard and geographical location.

2.2.9 The immediate effects of a disaster event are either reduced or amplified by the presence (or lack) of mitigation actions and coping responses. After any coping strategies are implemented the hazard impact is realised. The impact of the event is moderated by the absorptive capacity of the local community. If the absorptive capacity of the local community is not exceeded then recovery is relatively quick. If the absorptive capacity is exceeded (either because the scale of the event is overwhelming or the coping responses are insufficient) then the community either adapts (through improvisation or social learning) and recovers relatively quickly, or does not adapt and recovery is much slower (or in extreme cases doesn't happen). If social learning occurs then there is a greater likelihood that mitigation and preparedness will be improved.

2.2.10 In an attempt to operationalise the model Cutter (ibid) suggested (from a review of other research) a range of resilience indicators that could be tested against a real world application. These include:

- **Social** - demographics; social networks; community values-cohesion; faith based organisations;
- **Economic** - employment; property values; wealth generation; municipal finance/revenues;
- **Institutional** - participation in hazard reduction programmes; hazard mitigation plans; emergency services; zoning and building standards; emergency response plans; interoperable communications; continuity of operations plans;
- **Infrastructure** - lifelines and CI; transportation networks; residential housing stock and age; commercial and manufacturing establishments;

- **Community Competence** - local understanding of risk; counselling services; absence of psychopathologies (alcohol, drug, spousal abuse); health and wellness; quality of life.

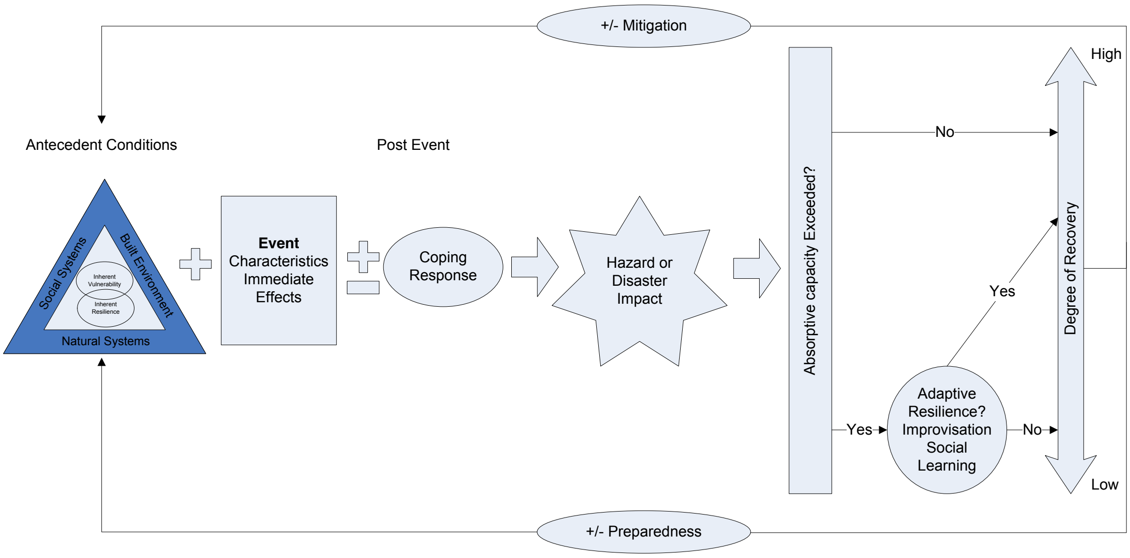

Figure 2: Schematic representation of the disaster resilience of place (DROP) model (Source: Cutter et al, 2008)

2.2.11 Again however, until the model is tested against a real-world event it is not possible to quantify the impact that any of the above have on the resilience of any given location to a disaster event.

2.2.12 One potential problem with Cutter's model is the implied linear relationship between event characteristics, coping response and hazard impact. It could be reasonably argued that, due to varying timescales for different responses and impacts, and social differentiation in how an event unfolds, that a hazard impact for one actor can affect long-term coping response of others (e.g. via economic links). If such a relationship exists then it will demonstrate characteristics more normally associated with a complex system than a linear deterministic system.

2.3.13 The idea that community resilience to disasters is a complex system was proposed by Cavallo (2014). Cavallo (ibid) argued that to fully understand the issues that affect community resilience you need to move away from a command-control approach to a system of systems approach in which community resilience is seen as a dynamic system which changes over time as system conditions change. As such Cavallo (ibid) argued for a re-definition of resilience as the distance between current system conditions and the system's critical thresholds. In such an approach predicting the timing or precise nature of a disaster event becomes less important than accepting that a series of critical thresholds exists (through awareness raising) and preparing for them. This action alone Cavallo (ibid) argued will increase community resilience by increasing the distance to the thresholds.

2.2.14 Boon et al (2012) also viewed resilience as a complex system and applied Bronfenbrenner's bioecological theory to modelling community resilience to natural disasters. Boon et al (ibid) argued that Bronfenbrenner's theory provides a useful framework for organising the factors that enhance an individual's resilience in relation to their ecosystem which in turn allows personal factors (e.g. self-efficacy, optimism etc.) to be assessed alongside external factors (e.g. neighbourhood networks, health provision etc.) to promote individual resilience. Bronfenbrenner's approach effectively creates an inter-related hierarchy of systems with the individual citizen at the centre of the model surrounded by micro, meso, exo and macro systems (Figure 3). Boon et al (*ibid*) applied Bronfenbrenner's approach to a generic assessment of community resilience using empirically derived indicators/themes from literature to assess baseline levels of community resilience and then assessing levels of preparedness, risk perceptions, knowledge, self-efficacy, coping mechanisms and resilience of randomly selected individuals across the micro, meso, exo and macro systems to assess the overall resilience of the community.

2.2.15 Another view of community resilience as a complex inter-related system was used by the CREW (Community Resilience to Extreme Weather) project which examined the factors that affected community resilience to extreme weather events (CREW, 2012). The CREW project built on the theory outlined above for general resilience and developed a working model of community resilience to extreme weather events (Figure 4) to identify how community resilience could be integrated into adaptation planning (mitigation in the context of the LIQUEFACT project) to reduce the vulnerability and improve the adaptive capacity of a community to a potential future disaster event.

2.2.16 In the CREW model each individual stake-holder's resilience to a disaster event is perceived to be a combination of the specific characteristics of the event, of the coping measures (both technical and behavioural) that the stake-holder has in place to deal with the event, and the stakeholder's level of adaptive capacity to absorb the consequence of the event and move forward (either in the same form as prior to the event or in an adapted (changed) state). The overall community's resilience to a disaster event is perceived to be a combination of individual stake-holder resilience whose 'contributions' are either enhanced (a driver) or reduced (a barrier) by the inter-relationships that exist between stake-holder groups (policy makers, households and businesses). Each stakeholder group was viewed to have a dynamic internal structure and characteristic vulnerability, resilience and adaptive capacity, and group interrelations were seen to affect community resilience. The aim of the CREW project was to explore these inter-relationships and identify which acted a drivers or inhibitors to adaptation planning.

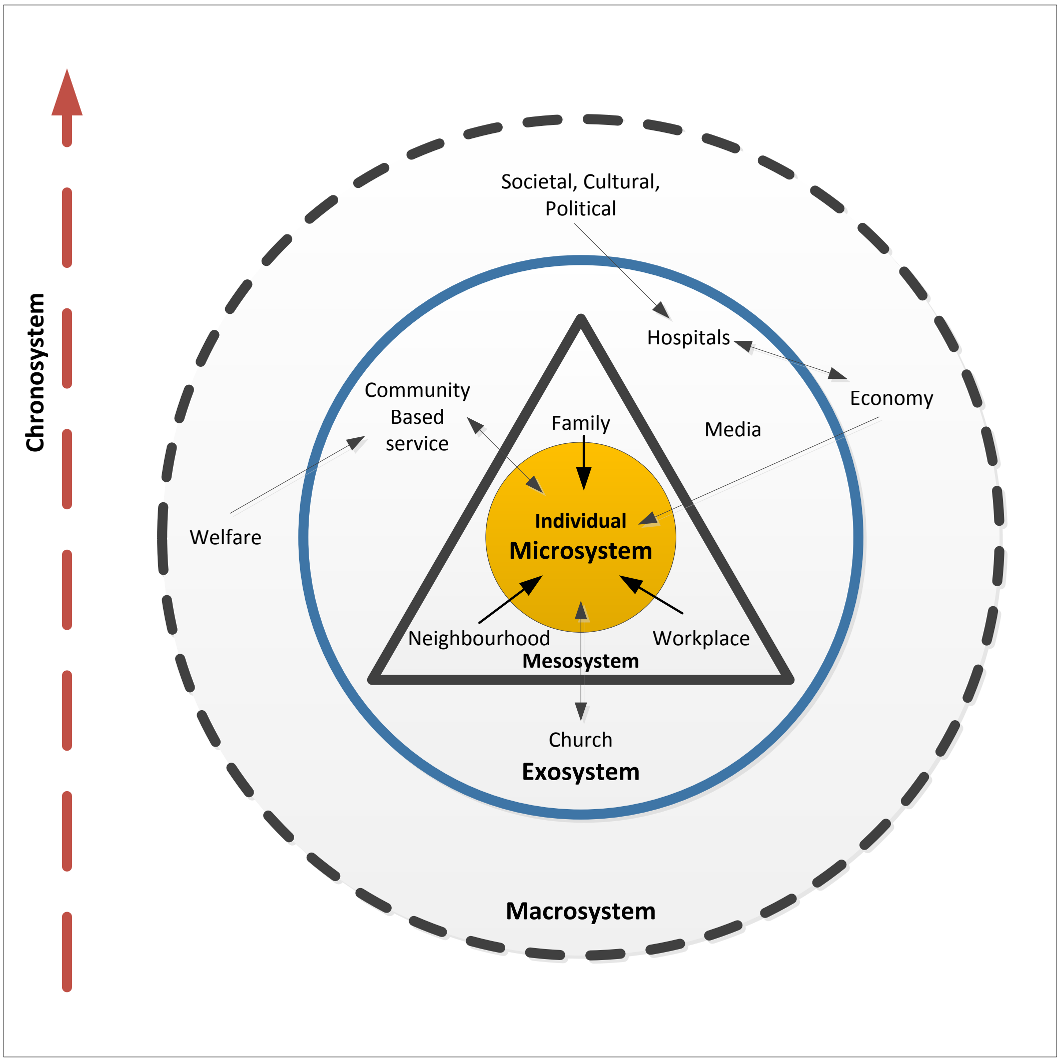

Figure 3: Conceptual scheme of Bronfenbrenner's systems and their interactions

(Source: Boon et al, 2012)

2.2.17 The CREW project used an action research approach to explore the application of the above theoretical model to community resilience to extreme weather events in South East London. Through a series of engagements with all stakeholder groups, the research team explored a range of future extreme weather event scenarios and identified a number of issues that affected the perceived community resilience to each scenario event. The CREW project concluded that there was a lack of clarity regarding the responsibility of different agencies to respond to an event and in particular misunderstandings between what the agencies responsibilities were and what the local communities thought they were. In many cases this resulted in a false sense of security, confusion, and a lack of trust between stakeholders. There was also a clear lack of preparation amongst the household and business stakeholders and unrealistic expectations that government agencies would be available to deal with both the immediate aftermath of an event (through emergency responders) and with the medium to long term recovery of the community. Again the mismatch between what support the householder and business stakeholders believed would be available, and what will be available, led to confusion and a lack of trust between stakeholders. These barriers ultimately manifested themselves in poor adaptation planning where a responsive 'wait and see' approach prevailed which is detrimental to the concept of a better prepared community being a more resilient community (Jones et al, 2013).

2.2.18 The range of factors and indicators cited in the various theories/toolkits/frameworks to measure community resilience to disaster events are summarised in Table 1. The factors and indicators presented in Table 1 will be used to further inform the development of the RAIF in Work Package 5 and the specification of the indicators and metrics used to measure vulnerability and resilience of buildings/CI systems to EILD event in Work Package 7.

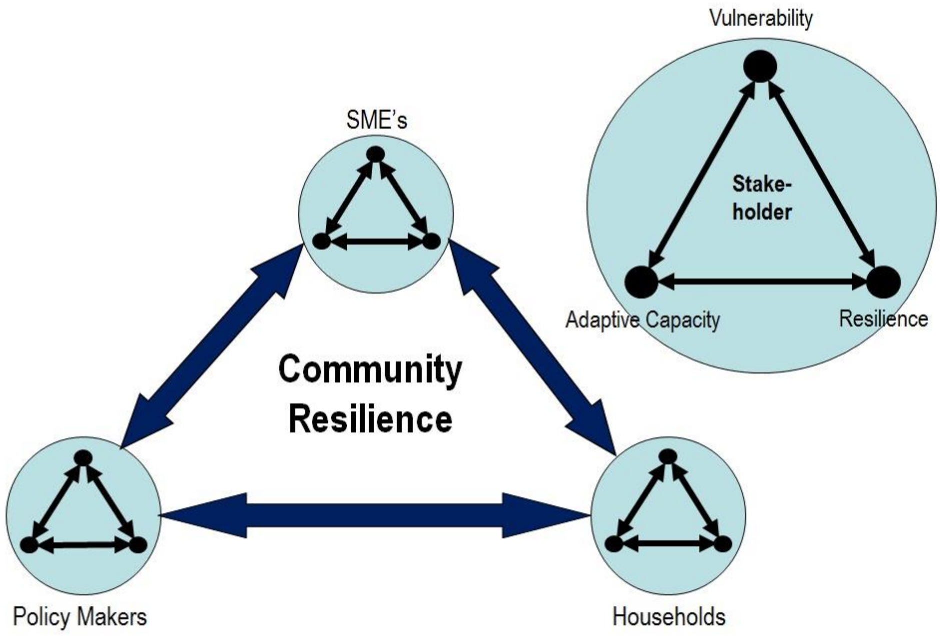

Figure 4: Model of community resilience to extreme weather events

(Source: CREW, 2012)

Table 1: Characteristics/factors known to affect community resilience and how these are observed/expressed within a community.

Resilience Factor / Characteristic	**Indicator / Expectations**
Robustness	Damage avoidance in lifelines and CI (transportation networks, residential housing stock, healthcare facilities, communication networks, commercial and manufacturing establishments etc.); Continuity of service provision; Continuity of functional systems performance; Avoidance of casualties; Avoidance / minimisation of economic losses.
Redundancy	Backup and/or duplicate systems; Backup or access to alternate resources to sustain operations (insurance, alternative sites, robust supply chains etc.); Alternative community logistics (food, water, power etc.); Untapped resources/contingency budgets.
Resourcefulness	Access to money; Information; Technology; Human resources; Household emergency plans; Business continuity plans; Diagnostic and damage detection systems; Contingency plans across stakeholder groups.
Rapidity	Disaster preparedness (Organisational capacities, Early warning systems, Contingency planning, Emergency response planning, etc.); Reduced time of recovery to return systems, as closely as possible, to business as normal.
Personal Factors	Critical awareness; Self-efficacy; Sense of community; Outcome expectancy (positive or negative); Action coping and resource availability; Education and training; Psychological preparedness; Empowerment; Social norms; Trust; Personal responsibility; Social responsibility; Experience; Resources; Adaptive capacity; Cultural attitudes and motivations; Social networks; Property values; Livelihoods; Participation in recovery; Volunteering.
Community Factors	Collective efficacy; Participation; Commitment; Information exchange; Social support; Decision making; Resource availability; Engagement; Leadership; Demographics; Sense of community; Community values-cohesion; Collective efficacy; Place attachment; Adaptive capacity; Local understanding of risk (hazard assessment, vulnerability assessment, impact assessment, resource management, mitigation); Counselling services; Health and well-being services; Community organisations (e.g. faith based etc.); Employment.
Institutional Factors	Empowerment; Trust; Resources; Mechanisms for community problem solving, Adaptive capacity, Participation in hazard reduction programmes; Hazard mitigation plans; Zoning and building standards; Emergency response plans; Interoperable communications; Continuity planning; Municipal finance/revenues.
Governance	Policy & Planning; Legal and regulatory systems; Integration across time and

Factors	scale; Leadership; Partnerships; Accountability.

Derived from: Ainuddin & Routray (2012); Becker et al (2013); Boon et al (2012); Bruneau et al (2003); Cutter et al (2008); DPRAP (2013); GOAL (2012); Normandin et al (2009); and Paton (2007).

2.3 Disaster Risk Reduction Frameworks

2.3.1 There have been many attempts at producing guidance and toolkits to measure and reduce disaster risks and improve community resilience (see Table 2). Typically these tools seek to identify the components/factors that affect community and CI resilience and then develop a range of qualitative and quantitative indicators/metrics to measure the resilience of each component/factor. These components/factors can then be combined to obtain an overall assessment of community or CI system resilience. The individual component/factor resilience and the overall community/CI resilience is typically calculated using a simple or weighted summation approach to obtain the resilience scores. Whilst this can provide a high level assessment of the impact that the various components/factors have on community resilience, the modelling approach doesn't reflect the inter-dependencies and interactions that are known to exist between components/factors and indicators/metrics. As such these generic approaches do not provide the level of detail that will be needed by the RAIF as it attempts to quantify the specific benefits (and costs) associated with alternate EILD event mitigation interventions. As such, more detailed and specific resilience scoring tools will be needed; one to measure community resilience; the other to measure CI system resilience. These will be developed in LIQUEFACT Work Package 5.

Table 2: List of toolkits for measuring community resilience to disaster events.

Toolkit	Description
GOAL	This toolkit measures community level resilience through the assessment of a broad range of resilience components in five thematic areas. • Governance (six components) • Risk Assessment (three components) • Knowledge and Education (three components) • Risk Management / Vulnerability Reduction (12 components) • Preparedness and Response (six components) Each component is scored on a 1-5 scale and then aggregated to provide an assessment of the resilience of each key component and the overall level of resilience of the community. The output is in the form of a dashboard radar plot that can compare different communities or the same community before and after interventions https://www.goalglobal.org/images/5101_HN_OP_006_11_Resilience_Toolkit_English_B02.pdf

DPRAP CoBRA	This toolkit was developed to measure the socio-economic and environmental impacts of community based disaster risk reduction to drought across the Horn of Africa. The specific aim of the toolkit is to "design a quantitative impact assessment of interventions at the community or household level". The CoBRA model establishes a baseline assessment of an individual household's resilience to an event and then measures how this might change following a range of interventions. Resilience is measured at a set point in time through a composite of five components (human, physical, natural, social and financial) that provide individual and overall resilience scores. Measurements are then repeated after a disaster event/intervention and improvements (or a reduction) in resilience can be calculated. Although the metrics developed in the toolkit are not directly applicable to earthquake disasters, the principles underpinning the approach are. https://issuu.com/edwintoo/docs/cobra_conceptual_framework_and_meth
Menoni et al	The EU ENSURE (Enhancing resilience of communities and territories facing natural and nontech hazards) project examined the relationship between flooding vulnerability and resilience in Sondrio (Italy). As part of the project a matrix approach was developed to assess the resilience of the built environment, infrastructure and social systems. The matrix approach provided a framework for assessing the existence (or not) of a range of factors that would affect resilience to a flooding event. http://link.springer.com/article/10.1007%2Fs11069-012-0134-4
Bruneau et al	This framework was developed specifically to measure the seismic resilience of communities. The framework is based around a series of matrices that define at a global level (through performance criteria) the robustness, redundancy, resourcefulness and rapidity requirements of a community's technical, organisational, social and economic systems. Further matrices repeat the process (robustness, redundancy, resourcefulness and rapidity requirements) for critical systems (power, water, health, emergency response) from a technical, organisational, social and economic perspective. This multiple performance metric approach allows community resilience to be broken down into three complimentary measures: reduced failure probabilities; reduced consequences from failures; and reduced time for recovery. http://earthquakespectra.org/doi/abs/10.1193/1.1623497
Kellett et al	The Future Framework for Disaster Risk Reduction: A Guide for Decision Makers is a set of guidance for government decision makers on what should be included in a disaster risk reduction framework. Whilst the guidance doesn't provide specific tools it does highlight 11 areas (making the case, architecture, monitoring and accountability, financing, vulnerability and inclusion, disaster risk, environmental and ecosystems, science and technology, conflict and fragility, stakeholders and leadership, sustainable development) that need to be addressed in any disaster risk reduction framework.

	https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8996.pdf
Resilience Alliance	Provides a framework for assessing resilience in social-ecological systems. Their workbook for practitioners provides guidance on developing and implementing management solutions to improve system resilience. The framework provides tools for describing the system under threat; applying the adaptation cycle; identifying system interactions; understanding governance systems and social networks; developing conceptual models and setting threshold criteria. The resilience assessment resulting from enacting the framework can be implemented and integrated into strategic plans and management processes to improve the resilience of the system. http://www.resalliance.org/files/ResilienceAssessmentV2_2.pdf
IFRC	Earthquakes: Guidelines on Preparing, Responding and Recovering. The International Federation of Red Cross and Red Crescent produce guidelines for national societies in preparing, planning and implementing field operations in response to an earthquake event. The guidelines are built on the Hyogo Framework and although this has now been superseded by The Sendai Framework (see next section) the advice in the guidelines is valid. http://www.preventionweb.net/files/26164_earthquakeguidelinesenweb.pdf
Ainuddin & Routray	Developed a multiple indices approach to measuring community resilience to earthquake hazards in Baluchistan. Their approach was based on four components (social, economic, physical and institutional) each representing its own domain and measured through 17 individual indicators. Each indicator was expressed in percentage terms and weighted to represent the relative importance of each indicator to each other. Due to lack of data, the authors used a subjective assessment of the relative weights and whilst this doesn't negate the principles behind the approach it does call into question the robustness of the specific comparisons presented in the paper. The overall community resilience was then calculated by combining the individual component scores. http://link.springer.com/article/10.1007/s11069-012-0201-x

2.3.2 The latest international guidance on improving community resilience to disaster events is contained in the Sendai Framework for Disaster Risk Reduction 2015-2030[2] (UN General Assembly, 2015). The Sendai framework is a 15-year non-binding agreement that was adopted at the Third United Nations World Conference on Disaster Risk Reduction, held from 14 to 18 March 2015 in Sendai, Miyagi, Japan. The stated intention of the Sendai Framework is to support a *"… substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental*

[2] See http://www.unisdr.org/we/coordinate/Sendai-framework for full details.

assets of persons, businesses, communities and countries.''. To this end the Sendai Framework encourages countries to adopt a concise, focused, forward-looking and action-oriented framework for disaster risk reduction that considers a wide spectrum of small to large scale, frequent and infrequent, sudden and slow onset disasters caused by natural and man-made hazards. The Sendai Framework is based on (but not limited to) the following guiding principles:

- Disaster risk reduction is a shared responsibility between government, authorities, sectors and stakeholders. It requires all-of-society engagement;
- When managing disaster risk, consideration should be given to protecting people, their health, property and livelihoods, as well as productive, cultural and environmental assets;
- Disaster risk reduction depends on coordination mechanisms within and across sectors and with relevant stakeholders; and requires empowerment of local communities;
- Disaster risk reduction requires a multi-hazard and risk–informed decision making based on scientific information complemented with local knowledge that contextualises the information to local circumstances;
- Disaster risk reduction is more cost-effective than post disaster response and recovery and a "build-back-better" philosophy reinforces future risk reduction.

2.3.3 When developing implementation plans the Sendai Framework suggests that national states should focus on four priority areas for action.

- **PRIORITY 1: Understand the disaster risk**

  A holistic understanding of disaster risk in all its dimensions is essential to support effective risk management. Using relevant and reliable data (nationally and locally) will provide base-line information on vulnerability, adaptive capacity, exposure and hazard characterisation which will allow primary and secondary impact scenarios to be modelled and the effectiveness of coping strategies to be evaluated. The scenarios can also provide a mechanism to communicate the disaster risks to central planners and the wider community.

- **PRIORITY 2: Strengthen disaster governance to manage risk**

  Develop clear vision, plans, guidance, command, control, and coordination activities within and across sectors that engage all the stakeholders in disaster risk management. In developing the systems, consideration should be given to publicly and privately owned critical infrastructure as well as to households, communities and businesses. Whilst systems can be designed centrally, they should be enabled locally with local authorities empowered to act at the local level.

- **PRIORITY 3: Invest in disaster risk reduction to improve resilience**

Public and private investment in disaster risk reduction is essential to enhance economic, social, health and cultural resilience of people, communities, countries and their assets. Effective mechanisms should exist to promote disaster risk transfer (e.g. insurance, risk sharing and retention, financial protection etc.) for both public and private assets and in particular CI assets including appropriate design standards, building materials, and maintenance and refurbishment strategies. With regards to business resilience, effective understanding of the integration of disaster risk management into business models, including the supply chain, is critical if livelihoods are to be protected.

- **PRIORITY 4: Enhance disaster preparedness and build-back-better**

  Pre-planning is essential for an effective recovery, rehabilitation and reconstruction following a disaster event. This phase also offers an ideal opportunity to build-back-better by integrating disaster risk reduction into development and reconstruction projects. To prepare for disaster events requires contingency plans and programmes to be developed and tested routinely across the community. These plans need to consider forecasting and early warning systems as well as communication systems and channels. Policies to improve the resilience of existing CI should be developed and implemented as part of routine refurbishment. Logistics required immediately after a disaster event should be stockpiled and a distribution system established for their release immediately following a disaster event.

2.3.4 One of the pivotal strengths of the Sendai Framework is that whilst it recognizes that the State has the primary role to reduce disaster risk, it also recognizes that this responsibility should be shared with other stakeholders including local government and the private sector including community organizations and businesses. However, whilst the Sendai framework provides the high level strategic guidance needed to drive improvements in disaster risk reduction (e.g. the Disaster Resilience Scorecard for Cities – reviewed later in this report) it doesn't provide detailed operational guidelines on how to deliver improvements at the built asset level. In particular it doesn't provide an action-oriented framework that building/CI owners/managers can use to identify disaster risks and guide mitigation investment decisions to improve building/CI and community resilience. This is particularly true in the facilities management field, where the Sendai principles need to be integrated into disaster management and business continuity plans, and maintenance and refurbishment strategies, if the impact of disaster events on critical built assets and infrastructures is to be reduced and community resilience improved. The RAIF is intended to address this shortcoming.

2.4 The LIQUEFACT Resilience Assessment and Improvement Framework

2.4.1 The RAIF is based on the risk/resilience framework developed by Jones et al (CREW, 2012) in the CREW project which in turn was based on Cutter's DROP model (Cutter et al, 2008). The CREW project developed and tested a six stage adaptation framework that was integrated into a built asset management model that would allow building owners/managers to identify and programme interventions (technical, operational, organisational and managerial) to improve the resilience of their built assets to extreme weather events. Whilst the stressor behind the disaster risk associated with the LIQUEFACT project is different to that used in the CREW project the general theory supporting the adaptation framework is the same.

2.4.2 The underlying theory is based on Cutter's (2008) Disaster Resilience of Place model (Figure 2) in which antecedent conditions, including coping response and absorptive capacity, directly affect speed of recovery and system resilience. The LIQUEFACT project has re-interpreted the adaptation framework developed in the CREW project to reflect the expectations inherent in the Sendai Framework and the specific characteristics associated with EILD events. To this end the RAIF draws together two main activities; a risk-based assessment of the antecedent conditions that affect building/CI resilience pre event and a resilience improvement framework that will allow alternative mitigation options to improve building/CI and community resilience to be evaluated against a range of post event scenarios. The RAIF is show in Figure 5.

2.4.3 **Stage 1 – Antecedent Condition Analysis:** The first stage of the RAIF requires an assessment of the vulnerability of an asset (e.g. individual building/CI asset, portfolio of buildings/distributed infrastructure assets, etc.) to an EILD event. The first stage of this assessment is to identify whether the asset(s) is located in a geographical area likely to be affected by an EILD event. For each built/CI asset(s) identified as at potential exposure to an EILD event the level of hazard is evaluated by considering the probability of an earthquake hazard and the susceptibility of the ground to liquefaction. The level of hazard will be classified using qualitative labels ranging from "Very Low" to "Very High" that express the level of likelihood of the ground below the asset to liquefy for any given earthquake characteristic.

2.4.4 In order to assess how an individual building/CI asset(s) is likely to be affected by an EILD hazard, an assessment needs to be made of the potential impact of liquefaction on the integrity of the building/CI asset(s) on the site. This in essence will be an assessment of the inherent level of vulnerability/resilience of a building/CI asset(s) topology to a potential EILD event. For buildings, for example, the vulnerability/resilience is likely to be a combination of construction and foundation type. The level of vulnerability/resilience will be classified using qualitative labels ranging from "Very Low" to "Very High".

2.4.5 This analysis will provide asset managers and other CI stakeholders with an assessment of the range of exposures that their asset(s) are likely to be susceptible to.

2.4.6 **Stage 2 - Impact Assessment:** The hazard-exposure and vulnerability/resilience scores from stage 1 will be used to assess the level of risk to building/CI asset(s) which in turn will be used as the basis to assess the loss of functionality (and consequential service performance) of the building/infrastructure asset(s) immediately following the disaster event. The loss of functionality will be made on a case by case basis using the expert knowledge of the facilities manager and building/CI users to interpret the impact that any given level of risk will have on functionality and performance (through the Analytical Hierarchy Process – AHP (Saaty, 1980)). It is currently assumed that the loss of functionality will be categorised using qualitative labels ranging from "minor cosmetic damage" to "major structural damage" with the loss of performance being a further qualitative statement contextualising the impact of the loss of functionality.

2.4.7 **Stage 3 - Community Impact Scenarios:** The impact of the loss of performance of individual building/CI assets on the resilience of a community following an EILD event will be assessed by integrating the performance outcomes identified in stages 1-2 of the RAIF (above) into a Fuzzy Cognitive Map (FCM) that describes the complex relationships (physical, social, organizational, economic etc.) that constitute a community's resilience to disaster events.

2.4.8 The resilience modelling component of the RAIF seeks to identify and investigate all the factors that influence the vulnerability, resilience and adaptive capacity of an urban community to an EILD event. Unfortunately, because of inter-relationships and interdependences between resilience indicators (resilience, vulnerability and adaptive capacity are in essence concepts and as such cannot be measured directly) and the uncertainties that these place on quantitative measurements, resilience in absolute terms is difficult to measure. However, the uncertainties associated with the resilience assessments can be accommodated by applying the FCM (Stylios, Georgopoulos, & Groumpos, 1997) to the development of resilience models. The RAIF will use FCM to define inherent vulnerabilities (physical, social, environmental, economic etc.) at the sub-system level (e.g. health care, transport etc.) to provide a resilience assessment of each sub-system to an EILD event. The RAIF will then combine the sub-system FCMs to provide a resilience assessment at the overall community level.

2.4.9 **Stage 4 - Mitigation Options:** Once the baseline assessment of the resilience of the sub-systems and community to an EILD event has been established and the required improvements in resilience have been defined, the ability of a range of mitigation actions to achieve the required improvements can be evaluated. This analysis requires a range of mitigation actions to be identified (both physical and operational) and the effect of each on the level of performance of individual buildings/CI asset(s) to be evaluated using the impact assessment matrix outlined in Stage 2.

2.4.10 Two types of mitigation actions need to be considered; those that seek to reduce a building/CI asset(s) vulnerability/increase its resilience and those that seek to reduce the hazard impact. The former are likely to be building level interventions, the latter are likely to be ground level interventions. The vulnerability and resilience of the modified building/CI asset(s) will be remodelled (stages 1-2) and the impact on resilience (stage 3) re-assessed. Mitigation options will be ranked according to their impact at the sub-system level and on their contribution to improving overall community resilience.

2.4.11 **Stage 5 - Improvement Framework:** Once the mitigation options have been identified a cost/benefit analysis will be calculated for each specific sub-system component. The cost/benefit analysis will need to consider both direct and indirect costs (e.g. physical, loss of revenue during refurbishment period, etc.) and benefits (e.g. to the organisation, community, etc.) and extend the analysis across geographical and temporal scales (e.g. the inter-relationships between multiple similar assets and the implications of delaying refurbishment until later in a building/infrastructure life cycle).

2.4.12 Once the cost/benefit analysis has been completed for all sub-system components, consideration will need to be given to setting intervention priorities and sequencing of work. The adaptive capacity of all stakeholder groups to fund and manage the retrofitting of mitigation interventions will need to be assessed (e.g. availability of capital, governance requirement, legislation etc.) and priorities set for mitigation interventions to be enacted as it is very unlikely that sufficient adaptive capacity will be available to adopt all the mitigation actions suggested by the AHP and FCM models. Additionally the timescales will be set over which these interventions will be programmed. It is likely that the retrofitting of buildings/infrastructure mitigation interventions will be programmed periodically over the assets normal refurbishment cycle – up to 30 years in some cases.

2.4.13 **Stage 6 - Built Asset Management Planning:** once priorities have been set, in depth built asset management plans can be developed. These plans require detailed design solutions to be carried out for each mitigation intervention and all financial and legal conditions to be addressed before contracts are let. Once implemented, the performance of the mitigation

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intervention is monitored against the performance improvement specification (detailed in stage 4) through detailed simulation or in response to an EILD event.

2.4.14 Once assessments have been completed for an individual built/CI asset they can be combined across the whole built asset portfolio (e.g. healthcare assets) and then these can be combined with other sub-systems (e.g. transport) to assess the resilience of a community to the combined stressors associated with a disaster event.

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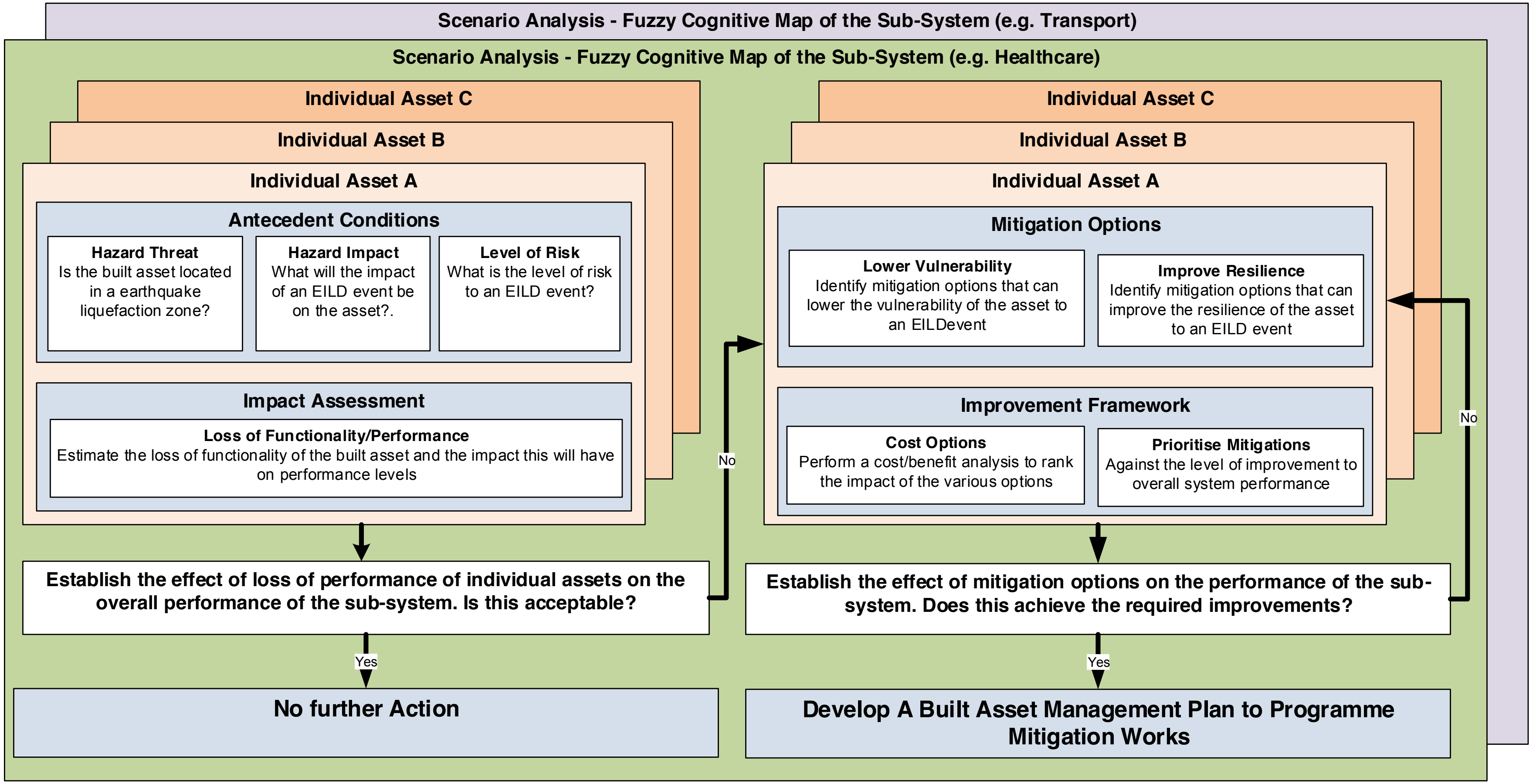

Figure 5: Resilience Assessment and Improvement Framework

3 REVIEW OF CURRENT EU PROJECTS ON CI AND COMMUNITY RESILIENCE

3.1 Background

3.1 This section of the report critically reviews six current EU funded projects that are exploring issues pertinent to improving the resilience of buildings/CI systems and communities to natural and manmade disaster events. The projects reviewed have been identified through the CODIS (Community Research and Development Information Service) database of EU funded projects. A search of the database using the search terms "critical AND infrastructure AND disaster AND resilience" identified 20 current or recently completed FP7 and HORIZON 2020 projects. A review of the aims and objectives of these projects identified six (Table 3) that appeared directly relevant to the LIQUEFACT project. Each of these projects was further reviewed through analysis of the publically available reports accessed through the individual project web sites.

Table 3: List of projects that measure community resilience to disaster events

Project acronym	**Project name**	**Website**
RESILENS	Realising European ReSiliencE for CritIcaL INfraStructure	http://resilens.eu/
IMPROVER	Improved risk evaluation and implementation of resilience concepts to critical infrastructure	http://improverproject.eu/
SmartResilience	Smart Resilience Indicators for Smart Critical Infrastructures	http://www.smartresilience.eu-vri.eu/
Darwin	Expecting the unexpected and know how to respond	http://www.h2020darwin.eu/about
RESIN	Supporting Decision Making for Resilient Cities	http://www.resin-cities.eu/home/
EU-CIRCLE	A pan-European framework for strengthening Critical Infrastructure resilience to climate change	http://www.eu-circle.eu/

3.2 Realising European Resilience for Critical Infrastructure (RESILENS)

3.2.1 RESILENS is a three year project which aims to improve the understanding of CI resilience management and the uptake of resilience measures by CI stakeholders through the development of a set of European Resilience Management Guideline (ERMG) to support the practical application of resilience actions to all CI sectors. The ERMG will comprise a Resilience Management Matrix and Audit Toolkit which will enable CI system (encompassing assets and organisations) owners and managers to quantitatively and qualitatively assess and index the level of resilience of their systems against a range of disasters. As such the principles underpinning the EMRG and its associated tools should be directly relevant to the LIQUEFACT project.

3.2.2 The ERMG (RESILENS D3.2, 2016) is a tool (currently in draft form) which CI managers can use to improve their resilience management organisation processes. The ERMG will provide the contextual framing for CI resilience management and present owners/mangers with a series of strategies and processes which they can apply to their organisation to improve the resilience of its operations. These strategies and processes are related to the three stages of resilience management:

- Stage 1 - prepare, prevent and protect.
- Stage 2 - mitigate, absorb and adapt.
- Stage 3 - respond, recover and learn.

The tools will provide managers with an overview of their organisational resilience at each stage and present a series of approaches (or interventions) which can be applied to improve the resilience of each stage. The ERMG will also develop a series of tools which will allow owners/managers to measure the current resilience of their CI and set benchmarks for improvement in the future (CI-RAT). EMRG will also develop a tool (PARET) to support the development of resilience enhancing strategies. These tools are similar in principle to the RAIF being developed in the LIQUEFACT project.

3.2.3 The RESILENS D2.2 (2016) provides details of the qualitative, semi-quantitative and quantitative methods and measures that will be used by the CI-RAT tool. The report reviews each of the methods in turn, examining the types of metric used by each method and assessing their relevance to the RESILENS project.

3.2.4 Quantitative approaches use deterministic, probabilistic, optimisation, simulation, and fuzzy cognitive mapping methods. In the context of RESILENS (ibid) these will consist of indices and characteristics (I&C) that will describe the system at the physical, operational and organisational levels. The I&C's will be weighted to reflect the relative importance of each

I&C to each level. This way the individual I&C's can be combined to provide a partial resilience score for each level (e.g. physical) and an overall score for the resilience of the whole system. In addition to describing the methodology, the report also identified the main difficulties it expected to encounter when applying the methodology to the CI-RAT, including the difficulty identifying the most suitable I&C's to describe the system. The report drew particular attention to the need to ensure that no overlap of information existed between C&I's (otherwise the same issue would be scored more than once), to ensure that an objective measure can be made of each I&C and ensure that the most suitable weights are given to each I&C. These issues will also be pertinent to the development of the LIQUEFACT RAIF model.

3.2.5 Semi-quantitative methods use resilience-based system characteristics (e.g. redundancy) as a means of qualifying overall system resilience. The application of such methods normally rely on expert opinion to identify system characteristics or domains and the application of a scaling measure (e.g. Likert, percentage etc.) to score the importance of each characteristic or domain. An aggregation of the responses across each domain can then be used to assess overall system resilience. This approach is most noticeably used in the UNISDR scorecard for assessing community resilience (reviewed later in this report) and Cutter's DROP model (that forms the basis of the LIQUEFACT RAIF model). The RESILINS project (ibid) will also use the critical assumptions drawn from Cutter's DROP model as the basis to assess CI resilience. As such the CI-RAT tool should be consistent with LIQUEFACT's RAIF model.

3.2.6 Qualitative methods use descriptive and reflective approaches to explore the social and organisation aspects of CI resilience by focussing attention on issues such as organisational culture, leadership, politics etc. Whilst acknowledging the importance of such approaches, the RESILENS report (ibid) drew attention to the difficulty in applying the findings from previous organisational studies directly to another organisation (because of context dependency). This said, the general principles used to identify the findings can be used to guide reflection into the role that culture/environment, leadership/hierarchy, reporting and monitoring, training/learning, flexibility, adaptive capacity have on CI and community resilience and as such they do play an important role in guiding an organisation's approach to disaster resilience management.

3.2.7 Following their review of alternative methods and toolkits the RESILENS project opted for a similar approach to that used by the UNISDR as the basis for their CI-RAT toolkit. The UNISDR toolkit is based on ten 'essentials' covering the range of issues associated with resilience. Each 'essential' is in turn divided into a number of sub-issues that can be identified and a measure (score) assigned. Adopting a similar approach the CI-RAT identified 54 items (Table 4) grouped into 12 components and three requisites (phases) (RESILENS

D2.2, 2016). Each item will be scored from 0-5 to allow the resilience of CI to be assessed at each stage as well as an overall CI system score to be calculated. More details on the UNISDR Scorecard will be provided later in this report.

3.2.8 The RESILENS report (RESILENS D2.2, 2016) also briefly described the PARET tool which will allow CI managers to understand what the resilience score obtained through CI-RAT means to their organisation and to identify what actions can be taken to improve it. Using the PARET tool the CI managers will be able to identify changes to procedures that affect individual items (or multiple items) in the CI-RAT and model the potential impact of such changes on individual component scores and the overall resilience of the CI system. In this respect the PARET tool has very similar objectives to resilience aspects of LIQUEFACT's RAIF tool.

3.3 Improved Risk Evaluation and Implementation of Resilience Concepts to Critical Infrastructure (IMPROVER)

3.3.1 IMROVER is a three year project whose overall objective is to improve the resilience of European CI to crises and disasters through the implementation of resilience concepts. The project aims at developing a methodology for implementing *"combinations of societal, organisational and technological resilience concepts to CI based on risk evaluation techniques and informed by a review of the positive impact of different resilience concepts on critical infrastructure"*. In this respect the IMPROVER project has similar objectives to the LIQUEFACT project.

3.3.2 The IMPROVER project focuses on the high interconnectivity of society and on the interdependencies among CI systems that can be affected by natural and man-made disasters. IMPROVER define CI as *"an asset, system or part thereof located in Member States which is essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people, and the disruption or destruction of which would have a significant impact in a Member State as a result of the failure to maintain those functions"*. The project analysed the concept of CI system resilience and identified the need to maintain a minimum level of key societal functions in order to reduce adverse impacts of CI failure on society as a key factor that has to be addressed in any CI resilience scoring system. Consequently, the key parameters to be associated with resilience are the performance of the system and its acceptable level of inoperability, rather than the direct impact of a disaster event on the physical CI assets. In order to operationalise the methodology, the IMPROVER project proposed a four level hierarchy of indicators. This is similar to the AHP approach outlined in the LIQUEFACT proposal and RAIF model.

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3.3.3 In order to inform the development of a set of indicators to measure the resilience of CI systems, the IMPROVER project reviewed the international literature pertinent to resilience and mapped this against the needs of different stakeholders (IMPROVER D1.1,2016). In the review the authors explored the definitions of resilience and drew attention to differences between engineering resilience, ecological resilience, and social-ecological resilience and considered the relevance of each to assessing the resilience of CI systems. In this context engineering resilience focuses on a system's behaviour near its state of equilibrium and uses a measure of the rate at which a system returns to its equilibrium state following a disturbance to assess its resilience. Ecological resilience on the other hand starts with the assumption that a system can have many states of equilibrium and as such will have multiple recovery trajectories. In this case, measuring the rate of recovery would not provide a robust measure of the system's resilience and instead resilience is measured by the magnitude of the disturbance that can be absorbed before the system changes. In essence ecological resilience is aligned with complex adaptive systems where feedback and self-organisation allow the system to re-organise in response to external disruptions. Social-ecological resilience extends the concept of ecological resilience to the different stages in the evolution of complex adaptive systems. In such systems resilience depends on which evolutionary phase is being considered. Finally, system resilience is further complicated by the concept of "panarchy" which considers the impact that sub-systems can have on overall system performance. Thus, social-ecological resilience can be defined by the magnitude of the disturbance the system can absorb and still function, the degree to which the system is capable of self-organisation, and the degree to which the system can learn and adapt (IMPROVER D1.1 pp 15, 2016). In summarising the alternative definitions of resilience, the authors acknowledged that no single definition of resilience could be applied to all CI systems where context and function would inform adaptation and bounce-back. This approach to resilience is similar to that adopted by LIQUEFACT where the RAIF considers CI and community resilience using a system of systems approach.

Table 4: Summary of resilience indicators identified in the RESILENS project (Source: Summarised from RESILENS D2.2)

Component	Item Measured
Organisation and coordination	Organisational responsibility and coordination – aspects associated with CI protection and resilience
	Leadership and governance
	Culture
	Arrangements for training and education of organisation personnel with an open gap and failure reporting system
	Identification of stakeholders, regulations and standards related to CI resilience
	Level of cooperation and coordination among the organisational entities and between the organisation and external stakeholders
	Communication and knowledge sharing
	Coordination with CI stakeholders, relevant to emergency situations, disasters and cascading events
	Resilience practices
Identification, analysis and management of current and future risk	Identification of risks and determination of the DBTs
	Identification of assets and of critical operational business processes
	Mapping analyses of the probability, vulnerabilities and consequences of the various hazards, including links between assets and cascading effects
	Consequences assessment - loss of core services
	Risk assessment and determination of a policy for risk treatment in a methodical and cyclic manner
Budget allocation for CI protection, redundancy and resilience enhancements and the organisation's financial capacity	Planning and budget allocation for CI protection in order to enhance resilience.
	Planning and budget allocation to enhance redundancy and the supply of core services in emergency and disaster situations
	Planning and budget allocation to enhance the organisational preparedness for emergency situations and disasters, including cascading events
Incident response and business	Mapping emergency scenarios

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continuity planning	Awareness of the role that ecosystem services may play in crisis and disaster situations
	Preparing incident response plans also covering disasters and crises
	Preparing a recovery and business continuity plan for emergencies, disasters and crises
Safeguarding CI assets with electronic and physical means	Safeguarding CI site perimeter
	Access management arrangements for employees, contractors and suppliers
	Protection against forced entry into secured sites, burglar alarm and intrusion detection
	Threat detection
Safeguarding logical assets	Safeguarding the communication network of mission critical systems from computer hacking and cyber attacks
	Logical protection of mission critical systems through threat detection and IDS systems
	Assimilation of procedures and policies for network administrators, contractors, employees filling operational and administrative positions
Building codes and infrastructure hardening	Building codes for hardening structures, infrastructures and critical physical assets
	Hardening of structures, infrastructures and critical physical assets
Early warning and information management systems	Early warning system
	Information management and personnel awareness
Robustness of communication networks, mission critical systems, power / energy supply, supply chain and core services	The robustness of backbone communication network
	Redundancy, back-up and robustness of mission critical systems, and their ability to withstand failures, malfunction, disasters and hostile attacks, based on the DBT
	The robustness of power supply systems
	The robustness of the operational supply chain
	The robustness of power / energy supply systems (power / energy system
	The robustness of core services provided by the CI operator

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Immediate actions	Immediate actions to avoid a mass casualty incident
	Immediate actions to prevent loss of essential information and core services
Responsiveness - exercises for identified potential emergencies, disasters, crises and unexpected events	Conducting exercises for the organisation's employees on handling identified potential emergencies, disasters, crises and unexpected events
	Joint exercises for the organisation and external stakeholders – first responders, community and governmental responders
	Availability of organisational labour and capacities necessary during most severe and most probable scenarios
	The extent/availability of resources provided by responding bodies and their capacities, necessary during most severe and most probable scenarios
	Availability of external labour (contractors, experts), necessary during most severe and most probable scenarios
	Availability of community labour, necessary during most severe and most probable scenarios
	Availability of engineering equipment, necessary during most severe and most probable scenarios
	Availability of communication means, necessary during most severe and most probable scenarios
	Ensuring availability of welfare and relief equipment at CI operators and owners facilities, necessary during most severe and most probable scenarios
	Line of communication with the public, necessary during most severe and most probable scenarios in accordance with the CI operator or owner response plan where the CI operator or owner provides this communication or has established links with the providing organisation
	Command and control during incidents in accordance with the CI operator or owner response plan
Funding resources availability	Liquid financial sources for recovery from disasters ('rainy day fund')
	CI Protection (CIP) and CI Resilience (CIR)
	Learning from past incidents – emergencies and crises affecting CI and society

3.3.4 Following their review of general resilience, IMPROVER then examined the concept of disaster resilience and its relationship to disaster risk reduction (IMPROVER D1.1, 2016). Whilst the report cited the generally accepted definition of disaster resilience as *"the capacity of a system, community, or society potentially exposed to hazards to resist, absorb, accommodate and recover from disasters timely and efficiently"* it drew attention to the differences in the academic literature between those who view resilience as an outcome and those who view it as a process. Those who view resilience as an outcome define resilience as the system's ability to bounce back or cope with a disaster or survive the disaster with minimum impact or damage. Those who view resilience as a process define resilience as the ability of the system to adapt and learn so as to mitigate future disasters. The report also cited the work of Djalante et al (cited in IMPPROVER D1.1, 2016) who argued that resilience should be considered as both a process and outcome with Djalante and Thomalla (cited in IMPROVER D1.1, 2016) identifying sustainable development, disaster risk reduction, and community resilience as important elements of integrated disaster resilience. This again is consistent with the approach adopted in the RAIF.

3.3.5 When considering community resilience the report (IMPROVER D1.1, 2016) reviewed various models of community resilience, identifying Cutter's Disaster Resilience of Place (DROP) as the most appropriate for assessing community resilience and for improving the resilience of European CI systems. This theoretical position is the same as that cited in the LIQUEFACT proposal and used as the basis of the RAIF.

3.3.6 In reviewing the DROP model the report (IMPROVER D1.1, 2016) drew attention to the primary importance of the technical, organisational and social/societal dimensions, whilst also acknowledging the role of the economic and environmental dimensions when assessing the resilience of CI systems to disruptions.

- The technical dimension of resilience views resilience from an engineering perspective. In the context of CI this relates to the ability of the physical components within a CI system to retain and/or restore functionality after a disaster event. The attributes of a resilient system consist of robustness, redundancy, resourcefulness, and rapidity. Resilience is measured through indicators applied before a disaster event (e.g. probability of failure, quality of infrastructure, functionality, substitutability, interdependency, mitigation actions, disaster planning, communications/information sharing, security etc.) and after the event (systems failure, severity of failure, post event functionality, damage assessment, cost of reinstating functionality, recovery time, recovery/loss ration etc.) (Prior T, 2015 cited in IMPROVER D1.1, 2016)

- The organisational dimension of resilience views resilience from an ecological perspective (author's interpretation as no direct statement was found in the report). In the context of CI systems it relates to organisational capacity, planning, training, leadership, awareness and understanding of the operating environment and the ability to respond to rapid change. Resilience is measured through indicators that measure characteristics of an organisation (e.g. leadership, culture etc.) and activities/capabilities of an organisation (e.g. risk management, communications etc.) (Gibson and Tarrant, 2010 cited in IMPROVER D1.1, 2016).
- The social/societal dimension of resilience views resilience from a social-ecological perspective (author's interpretation as no direct statement was found in the report). In the context of CI systems, which underpin most modern societies, the challenge is to understand the relationship between CI services in a time of disruption and the resilience of the community that is being supported. Whilst the report discussed a wide range of indicators from literature it didn't identify which of them are directly relevant to CI systems, instead referring to different concepts in different countries.

3.3.7 Following a review of community resilience the report (IMPROVER D1.1, 2016) examined CI resilience. The report cited the EU definition of CI as an *"asset, system, or part thereof located in Member States which is essential for the maintenance of vital societal function, health, safety, security, economic or social well-being of people, and the disruption or destruction of which would have a significant impact in a Member State as a result of the failure to maintain those functions"*. The report drew attention to the fact that most modern CI's are considered to be complex systems and, despite the increase in the number of national policies and strategies that include resilience as a key component of their CI protection programmes, there are not many official definitions of what CI resilience is.

3.3.8 Where definitions do exist they emphasise the need for the CI system to have the capability to anticipate, resist or absorb, react, adapt and recover from an event. In the case of recovery this could be to its original state or a modified state. However, in either case, during the recovery period the system must be able to provide an acceptable minimum level of service whilst undergoing change. The concept of a minimum level of service is critical in ensuring that impacts on the wider community are minimised and this is why, when assessing the resilience of CI, it is essential to focus on the performance (service delivery) of the system and not just on the impact of the disaster event on the physical assets. However this poses a problem to those trying to develop CI resilience scoring systems as each infrastructure system will have different performance characteristics. This makes defining resilience for CI systems complex and the definition of a single set of indicators impossible. What can best be hoped for is to identify the antecedent dimensions (optimal and minimal performance levels) of the system and then assess the ability of the system to deliver these service levels against disaster scenarios. In essence, resilience in this context is viewed as a conceptual framework composed of multiple interconnected dimensions. The idea of a multi-dimensional framework linking CI disaster resilience to community resilience is addressed by the Australian Government (Australian Government, 2010) in their CI resilience strategy. This concept also underpins the RAIF model being developed in the LIQUEFACT project.

3.3.9 In a separate study (IMPROVER D4.1, 2016) IMPROVER explored the social resilience criteria that CI providers need to consider during a disaster event. Through a series of structured interviews with infrastructure operators and experts (n=42) and a questionnaire survey of the general public (n=403) IMPROVER examined service level expectations across a range of CI systems. Whilst the performance criteria were specific to each CI system, some general lessons can be drawn on the expectations of the public following a disaster event. It did appear possible across different types of infrastructure to identify service level performance expectations that could inform the minimum level of service provision expected during and immediately following a disaster event. For some CI's it was possible to define only qualitative performance expectations (e.g. the general expectation amongst the public that the transport system should allow them to evacuate an area using their car) whilst for others is was possible to identify a quantitative metric as well (e.g. there was an expectation for water supply to be restored within 8 hours). Whilst both of these examples are specific to the context of the individual infrastructure service area (e.g. country, region etc.) the finding is important to the LIQUEFACT project as it provides evidence to substantiate one of the key assumptions underpinning the RAIF; that CI providers will be able to express an optimal and minimal service performance level in the occurrence of a disaster event and hence be able to establish a baseline against which the effect on resilience of alternative mitigation actions can be judged.

3.3.10 A further study (IMPROVER D2.2,2016) developed an outline assessment tool to calculate a CI resilience indicator (CIRI) that could be applied to all types of CI and tailored to address different hazard scenarios. The CIRI tool comprises a four level hierarchy structure that can be contextualised against three resilience domains (societal, organisational, and technological), four hazard types (natural, man-made non-malicious, man-made malicious, and multi-hazard), and any number of situational factors (e.g. seasonal, business hours etc.). Level 1 indicators in the hierarchy represent the crisis management cycle (risk assessment, prevention, preparedness, warning, response, recovery, and learning) and are applicable to all types of CI. Level 2 indicators provide generic indictors that operationalise the Level 1 indicators. These indicators are largely drawn from the resilience literature. Level 3 and Level 4 indicators express the Level 2 indicators in a measurable form and are contextualised to reflect the specific circumstances being assessed. Once the Level 3 and 4 indicators are identified they are assessed against a maturity level. Maturity levels are scored from 0 to 5 using Table 5. Once scored the indicators at each level are aggregated (using simple or

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weighted aggregation) and combined to provide an overall CIRI score. This approach, whilst different in its detail, is consistent with the Analytical Hierarchy Process model outlined in the LIQUEFACT proposal and used as the basis for assessing CI resilience in the RAIF.

Table 5: COBIT 4.1 Process Maturity Model. (Source IMPROVER D2.2)

Level 3 Metrics			Level 4 Metrics
0	Non-existing	Complete lack of any recognisable processes. The organisation has not even recognised that there is an issue to be addressed	Specific metrics of any indicator are transformed into processes, procedures, series of actions, series of operations, schemes, methods, or systems, corresponding one of the maturity levels 0-5
1	Initial/Ad Hoc	There is evidence that the organisation has recognised that the issues exist and need to be addressed. There are, however, no standardised processes; instead there are ad hoc approaches that tend to be applied on an individual or case by case basis. The overall approach to management is disorganised.	
2	Repeatable but Intuitive	Processes have developed to the stage where similar procedures are followed by different people undertaking the same task. There is no formal training or communication of standard procedures, and responsibility is left to the individual. There is a high degree of reliance on the knowledge of individuals and therefore errors are likely.	
3	Defined Process	Procedures have been standardised and documented, and communicated through training. It is mandated that these processes should be followed, however, it is unlikely that deviations will be detected. The procedures themselves are not sophisticated but are the formulations of existing practices.	
4	Managed and Measurable	Management monitors and measures compliance with procedures and takes action where processes do not appear to be working effectively. Processes are under constant improvement and provide good practice. Automation and tools are used in a limited or fragmented way.	
5	Optimised	Processes have been refined to a level of good practice, based on the results of continuous improvement and maturity modelling with other organisations. IT is used in an integrated way to	

		automate the workflow, providing tools to improve quality and effectiveness, making the organisation quick to adapt.	

3.4 Smart Resilience Indicators for Smart Critical Infrastructures (SmartResilience)

3.4.1 The SmartResilience project is a three year project which aims to develop an innovative "holistic" methodology for assessing the resilience of smart CI systems. The project has reviewed existing resilience indicators and analysed their suitability for assessing the resilience of new, smart CI systems. The SmartResilience project will also develop a set of smart resilience indicators, including those from Big Data, and develop a resilience assessment methodology and associated tools to provide an integrated assessment of a city's resilience to disaster events. The tool will be tested and validated through eight case studies.

3.4.2 As a precursor to developing a range of smart resilience metrics the SmartResilience project reviewed existing frameworks for resilience assessment and in particular analysed a number of current EU projects to identify similarities in definitions and the range of indicators used by each project. As a consequence of this review the SmartResilience project identified eight dimensions and issues associated with CI resilience (SmartResilience D1.1, 2016):

- Anticipate
- Prepare
- Be Aware/Attentive
- Absorb
- Respond
- Recover
- Adapt
- Understand the risk

The review also noted that the focus for measuring SmartResilience was not on measuring the resilience of the physical asset(s) but on indirectly measuring the various resilience dimensions through the development of resilience indicators at each phase of the resilience curve (SmartResilience D1.1 pp4, 2015). In essence, SmartResilience focuses on measuring smart functionality rather than generic system functionality. This is again consistent with the approach adopted by LIQUEFACT where the indirect impact of liquefaction on service level performance is measured as a consequence of the physical damage to a built asset.

3.4.3 In addition to reviewing resilience indicators the SmartResilience project also investigated end-user challenges and requirements for assessing resilience (SmartResilience D1.3, 2016). Through a review of literature and a series of interviews with end-users, the project identified the need for indicators to be contextualised for local circumstances and end-user needs. As such the SmartResilience projects concluded that one prescriptive set of indicators is unlikely to address the range of issues faced by different infrastructure organisations. This finding was further enforced when the feedback from the different infrastructure sectors was considered. Of direct relevance to the LIQUEFACT project are the end-user challenges faced by healthcare providers, transportation infrastructure, water supply providers, and energy supply providers, as well as the inter-relationships between CI systems.

3.4.4 With relation to healthcare infrastructure, the key challenges were a better understanding of the scenarios that might lead to severe disruption and the formulation of effective response plans that are regularly tested in large scale simulations. Further, as service delivery models become ever more complex, the interconnectedness between systems will become critical with both physical (e.g. power) and virtual (e.g. data) supply chains potentially being the weak link in the service delivery model. As such any resilience models must consider the resilience of the supply chain.

3.4.5 For a transportation infrastructure the key challenges were more related to the nature of the hazard and the effect that this has on business continuity and speed of recovery. Whilst most transportation infrastructure providers should have emergency response and disaster management plans in place, there is a need to invest in human resources so that staff are aware of how to respond should the actual disaster event vary from the planned (and hopefully tested) scenario. With relation to speed of recovery, one of the major challenges is persuading stakeholders of the benefits of investing in mitigation interventions that go beyond the response phase into the recovery phase. As such any resilience models must make the cost/benefit case.

3.4.6 For the water supply infrastructure, the key challenges were associated with the abstract nature of the water system resilience concept and the lack of relevant indicators and metrics to measure the concept. In the future this is likely to be confounded by: the need to assure the quality and availability of water (climate change), increased demand due to urbanisation and population growth, and the risk of microbial outbreaks. Whilst all these issues appear to be specific to the case study example, they do, in the authors' opinion, reflect a more generic resilience issue around service level expectations, both in terms of level of supply and customer expectations, that will need to be addressed in resilience models.

3.4.7 For the energy supply infrastructure, the key challenges were focussed around the need to better understand new hazards and for a better indicator based system to support the improvement of resilience over time. There was also a need for indicators to measure and follow-up on proposed actions and for better communication and coordination between suppliers and regulators. In the future the major challenge was again perceived to arise from an ever more complex energy system involving a wider range of energy generation systems and the development of smart grids. Again, whilst this might initially seem to be a specific issue related to the energy sector, it could also be indicative of any sector where the service delivery models are undergoing significant (radical) change. Such change inevitably introduces unknown risks into the service delivery model making the modelling of resilience even more complicated.

3.4.8 With respect to the challenges facing those who are seeking to better understand the inter-relationships between indicators, the key challenge is to understand cascading risks and the affect that accumulating risks have on overall system resilience. In particular, indicators are needed that can aggregate risks from several sources which in turn means risk indicators need to be consistent between (and across) organisations. This however could run contrary to the need for resilience indicators to be contextualised for the infrastructure type being considered. This will be a key issue to be addressed in the LIQUEFACT project.

3.4.9 Whilst it is acknowledged that the above examples are drawn from single case studies, the key issue identified for the LIQUEFACT project is that the impacts a disaster has on service delivery is of key concern to CI providers and not on the damage disaster event caused to their physical assets. This issue is clearly addressed in the RAIF.

3.5 Expecting the unexpected and know how to respond (DARWIN)

3.5.1 The Darwin project is a three year project focusing on improving responses to expected and unexpected crises affecting critical societal structures during natural disasters (e.g. flooding, earthquakes) and man-made disasters (e.g. cyber-attacks). DARWIN aims to develop European resilience management guidelines for CI managers, crisis and emergency response managers, service providers, first responders and policy makers. The DARWIN guidelines will provide CI operators up-to-date and effective guidance to facilitate faster, more effective and highly adaptive responses to crises. The guidelines will be tested in strategic pilot studies in two key sectors: healthcare and air traffic management. The DARWIN guidelines will have a direct impact on the safety of European citizens in times of crisis and disaster into the future. The DARWIN resilience guidelines will also be of significant benefit for governments of EU member states. To this end the outputs from DARWIN are similar to those envisaged for the LIQUEFACT project.

3.5.2 In preparation for the development of the DARWIN Guidelines the DARWIN project team performed a very thorough literature review of resilience concepts as they relate to crisis management. The review examined 419 articles and identified eight reoccurring concepts in resilience and crisis management (DARWIN D1.1, 2015). The eight concepts where:

- Link between community resilience and other efforts
- Continuity and persistence of critical services and functions
- Attention to vulnerable groups
- Generic characteristics of the resilience concept
- Special characteristics of community resilience
- Sensitivity to social and cultural foundations
- Resilience in the context of compliance, planned protection and risk management
- Resilience of CI

3.5.3 Associated with each of these concepts were a number of practices and approaches that were examined through a Delphi study to identify those where expert consensus could be obtained. In all 56 concepts, practices and approaches were subject to a two round Delphi study. In the first round 42 concepts, approaches and practices achieved an 80% or higher consensus for being incorporated into resilience management guideline; 14 didn't. In the second round the 14 concepts, approaches and practices that didn't achieve consensus along with three new concepts, approaches and practices identified in round 1 were included with nine of these obtaining 80% or higher consensus. The 51 concepts, approaches and practices that between the two Delphi rounds obtained 80% or higher consensus were then categorised as:

- Collaboration concepts, approaches and practices (eleven in all)
- Planning concepts, approaches and practices (eight in all)
- Procedural concepts, approaches and practices (eight in all)
- Training concepts, approaches and practices (six in all)
- Infrastructure concepts, approaches and practices (five in all)
- Communication concepts, approaches and practices (three in all)
- Governance concepts, approaches and practices (three in all)
- Additional concepts, approaches and practices (seven in all)

Although the DARWIN guidelines are primarily intended for crisis management their range and generic form are consistent with the approaches identified by the LIQUEFACT project.

3.6 Supporting Decision Making for Resilient Cities (RESIN)

3.6.1 The RESIN project is a 41 month, interdisciplinary, practice-based research project that aims to compare and evaluate the methods that can be used to plan for climate adaptation in order to move towards formal standardisation of adaptation strategies. The project investigated climate resilience in European cities and will develop practical and applicable tools to support cities in designing and implementing climate adaptation strategies for their local contexts. The project reviewed approaches to climate change adaptation, resilience and disaster risk reduction definitions in different disciplines (social, sciences, economics, engineering etc.) and sectors (energy, infrastructure, health, tourism etc.) to identify the most appropriate definition for the project. The RESIN project defined resilience as the ability to function, survive and thrive, no matter what stress or shocks happened. It should include the ability to maintain critical operations of infrastructures in the face of crises, to skilfully prepare for, respond to and manage a crises, to skilfully prepare for respond to and mange a crisis or disruption as it unfolds and to return to and/or reconstitute normal operations, as quickly as possible, after disruption.

3.7.6 The RESIN project is currently (April 2017) developing an impact and vulnerability analysis tool to support and guide the process of impact and vulnerability analysis for CI and built-up areas and a decision support system for stakeholder analysis, risk and vulnerability assessment, prioritising between adaptation options and risk reduction strategies, and monitoring and evaluation. These tools are based on a series of 'State of the Art' reports (http://www.resin-cities.eu/resources/sota/, 2017) that review urban CI systems: resilience, adaptation and disaster risk reduction and vulnerability assessment (amongst others). The Impact and Vulnerability Analysis tool is supported by a review of vulnerability indicators that recognise that when considering CI systems the focus of any assessment should be on the *"capacity of resilience i.e. the ability of the system to anticipate, cope with or absorb, resist and recover from the impact of a hazard"* rather than on a narrow hazard-centric view that informs traditional risk management approach (RESIN, 2015). Further, RESIN identified a key difference between vulnerability assessments compared to damage assessments for CI systems, concluding that vulnerability assessments should focus on determining the consequences of hazard impacts as well as the damage caused to the physical assets by hazard impacts. Although no specific resilience indicators were apparent in the RESIN project the focus on resilience rather than resistance, and impact on services rather than physical assets, when examining the vulnerability of CI systems is consistent with the approach adopted by the RAIF model.

3.7 A PanEuropean Framework for strengthening Critical Infrastructures Resilience to Climate Change (EU-CIRCLE)

3.7.1 EU-CIRCLE is three year project to develop a resilience framework to assess European Infrastructure's resilience to climate stressors. The main objectives of EU-CIRCLE are to understand the impacts that current and future climate has on the performance of European CI systems, with a view to developing a framework which will support a change in thinking from prevent and respond to climate disasters to developing resilient infrastructure solutions. In particular, EU-CIRCLE will address the issues of interconnectivity and interdependence between systems; acknowledging that extreme climate related events are liable to lead to 'cascade failures'. Although the fundamental stressor addressed by EU-CIRCLE is different to those of LIQUEFACT, the output objectives are similar. As such the approaches adopted by EU-CIRCLE are relevant to the LIQUEFACT project.

3.7.2 The EU-CIRCLE project has developed a climate hazard risk assessment framework that is similar in concept to that developed by Jones et al (CREW, 2008) in the CREW project and cited in the LIQUEFACT proposal. The EU-CIRCLE risk framework is based on six steps (EU-CIRCLE D3.4, 2016):

1. Establish CI resilience policy or set specific business goals
2. Identify hazard risks
3. Identify assets, systems, networks and their functions
4. Assess and evaluate risks
5. Identify, prioritise and programme mitigation measures
6. Measure effectiveness of interventions

3.7.3 The six steps are integrated into a decision framework that will (full details not publically available at the time of writing this report) measure the disruption and impact of a hazard on an individual asset and on society in general. When considering impacts, EU-CIRCLE identifies two separate but interconnected types of impact: direct impacts to the CI and indirect impacts to society. Generic direct impacts include:

- Damage to CI assets
    - Severity of damage
    - Type of damage
    - Degree of damage
- Impacts on CI functional performance
    - Fragility of the service
    - Reduction in the service
    - Changes in service demand

    - Robustness and Redundancy of service
    - Response and Recovery of service provision (at different service levels)
- Safety and Operating processes
    - Asset condition
    - Safety critical components
    - Risk levels
- Casualties
    - To CI staff and the wider public
    - Mortality and morbidity statistics
- Economic and Financial
    - Cost of damage to CI
    - Loss of income
    - Penalties incurred from service level agreements.
    - Cost of replacement services
    - Recovery costs
    - Future increased maintenance costs
- Environmental loss
    - Pollution
- Reputational Loss.

Generic indirect impacts include:

- Impact on society groups
    - Number and demographic of people affected by loss of (or reduction in) service
    - Number and type of properties affected by loss of (or reduction in) service
    - Psychological effects on individuals
- Causalities
    - Mortality and morbidity rates
- Economic impacts
    - Disruption to economic activity
    - Local and regional financials losses
    - Migration of people and industries
    - Impact on real estate asset values

Although EU-CIRCLE considered only horizontal infrastructure the same principles could be applied to building oriented CI systems (e.g. healthcare sector).

3.7.4 In order to assess the resilience of CI, the EU-CIRCLE project is developing a set of indicators from an analysis of existing resilience frameworks (EU-CIRCLE D4.1, 2016). The EU-CIRCLE indicators seek to identify, and where possible quantify, the hazards, risks and vulnerabilities that need to be considered in a resilience framework. In particular the indicators seek to address the 'resilience of what' and the 'resilience for what'. Whilst not limited to the guidance outlined in the UNISDR Disaster Resilience Scorecard, the proposed indicators do draw on the CI section of the scorecard. Although the final set of indicators being developed in the EU-CIRCLE project is not yet publically available (April 2017), a list of general indicators is provided in EU-CIRCLE D4.1. These generic indicators are grouped into five sections:

- Anticipation:
    - Probability of failure
    - Quality of infrastructure
    - Pre-event functionality of infrastructure
    - Quality/extent of mitigating features
    - Quality of disaster planning/response, communication/information sharing
    - Learnability
- Absorption:
    - Systems failure
    - Severity of failure
    - Reliability of supply chain
    - Level of post event functionality
    - Resistance and robustness of systems
- Coping:
    - Withstanding
    - Redundancy
    - Resourcefulness
    - Response
    - Economic sustainability
    - Interoperability
- Restoration:
    - Post-event damage assessment
    - Post-event recovery time
    - Recovery/Loss ration
    - Cost of reinstating service provision
- Adaptation:
    - Substitution (replacement service)
    - Adaptability/Flexibility
    - Impact reduction
    - Consequences of reducing availability.

3.7.5 The final consideration in the development of resilience indicators is the method by which indicators can be combined to produce a meaningful value for the resiliency of an individual CI asset. From a review of alternative approaches (EU-CIRCLE D4.2, 2017), EU-CIRCLE identified the Analytical Hierarchy Process as the most appropriate method for identifying the relative weights that should be applied to each indicator and Multi-attribute Utility Theory as the most appropriate method for combining analytical and subjective valuations into overall resilience scores. These methods are consistent with the approaches outlined in the LIQUEFACT proposal and included in the RAIF model.

3.8 Summary of Current Approaches to Assessing CI Resilience

The LIQUEFACT project has reviewed 6 current EU funded projects that are exploring issues pertinent to improving the resilience of buildings/CI systems to natural and manmade disaster event (RESILENS, IMPROVER, SmartResilience, DARWIN, RESIN, and EU-CIRCLE) to identify the theoretical approach that they have used to model the resilience of CI systems and the indicators and metrics they intend to use to assess the resilience of each system. The generic approach adopted by the toolkits is consistent with that used by the UNISRD Disaster Resilience Scorecard for Cities. Each toolkit seeks to identify a range of issues that affect the resilience of the CI system and then express each issue through a number of items that can be measured using a quantitative or qualitative scale. Where the various toolkits differ is in the way they define the issues, which will vary depending on the type of CI system being considered (e.g. Healthcare, Transportation, Power etc.), and the relationships they assume exist (or not) between issues (e.g. relationship between technical systems and performance of service delivery). As such no single toolkit currently under development will provide sufficient detail to allow the mitigation options appraisal required in the RAIF. Thus LIQUEFACT will develop its own CI toolkit that will seek to build on those currently under development in other EU funded projects and extend their scope to include an assessment of the impact of EILD events on service design and delivery as the primary resilience factor. Ultimately it is the performance of service delivery that is critical to the post-disaster recovery of communities to a disaster event.

4 THE UNISDR DISASTER RESILIENCE SCORECARD FOR CITIES

4.1 In 2015 the UNISDR (UNISDR, 2015) developed "The Disaster Resilience Scorecard for Cities" as an assessment method to allow cities to better understand how resilient they are to natural and man-made disasters. The Scorecard has been developed from the "Ten Essential" for Making Cities Resilient in support of the Sendai Framework for Disaster Risk Reduction 2015-2030. The "Ten Essentials" seek to provide a better understanding of: the disaster risks a city might face; how to mitigate the risks; and how to respond to disasters in a way that seeks to minimise loss of life, livelihoods, property, infrastructure, economic activity, and the environment. The "Ten Essentials" are grouped into three sections (Figure 6). Essentials 1-3 address governance and financial issues; Essentials 4-8 address planning and disaster preparation; and Essentials 9-10 address disaster response and post-disaster recovery. The scorecard has been developed to enable cities to establish a baseline measurement of their antecedent level of disaster resilience for each "Essential" and to identify opportunities for investment and action to improve their disaster resilience over time. To this end the Scorecard's objectives are compatible with those of the LIQUEFACT project.

4.1.2 The Disaster Resilience Scorecard for Cities consists of 95 disaster resilience evaluation criteria (Table 6) grouped by subject/issue, details of the item being measured, a qualitative or quantitative statement of an indicative measurement, an indicative measurement scale (from 0 to 5, where 5 is best practice), and comments to help those applying the item being measured. Each item is assessed against two risk scenarios; a "most probable" scenario and a "most severe" scenario. These scenarios are defined by each city in response to its assumed hazard threat level. Where possible individual assessments are based on objective measures but where these do not exist subjective assessments can be made. Irrespective of which type of assessment is used, full justification for the scores given should be recorded; this will not only allow external validation but will also act as a start point for assessing future revisions. Where items are not under the direct control of a single stakeholder, scoring should be done following consultation with all relevant stakeholders. Finally, not all items listed in the scorecard will apply to all situations and as such the scorecard should be contextualised to reflect city specific circumstances and disaster type.

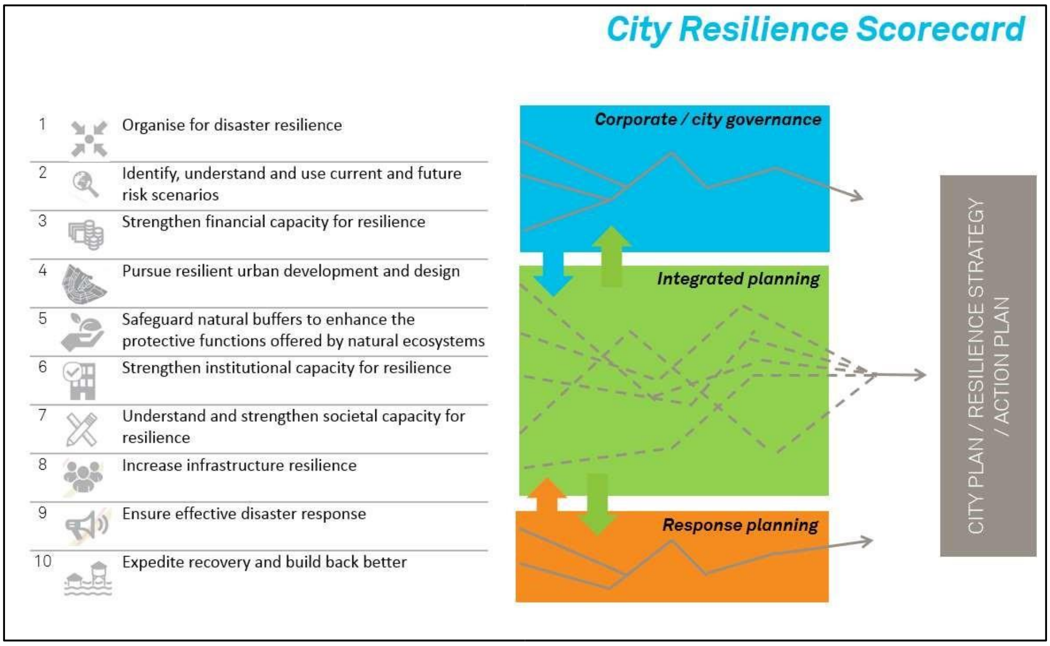

Figure 6: The City Resilience Scorecard (source: UNISDR, 2015)

Table 6: Summary of the subject/issues addressed in the UNISDR Disaster Resilience Scorecard for Cities (Source: Summarised from UNISDR, 2015)

Essential Element	Subject/Issue	Number of Items Measured
Organise for Disaster Resilience	Organisation and Coordination	5
	Integration of disaster resilience with other initiatives	1
	Capturer, publication and sharing of data	2
Identify, Understand and Use Current and Future Risk Scenarios	Risk Assessment	4
	Update process	1
Strengthen Financial Capacity for Resilience	Financial plan and budget	3
	Contingency funds	1
	Incentives and financing for business, community organisations and citizens	5
	Financing of resilience expenditures	1

Pursue Resilient Urban Development	Land use - effectiveness of zoning to prevent exposure build–up	3
	Building codes	3
	New developments	2
Safeguard Natural Buffers to Enhance Protective Functions Offered by Natural Ecosystems	Ecosystem services	3
Strengthen Institutional capacity	Skills and experience	1
	Public education and awareness	2
	Training delivery	1
	Languages	1
	Learning from others	1
Increase Societal and Cultural Resilience	Grass roots organisations	4
	Private sector / employees	2
	Systems of engagement	1
Increase Infrastructure Resilience	Protective infrastructure	2
	Communications	3
	Electricity	3
	Water and sanitation	3
	Gas	4
	Transportation	6
	Law and order, First responders	2
	Education	3
	Healthcare	3
	Administrative operations	1

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	Computer systems and data	2
Ensure Effective Disaster Response	Early warning	1
	Event management plans	1
	Staffing / responder needs	2
	Equipment and relief supplies	1
	Food, shelter, staple goods, and fuel supply	4
	Interoperability and inter-agency compatibility	2
	Drills	2
Expedite Recovery and Build Back Better	Post event recovery planning	3

4.1.3 Experience from those cities that have completed the scorecard suggests that they have done so at three different levels (UNISDR, 2015). Some cities have adopted a high level survey approach where a one to two day workshop supplemented with a pre-event questionnaire has been used to provide a simple (average or consensus) score for each "Essential" and, if required, an aggregated score across all essentials. Other cities have adopted a more focussed approach, concentrating on specific aspects of resilience (e.g. a selection of the "Essentials") to provide an in depth assessment of that specific aspect of resilience (in the case of LIQUEFACT this could be "Essential 8", CI systems). Some cities have taken the opposite approach and performed an in depth assessment of all of a city's resilience "Essentials" but it was noted that such an approach can be very time consuming.

4.1.4 The final decision that those using the scorecard need to make is their approach to aggregating the scores given to the items measured in each "Essential" and between "Essentials". Whilst a simple arithmetic summation or average will provide an overview of a city's resilience, it does assume that all the items are equally important within each "Essential" and that all the "Essentials" are equally important to the city's overall resilience. Such an approach, whilst providing a reasonable basis for general discussions on a city's resilience, is probably a little simplistic if the scorecard is to be used to assess the effectiveness of a range of mitigation actions to improve resilience (as required in the LIQUEFACT project). The scorecard does provide for an alternative approach aggregating the scores using weightings derived from expert opinion and applied through either a simple balanced scorecard approach or a more sophisticated multi-criteria approach such as FCM of AHP. Such an approach is consistent with resilience literature and theory and the other EU

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funded projects that are seeking to develop CI and community resilience toolkits. It is also consistent with the RAIF model developed by the LIQUEFACT project.

4.1.5 Given the current status of the Disaster Resilience Scorecard for Cities and its compatibility with the objectives of the LIQUEFACT project and RAIF, a modified version of the Scorecard will be used as the basis for measuring a city's antecedent resilience to EILD events.

5 ASSESSMENT OF COMMUNITY AND CRITICAL INFRASTRUCTURE RESILIENCE IN THE LIQUEFACT RESILIENCE ASSESSMENT AND IMPROVEMENT FRAMEWORK

5.1 Background

5.1.1 The aim of the RAIF is to provide CI owners/managers and other interested stakeholders with a tool to assess the impact that a range of physical (asset) and service level (performance) EILD mitigation interventions have on improving the resilience of their CI systems and the communities they support to the adverse effects of an EILD event. The RAIF integrates Cutter's DROP model (Cutter et al, 2008) into a built asset management framework to provide a range of tools to assess vulnerability, resilience, mitigation options and adaptive capacity and support the development of business models to identify and prioritise mitigation actions to improve CI and community resilience to EILD events (Figure 7). This approach is consistent with that adopted by other resilience toolkits (see section 2); by current EU projects addressing CI to disaster events (see section 3); and by the Sendai Resilience Scorecard for Cities (see section 4). This section of the report provides background details of the Community and CI resilience tools that will be developed in LIQUEFACT Work Package 5.

5.1.2 The community and CI resilience tools are part of a range of tools being developed by the LIQUEFACT project to assess the potential of a range of mitigation interventions to improve resilience to EILD events (Figure 8). The community resilience tool seeks to assess the antecedent (baseline) and post-mitigation community resilience to an EILD event. The CI tool seeks to assess the resilience of CI system(s) to the EILD event. Figure 7 shows the theoretical positioning of these toolkits (alongside the susceptibility models, risk assessment models, and vulnerability models) in Cutter's DROP model. Figure 5 shows the resilience toolkits mapped against the scenario analysis and mitigation options appraisal in the RAIF. It should be noted that the theoretical background to the RAIF and resilience toolkits are consistent with the approaches outlined in the LIQUEFACT proposal and with the theoretical models and toolkits being developed by the other EU funded projects investigating CI and community resilience to natural and man-made disaster events (see section 3). As such the outputs from LIQUEFACT should be directly compatible with the outputs from the other EU projects.

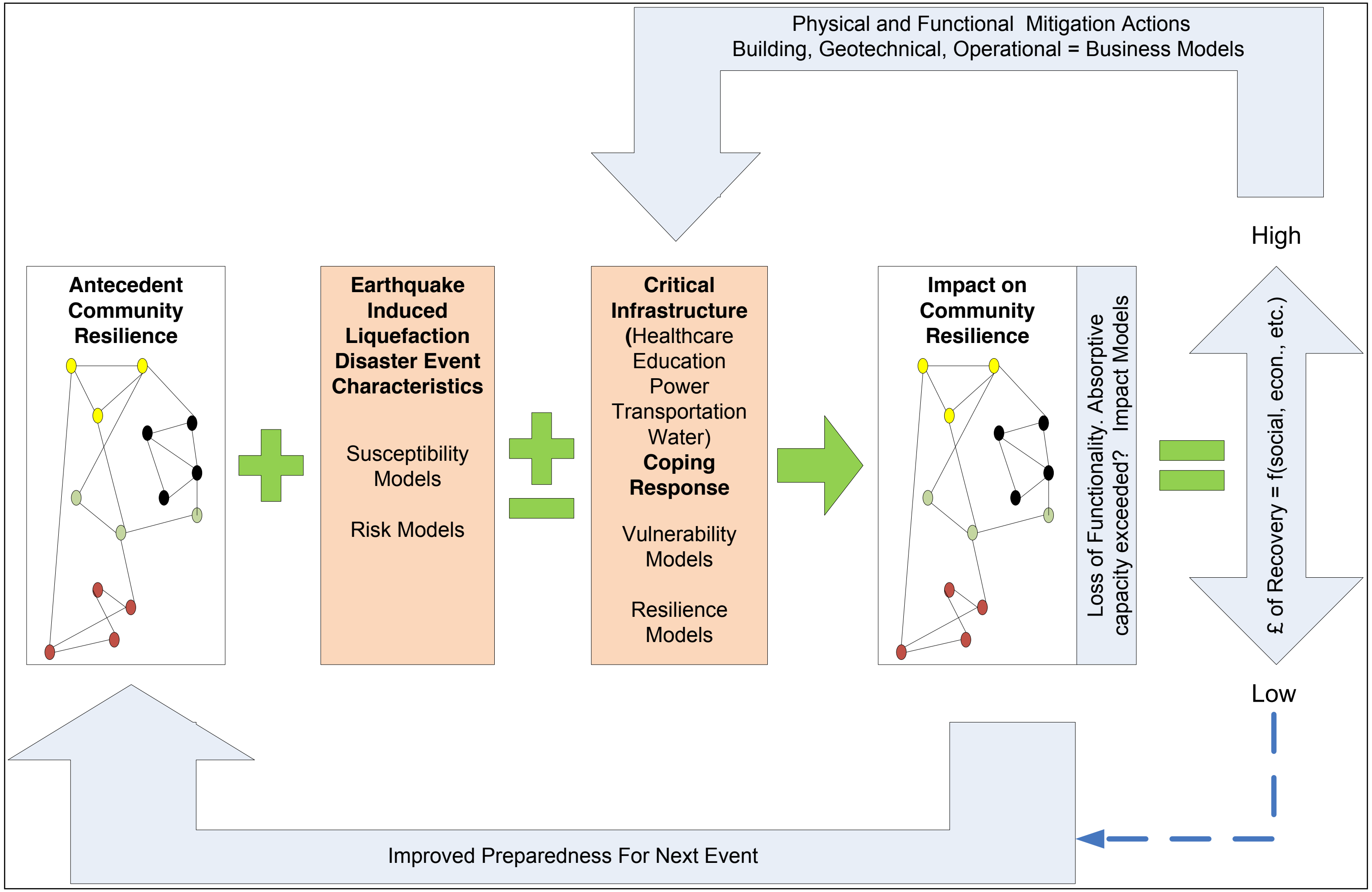

Figure 7: LIQUEFACT RAIF tools mapped onto Cutter's DROP Model

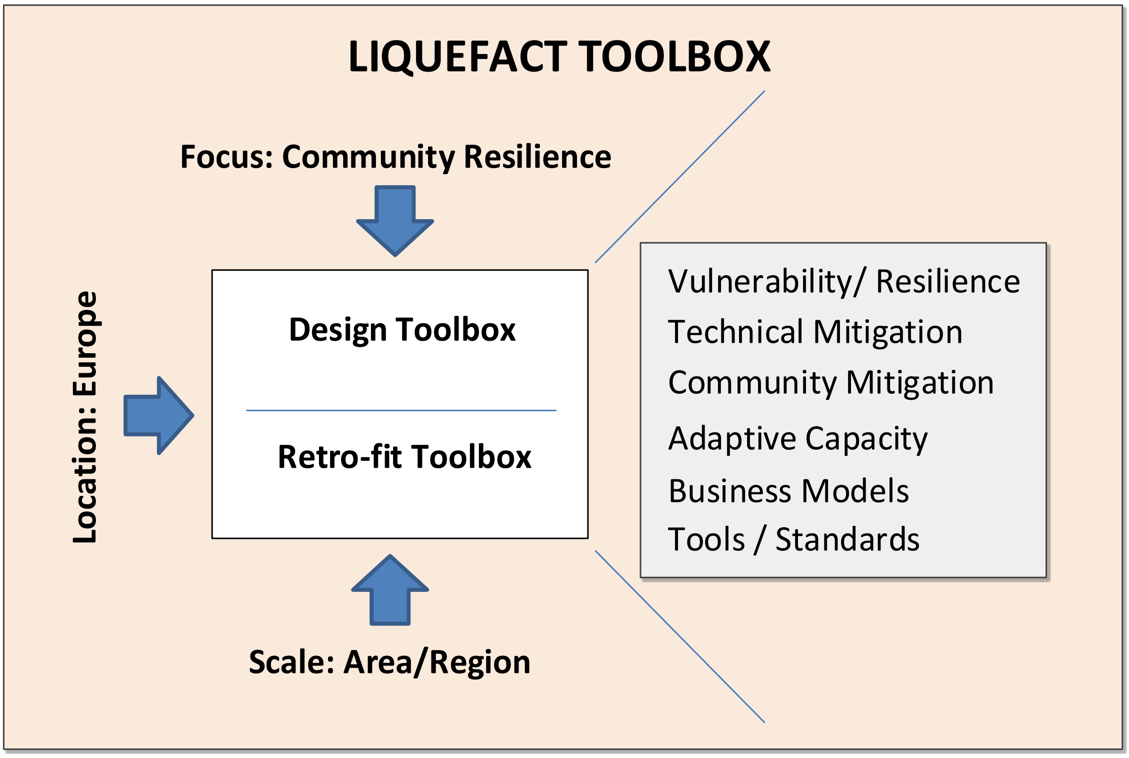

Figure 8: The LIQUEFACT Toolbox

5.2 Assessing community resilience to EILD events

5.2.1 The LIQUEFACT toolbox will use the UNISDR Disaster Resilience Scorecard for Cities (see Table 6 for a summary of the 'Essentials' and Appendix A for full details of the scorecard) as the basis for assessing community resilience to EILD events. The issues, items, indicators and metrics outlined in the scorecard will be reviewed by the LIQUEFACT project partners and Expert Advisory Panel to identify those items that are potentially affected by an EILD event and to rank the relative importance of each item to community resilience to an EILD event. The refined set of issues, items, indicators and metrics will be tested against extreme and probable EILD scenarios applied to the Emilia Romagna region of Italy to assess the community's antecedent level of resilience to EILD events. The resilience of each item will be scored using a 0 to 5 scale (see Appendix A) and normalised to provide a consistent assessment of each issue. The normalise scores for each issue will then be combined using expert derived weightings to provide an assessment of the resilience of each 'Essential'. These will be presented as a radar plot to inform discussion on the potential mitigation interventions required to improve the resilience of each 'Essential' to an EILD event. An assessment of the overall community resilience to EILD events will be modelled using a Fuzzy Cognitive Map (FCM), developed by an expert panel, that ranks the relative importance of each 'Essential' to provide the basis by which EILD mitigation interventions can be modelled and their cost/benefit assessed. The modified scorecard and modelling approach will be validated by a range of Emilia Romagna stakeholders as part of LIQUEFACT Work Package 7.

5.2.2 The generic approach outlined above was tested in LIQUEFACT Work Package 1 during the stakeholder workshop held in Bologna in the Emilia Romagna Region (Italy) on October 3rd 2016. The workshop was organized by UNICAS under the auspices of the "Associazione Geotecnica Italiana"; of the "Ordine degli Ingegneri della Provincia di Bologna"; and of the "Ordine dei Geologi della Regione Emilia Romagna. Two hundred and five participants from a range of occupational backgrounds (engineers, architects, geologists drawn from representatives of municipalities, local authorities, governmental institutions; academic institutions, and private consultants) attended the workshop. During the afternoon session they were asked to complete a questionnaire in which they scored the impact that they thought the range of concepts would have on community resilience to EILD events. In particular respondents were asked to describe the strength of the relationships that they believed existed between the concepts and community resilience using a five-level Likert scale expressed in linguistic terms as "very low", "low", "medium", "high" and "very high". The respondents were also asked to describe the type of influence that they believed each factor has on resilience using the "+" sign to express a positive influence (i.e. as the factor increases/decreases, the resilience increases/decreases) or the "-" sign to express a negative influence (i.e. as the factor increases/decreases, the resilience decreases/increases). If the respondent was confident that no relationship existed between the concept and community resilience they were told to leave the field blank. The final weight of each relationship was calculated as the average (mode and arithmetic mean) of the different scores provided by all the participants. The modal weights for all the concepts are shown in Table 7. The arithmetic mean weights for the grouped factors are shown in Figure 9. From both the mode and arithmetic mean score it is clear that, whilst all the factors (except political leadership) were considered of some importance to community resilience, those that addressed 'technical' issues were generally considered more important than those associated with 'social', 'economic' and 'organisational' issues. One hundred and twelve respondents completed the questionnaire survey.

Table 7: Average (modal) weights assigned by the respondents to the Resilience Questionnaire

FACTOR	WEIGHT		FACTOR	WEIGHT
Poor design and construction	high		Pre-disaster planning	medium
Unregulated land use planning	high		Education	medium
Lack of building codes	medium		Disaster preparedness	medium
Protection of CIs	high		Social cohesion	medium
Protection of built assets	high		Social support	medium
Stock assessment and retrofitting	medium		Social networks	medium

Network redundancy	medium		Poverty	medium
Disaster prone areas	high		Collaboration with research institutes	medium
Early warning	medium		Public participation	medium
Risk assessment	medium		Empowerment	medium
Trained staff	high		Disaster insurance	medium
Emergency response plan	high		Funding mechanism	medium
Public information	medium		Business continuity plan	medium
Hazard mitigation plan	high		Ability to mobilize resources	high
Political leadership	low			

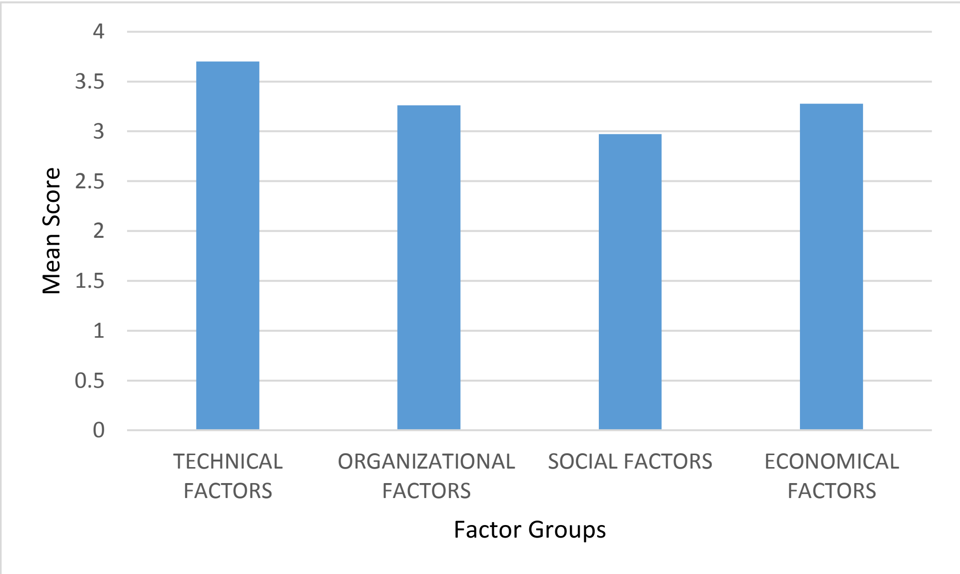

Figure 9: Arithmetic mean score of the weights assigned by the respondents by category of factors

5.2.3 Whilst the specific results from the Bologna workshop are relevant to the future development of the LIQUEFACT community resilience tool, the primary purpose of the questionnaire survey was to assess the ability of community based stakeholders to understand the different resilience concepts and provide both qualitative and quantitative assessments of their importance and weighting that would be consistent with the FCM and AHP approach identified as the basis for the LIQUEFACT resilience tools and the RAIF. To this end the workshop confirmed the suitability of the approach and as such it will be applied to the development of the FCM to assess community resilience to EILD events that will be developed in LIQUEFACT Work Package 5 and tested in Work Package 7.

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5.3 Assessing the Resilience of Critical Infrastructure to EILD events

5.3.1 Although the UNISDR Disaster Resilience Scorecard for Cities contains an 'Essential' element to assess the impact of CI resilience on community resilience, when the items included in the assessment are compared against the review of theory and literature and other EU projects, it is clear that the UNISDR scorecard does not provide the level of detail needed to allow CI managers/owners to critically assess their resilience to disaster events or to evaluate the potential of mitigation actions. As such the LIQUEFACT toolbox will develop a more detailed, bespoke tool, which will assess CI resilience and mitigation options to EILD events. The tool will be based on the principles outlined in the RAIF and will draw together the factors identified from literature and the other EU funded CI resilience projects (see sections 2 and 3). The tool will enhance the measurement of CI resilience by explicitly extending the range of factors beyond those associated with the direct impacts of a disaster event on physical assets and organisational preparedness to include factors that assess the indirect impacts of a disaster event on the ability of the CI provider to deliver their essential services. This will include an assessment of the resilience of both service design and service delivery models. By addressing this level of detail, the LIQUEFACT CI tool will support the development of business models to evaluate mitigation options which is an essential requirement of the RAIF. For consistency, the CI resilience tool will use a compatible scoring framework (i.e. 0-5 supported by qualitative statements) compatible with the UNISDR Disaster Resilience Scorecard.

5.3.2 The initial set of indicators included in the LIQUEFACT CI resilience tool is shown in Figure 10. The indicators are grouped into three factors: those associated with CI organisation and management systems; those associated with CI technical systems; and those associated with CI operational systems. Whilst each of the factors represents specific resilience issues they are all inter-related and as such the impact of an EILD event on one factor will influence the other factors (e.g. an EILD event may not cause structural damage to a technical system but it does to the operational delivery of services). As such, when combining the resilience scores from each factor to obtain an overall assessment of the CI resilience to EILD events, consideration will need to be given to the inter-dependencies and feedback and, as such it is proposed to combine the resilience scores using the Analytical Network Process (ANP) which was specifically developed to address such complexities (see Saaty, 1996 for more details). The ANP models, which will be unique to each CI provider, will be developed in Work Package 5 and tested in Work Package 7.

5.3.3 The indicators are further grouped by sub-factor to reflect the range of activities that influence the resilience of the primary factors. These sub-factors include:

- Organisation and Management – Finance, Coordination, Business Planning.
- Technical Systems – Physical Assets, Asset Infrastructure.
- Operational Systems – Service Design, Service Delivery.

Each sub-factor is assumed to be independent and as such their resilience scores will be combined using the Analytical Hierarchy Process (see Saaty, 1980 for more details) in which an expert panel drawn from each CI provider will assess the relative importance of each sub-factor to the primary factor using a pairwise comparison and a -9 to +9 point scale. The robustness of this approach and the assumed independence of each sub-factor will be tested in Work Package 7.

5.3.4 Each sub-factor is further divided into a range of specific indicators that will inform the development of a set of bespoke metrics for each CI provider. The indicators have been derived from a review of other projects and reflect the range of indicators that the LIQUEFACT researchers believe are relevant to assessing resilience to EILD events and that could be influenced by specific technical, operational, organisational and management mitigation interventions. Whilst some of the indicators should be applicable to all CI providers (e.g. having a specific budget identified to fund resilience measures) others will be specific to the particular CI circumstances (e.g. service design resilience in the health sector will be different to that in the transportation sector). As such, the list of indicators shown in Figure 10 will be used as the basis for detailed discussions with CI stakeholders (at various levels within each organisation) to develop specific metrics that reflect their particular circumstances. Each metric will adopt the same assessment approach used in the UNISDR Resilience Scorecard in which the sub-factor equates to the subject/issue; the indicator describes the item to be measured; the metric specifies the indicative measurement and provides a 6 point scale (0 – 5) against which the measurement is made. A commentary box will provide further guidance and give examples of the indicator being assessed. Once the final set of indicators, metrics, measurement scales, and examples have been developed for a particular CI provider, they will be scored by stakeholders drawn from the CI provider to provide an assessment of the resilience of each sub-factor to an EILD event. It is currently assumed that AHP will be used as the basis of the assessment but if the number of indicators becomes too large then a more simplistic weighting regime will be used to obtain a normalised score for each sub-factor. This is because the pairwise comparison used in the AHP approach becomes very time consuming for participants as the number of indicators increases and as such the inconsistency in weightings, which is strength of the AHP process, can become too great. The detailed metrics and modelling approach needed to assess CI resilience will be developed and tested in LIQUEFACT Work Package 7.

5.3.5 Finally, the approach outlined above is consistent with that being developed by other EU funded CI resilience projects (particularly IMPROVER, RESILIENS and EU-CIRCLE projects) and as such the outputs from LIQUEFACT's RAIF should contribute to and complement the greater understanding of CI resilience to disaster events.

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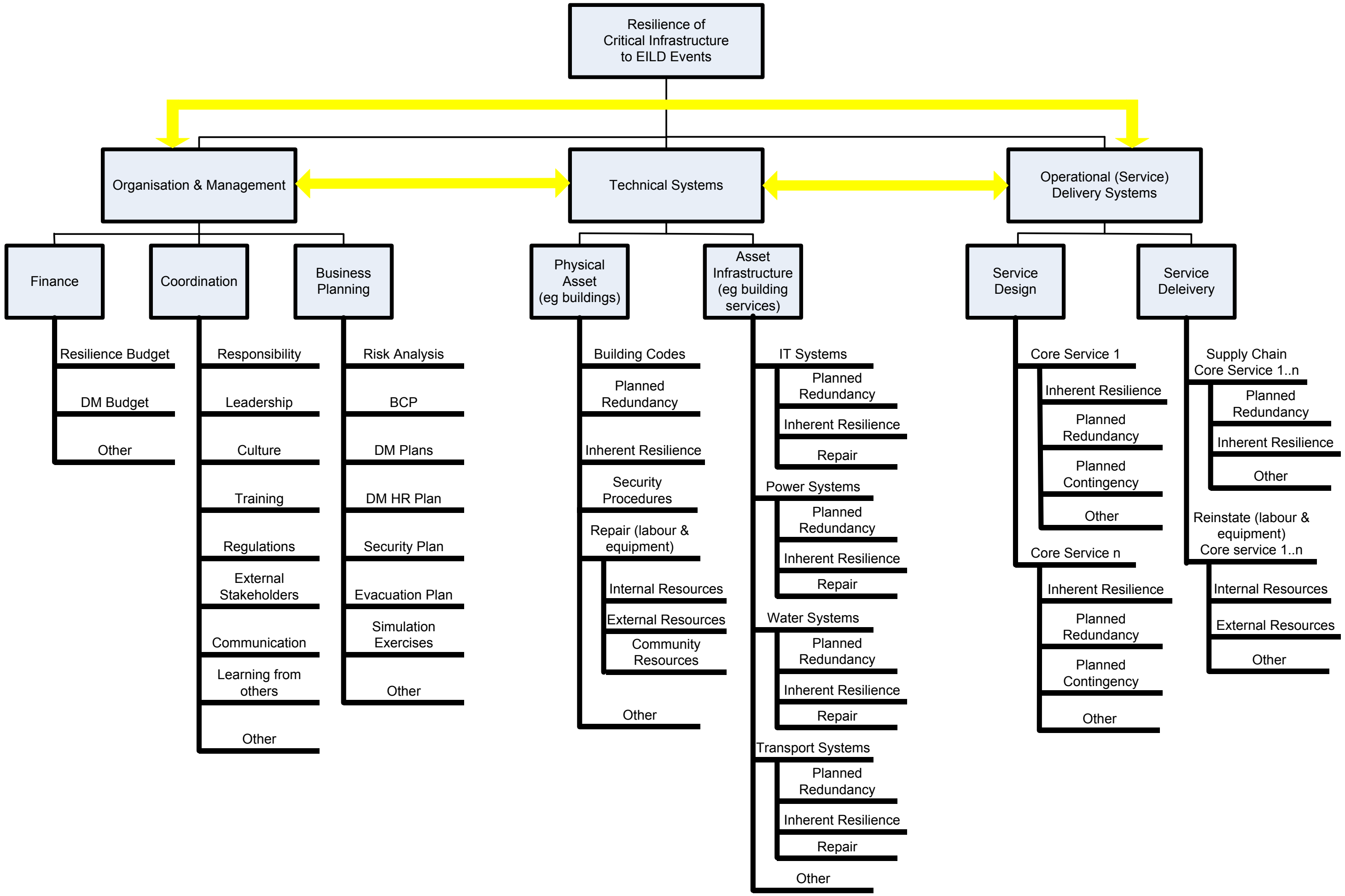

Figure 10: Critical Infrastructure Resilience Framework

6 SUMMARY AND NEXT STEPS

6.1 The LIQUEFACT project aims to develop a more comprehensive and holistic understanding of the earthquake soil liquefaction phenomenon and the effectiveness of mitigation techniques to protect structural and non-structural systems and components from its effects. To this end the LIQUEFACT project will develop a RAIF to assess the vulnerability, resilience, and the adaptive capacity of communities and CI to EILD events. The RAIF will also provide business models to assess the potential of mitigation interventions to improve community and CI resilience and the cost/benefit models to allow option appraisals and prioritisation of mitigation interventions into built asset management plans. This report reviews the background to the RAIF and presents the rationale behind the initial list of factors/indicators that will be used by LIQUEFACT to measure community and CI resilience to EILD events. These factors/indicators will be further explored in LIQUEFACT Deliverable 5.2.

6.2 The theoretical background to the RAIF is based on Cutter's DROP model (Cutter et al, 2008) and Jones's risk/resilience model developed as part of the CREW project (CREW, 2012). The RAIF integrates these models into a six stage built asset management framework that those responsible for managing CI systems can use to identify, evaluate and plan mitigation actions (technical, operational, organisational and managerial) to reduce their vulnerability or improve community and CI resilience to EILD events. To support the RAIF a series of resilience indicators need to be developed that model both community and CI resilience to EILD events. These indicators are the primary output from this report.

6.3 There have been a number of attempts to develop disaster reliance frameworks at both the community and CI system level. Typically these frameworks seek to identify the components/factors that affect community and CI resilience and then develop a range of qualitative and quantitative indicators/metrics to measure the resilience of each component/factor which can then be combined to obtain an overall assessment of community or CI system resilience. The individual component/factor resilience and the overall community/CI resilience is typically calculated using a simple or weighted summation approach to obtain the resilience scores and whilst this provides a high level assessment it doesn't reflect the inter-dependencies and interactions that are known to exist between components/factors and indicators/metrics. As such these generic approaches do not provide the level of detail that will be needed in the RAIF where two specific resilience tools are needed; one to measure community resilience; the other to measure CI system resilience.

6.4 In 2015 the UNISDR developed a Disaster Resilience Scorecard for Cities which provides a detailed approach that cities and regions can use to assess their resilience to a range of disaster events. The Scorecard consists of 95 indicators divided into 10 'Essentials' that cover governance and financial issues; planning and disaster preparation; and disaster response and post-disaster recovery. Each indicator in the Scorecard is described in detail and a 6 point measurement scale is provided for assessment. The measurement scale comprises quantitative scores supported by qualitative statements. The UNISDR Disaster Resilience Scorecard for Cities is consistent with previous community resilience models and represents the current state of the art in community resilience assessment. As such the Scorecard will be used as the basis for the assessment of community resilience in the RAIF.

6.5 Whilst the UNISDR Disaster Resilience Scorecard for Cities is the current international standard (Appendix A), it is a generic framework and as such needs to be contextualised for the specific disaster circumstances that cities/regions face. In the context of LIQUEFACT this will require the Scorecard to be contextualised against EILD events. The issues, items, indicators and metrics outlined in the Scorecard will be reviewed by the LIQUEFACT Expert Advisory Panel and project partners to identify those items that are potentially affected by an EILD event and to rank the relative importance of each to community resilience to an EILD event. The refined set of issues, items, indicators and metrics will be tested against extreme and probable EILD scenarios applied to the Emilia Romagna region of Italy to assess the community's antecedent level of resilience to EILD events and the impact that specific CI mitigation actions could have on the level of resilience. The resilience of each item will be scored using a 0 to 5 scale and normalised to provide a consistent assessment of each issue. The normalised scores for each issue will then be combined using expert derived weightings to provide an assessment of the resilience of each 'Essential'. These will be presented as a radar plot to inform discussion on the potential mitigation interventions required to improve the resilience of each 'Essential' to an EILD event. An assessment of the overall community resilience to EILD events will be modelled using a FCM, developed by an expert panel, that ranks the relative importance of each 'Essential' so as to provide the basis by which EILD mitigation interventions can be modelled and their cost/benefit assessed. The modified scorecard and modelling approach will be developed as part of LIQUEFACT Work Package 5 and validated by a range of Emilia Romagna stakeholders as part of LIQUEFACT Work Package 7.

6.6 Although the UNISDR Resilience Scorecard for Cities contains a section on the impact of CI on City/Region resilience, the indicators contained in this section of the Scorecard are not sophisticated enough to allow detailed business models of the cost effectiveness of mitigation options to be evaluated. As such the LIQUEFACT toolbox will develop a more detailed, bespoke tool, which will assess CI resilience and mitigation options to EILD events. The CI resilience tool is based on the generic approaches currently being adopted by other EU funded projects to assess CI resilience to disaster events and is consistent with the scoring approach used in the UNISDR Resilience Scorecard for Cities. As such the scores from the CI resilience scorecard should be directly compatible and feed directly into the UNISDR Scorecard. Where the LIQUEFACT CI tool differs from many of the existing tools is in the way it seeks to address the impact of disaster events on service delivery. The LIQUEFACT CI tool will enhance the measurement of CI resilience by explicitly extending the range of factors beyond those associated with the direct impacts of a disaster event on physical assets and organisational preparedness to include factors that assess the indirect impacts of a disaster event on the ability of the CI provider to deliver their essential services. This will include an assessment of the resilience of both service design and service delivery models and the use of multi-criteria modelling that acknowledges inter-dependencies and feedback between factors. Details of the generic factors, sub-factors and indicators to be considered by the CI resilience tool are given in Figure 10. These will be contextualised to reflect the specific circumstances of individual CI providers in LIQUEFACT Work Package 7.

6.7 The next steps in developing the community resilience tool is the development of a detailed research methodology which will be used to contextualise the UNISDR Disaster Resilience Scorecard for Cities to EILD events (Work Package 5) and research protocols that will be used to validate the contextualised Scorecard in Work Package 7 as part of the Emilia Romagna case study. Further details of research methodology will be given in LIQUEFACT Deliverable D5.2.

6.8 The next steps in developing the CI resilience tool is the development of a detailed research methodology which will be used to contextualise the CI resilience tool for the impact of EILD events on individual CI providers (Work Package 5) and research protocols that will be used to validate the contextualised Scorecard in Work Package 7 as part of the Emilia Romagna case study. Further details of research methodology will be given in LIQUEFACT Deliverable D5.2.

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Appendix A: UNISDR Disaster Resilience Scorecard for Cities

Disaster Resilience Scorecard for Cities

Using the Draft Revised "Ten Essentials" based on the Sendai Framework for Disaster Risk Reduction 2015-2030

Compiled for the United Nations International Strategy for Disaster Risk Reduction (UNISDR)

by IBM and AECOM

Current status as at April 30th 2015: this is a working document, and may continue change, possibly significantly, as further experience is gained with using it and as the HFA2 framework continues to be developed. Comments and suggestions are welcomed.

Disaster Resilience Scorecard for Cities, based on UNISDR's "Ten Essentials"

This scorecard provides a set of assessments that will allow cities to understand how resilient they are to natural disasters. It is based on the UNISDR's draft revised "Ten Essentials"[1] of disaster management. It has been compiled by IBM and AECOM, who are members of UNISDR's Private Sector Advisory Group (PSAG).

The term "resilience" is often taken to include responses to a spectrum of factors, ranging from "chronic" stresses such as environmental pollution, ground water depletion or deforestation, to "acute" stresses such as floods, droughts, earthquakes, hurricanes or wild-fires[2]. "Disaster resilience" as defined here is at the "acute" end of this spectrum: it covers the ability of a city to understand the disaster risks it may face; to mitigate those risks; and to respond to disasters that may occur, in such a way as to minimize loss of or damage to life, livelihoods, property, infrastructure, economic activity and the environment. Clearly, disaster resilience will be affected by the chronic stresses that the city may also face, for example where deforestation increases the propensity for flash flooding, or where water pollution exacerbates the impact of a drought.

As Figure 1, below, shows the Ten Essentials offer a relatively complete coverage of the many issues cities need to address to become more disaster-resilient:

- Essentials 1-3 cover governance and financial issues;
- Essentials 4-8 cover the many dimensions of planning and disaster preparation;
- Essentials 9-10 cover the disaster response itself and post-event recovery.

While Essentials 1-3 should be complete first, the remaining essentials are not intended to be completed in any particular order.

Using the Essentials, the Disaster Resilience Scorecard (hereafter, "the scorecard") is intended to enable cities to establish a baseline measurement of their current level of disaster resilience under each Essential, to identify priorities for investment and action, and to track their progress in improving their disaster resilience over time. It consists of some 90 disaster resilience evaluation criteria, with each evaluation criterion being broken down to set out the aspect of disaster resilience being measured, an indicative measurement and the measurement scale (from 0 to 5, where 5 is best practice).

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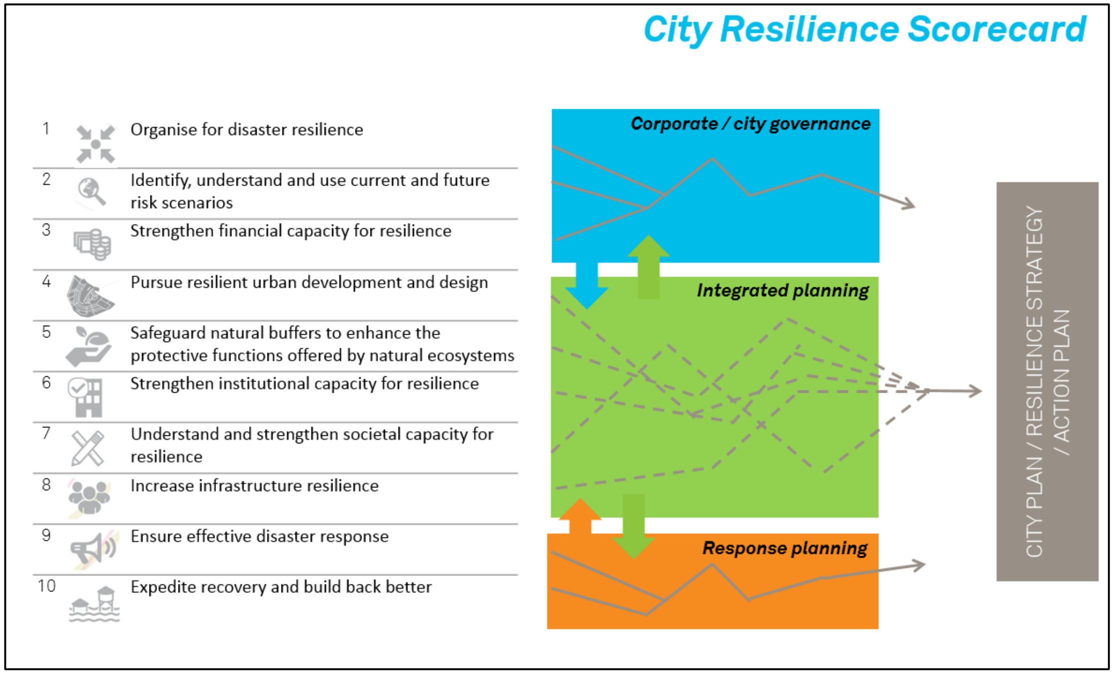
[1] The original pre-Sendai Ten Essentials are available from: http://www.unisdr.org/campaign/resilientcities/toolkit/essentials. The draft of the Revised Ten Essentials is incorporated in this document in the introduction to each section.

[2] These terms have been defined in numerous works by Prof. Joseph Fiksel, Ohio State University.

Figure 1



The scorecard provides an aspirational definition of disaster resilience – it is very unlikely that any city would currently score maximum points, and most will not score more than 50%. Its intention is to guide cities towards optimal disaster resilience, and to challenge complacency. This demanding standard reminds cities that there is *always* more that could be done, and to establish investment goals (including time and effort) for achievement over a period of years.

Disaster resilience for a city is a big subject, requiring cross-functional effort and input. As you complete the scorecard, keep in mind that:

- You will need a clear understanding of the risk of each possible disaster and its impacts on your city. The scorecard assumes that your city has two risk scenarios defined – a "most probable" and a "most severe" (ie a "worst case"). However, even if you do not have these defined as such, it may still be possible to draw on existing risk assessment work.

- While the scorecard aims to be systematic, individual scores may unavoidably be subjective – use your judgment to decide which scores apply most closely to your level of disaster resilience. Recording your justification for each evaluation score will enable validation, as well as future revisions and tracking progress.

- Some aspects of disaster resilience may not be under the control of your organization (for example, the city's electricity supply or phone system may be operated by a separate utility, or there may be a provincial or neighboring government that also needs to be involved). Ideally, the scorecard should be completed in consultation with these other organizations. The consultation process will also help to engage and build understanding, ownership and alignment with these other organizations.

- Consulting your citizens as you complete the scorecard will improve the validity of your results.

- Not all measures in the scorecard will apply to all cities or all disaster events (for example, there is a measure related to ports and your city may not have one).

- Being as accurate and realistic as possible will help accurately identify areas of vulnerability, enabling their prioritization for attention and funding. Wishful thinking or denial will eventually be ruthlessly exposed by nature, when a disaster happens!

- **The scorecard may not address all the disaster resilience issues facing your city. Equally, some scoring criteria may not be directly applicable to your city. If in doubt take advice from an expert in risk management or other relevant discipline.**

Cities that have completed the Scorecard have found that it can be approached at several levels:

- As a high level survey, often via a 1 or 2 day workshop – this may or may not be supported by questionnaires based on the scorecard which participants fill out in advance. Sometimes an average or consensus score is applied at the level of each Essential, rather than for each individual assessment.

- As a limited exercise focusing on some individual essentials, to create an in depth review of some specific aspects of resilience – perhaps community-level preparedness, or some such.

- As a detailed review of the city's entire resilience posture, taking some weeks or even months to complete.

Before proceeding to complete the scorecard please read the companion document, Scorecard FAQs. This contains guidance on process and issues that may be encountered. If you wish you can apply weightings to the essentials to allow some to have more impact in the assessment than others. A suggested set of weightings is available if required.

If you have any questions (or if you wish to suggest any improvements), please contact the authors: Peter Williams, at peter.r.williams@us.ibm.com; Michael Nolan, at michael.nolan@aecom.com; or Abhilash Panda, at pandaa@un.org. A glossary of terms used is included at the end of the document.

The scorecard is made freely available by the UNISDR, to be used by cities or local government agencies; companies providing derivative products or services based on the scorecard may also use it without charge.

We wish you success in completing the scorecard. Finally, we would like to thank those in a number of organizations and individuals whose comments and experience in using it have already allowed us to improve it.

30th April 2015.

The Disaster Resilience Scorecard for Cities

Essential 1: Organize for Resilience

Put in place an organizational structure and identify the necessary processes to understand and act on reducing exposure, its impact and vulnerability to natural disasters. Recognizing that the exact format/structure will vary within and between countries, this will include but is not limited to:

- Establishing a single point of coordination in the city, accepted by all stakeholders.
- Exercising strong leadership and commitment at the highest elected level within the city authority, such as the Mayor.
- Ensuring that all departments understand the importance of disaster risk reduction for achieving objectives of their policies and programs; and that they have a framework within which to collaborate as required.
- Ensuring that all city government discussions routinely capture resilience implications; that the resilience implications of policies, and standards in use are also assessed; and that action is taken upon these as needed.
- Engaging and building alliances with all relevant stakeholder groups including government at all levels (e.g national, state, city, parish or other subdivision, neighbouring cities or countries as applicable), civil society and community organizations, the private sector.
- Engaging and learning from other city networks and initiatives (e.g. city to city learning programmes, climate change, resilience initiatives etc.)
- Establish necessary strategies, acts, laws, codes or integrate resilience qualities into existing policies aimed at preventing the creation of risk and reduction of existing risk.
- Create policies to gather and manage data for sharing amongst all stakeholders and citizens.
- Putting in place reporting mechanisms for all citizens that capture key information about resilience and promote transparency, accountability and improved data capture over time (e.g. consider use of UNISDR tools LGSAT and City Resilience Scorecard) and enable information sharing with other organizations and with the public..

Data you will need to answer this section of the scorecard will include*: organization charts; lists of organizations by area, subject and so on; as applicable, MOUs and other role descriptions for each organization concerned; names of key individuals involved; meeting minutes and actions from the organizations concerned; a list of information and data available to reach stakeholder*.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
1.1 Organization and coordination	1.1.1 Co-ordination of all relevant **pre-event** planning and preparation activities exists for the city's area, with clarity of roles and accountability across all relevant organizations.	Presence of organizational chart documenting structure and role definitions at each relevant agency to achieve a single overall point of co-ordination. Structure agreed and preferably signed off by all participants via MOU or similar.	5 – Single point of coordination exists with agreed roles and responsibilities. 4 – Single point exists but with some minor exceptions. 3 – Single point exists in principle, but with some major omissions, or lack of agreement on some major areas. 2 – Initial steps taken to create a single point of coordination. 1 – No single point but plans exist to create one. 0 – No single point and no plans to create one.	The single point of co-ordination may be a person, or a group or committee (with sub-groups or committees as appropriate). It will coordinate the relevant (see below) activities of: - The city government and, if separate, highways, police, armed forces/civil defense, water, energy, or any other relevant city organizations); - Other tiers of government (eg state, ward-level) or neighboring municipalities); - Private sectors organizations with relevant roles – for example, utilities, phone companies, healthcare, logistics companies, fuel depots, property companies, and so on. Some cities may have different organizational arrangements for different types of disaster. However, these need at least to work through the same coordination point (person or committee) to ensure consistency in response arrangements; and also to enable management of simultaneous disasters as applicable. The test of relevance is whether the organization or activity must contribute in any way to preparing for the event scenarios covered below in Essential 2.
	1.1.2 Coordination of all relevant **event response** activities in the city's area, with clarity of roles and	Presence of organizational chart documenting structure and role definitions at each relevant	5 – Single point of coordination exists with agreed roles and responsibilities.	As above – the single point may be a person or a group.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
	accountability across all relevant organizations.	agency to achieve a single overall point of co-ordination. Structure agreed and preferably signed off by all participants via MOU or similar.	4 – Single point exists but with some minor exceptions. 3 – Single point exists in principle, but with some major omissions, or lack of agreement on some major areas. 2 – Initial steps taken to create a single point of coordination. 1– No single point but plans exist to create one. 0 – No single point and no plans to create one.	Event response coordination arrangements should be regularly tested, if not by real events, at least in simulation exercises – see Essential 9.
	1.1.3 Participation and coordination of all relevant organizations in the structure(s) defined.	Level of participation and coordination achieved (see right)	5 – Effective participation of all relevant agencies, private and public, in pre-event and event response activities. 4 – Effective participation but with some minor exceptions 3 – Participation but with significant gaps in participation, or failing to resolve some overlap, duplication etc. 2 – Some participation, perhaps between pairs of agencies – but not universal. Subject is receiving significant attention, however.	Effectiveness of participation and coordination can be measured by: - Attendance at meetings as required with staff of the right level for the decisions being made; - Timely and complete provision of agreed physical contributions (see below) - Absence of disagreement on roles, strategy, methods etc; - Achievement of planned timelines and milestones; - Extent to which proven either in practice or by simulation exercises (see essential 9). - Documented agreements to collaborate.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			1 – Intent exists to improve coordination but so far no impact. 0 – Collaboration is poor and no intent to improve it.	
	1.1.4 Co-option of physical contributions by both public and private sectors.	Identification of physical contributions for each major organization.	5 – All key contributions fully defined for pre and post-event, underwritten by MOUs. 4 – Most key contributions defined – some minor gaps in coverage. MOUs may not exist. 3 – Some contributions formally defined but full leverage of private sector yet to be achieved. 2 – One or two contributions defined for specific areas – perhaps via informal agreements. 1 – Plans being developed to seek contributions. 0 – No private sector contribution defined.	Physical contributions refer to plant and equipment, people, premises and accommodation, supplies, data, computer systems, and so on. These will supplement those provided by the city and may come from other agencies or from private sector organizations such as those defined above. The key is to have a clear view of what will be needed to supplement the city's own resources (defined in essential 9); and then to enter into explicit MOUs with the organizations that will supply those items.
	1.1.5 Coordination for all **post-event** activities in the city's area, with clarity of roles and accountability across all relevant organizations. .	Presence of organizational chart documenting structure and role definitions at each relevant agency to achieve a single overall point of co-ordination.	5 – Single point of coordination exists with agreed roles and responsibilities. 4 – Single point exists but with some minor exceptions. 3 – Single point in principle, but with some major omissions, or	As above – the single point may be a person or a group. Key activities will be: - Day to day government (especially if provided by a stand-in entity such as the armed forces, a neighboring state etc).

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
		Structure agreed and preferably signed off by all participants via MOU or similar.	lack of agreement on some areas. 2 – Initial steps taken to create a single point of coordination. 1– No single point but plans exist to create one. 0 – No single point and no plans to create one.	- Longer term management of rebuilding process – an organizational arrangement is needed for including all stakeholders including citizen groups. One major issue will be the speed with which this organization can be assembled and begin operation. The post event organization should in effect be mobilized at the same time as the event response organization, and will have a high degree of continuity with it.
1.2 Integration of disaster resilience with other initiatives	1.2.1 Extent to which *any* proposal in government is also evaluated for disaster resilience benefits or impairments.	Explicit stage in policy and budget approval process where disaster resilience side benefits, or impairments, of any city government initiative are identified and counted towards the Return on Investment (ROI) for that proposal. .	5 – Explicit decision step, applied to all policy and budget proposals in all relevant functional areas. 4 – Explicit or semi-explicit decision step, applied in most cases and in most functional areas. 3 –No formal process, but disaster resilience benefits are generally understood to be "helpful" to a proposal, in most functional areas. 2 – Decision step sometimes applied, but very likely to be overlooked in most functional areas if a proposal would impair disaster resilience. 1 – Applied ad hoc or occasionally. 0 – Not applied.	For example: - Traffic management systems may also help with evacuation, so increasing disaster resilience; - A development approval may locate people in harm's way; - A land use change may reduce benefit of wetlands in preventing floods. Includes, but not restricted to, the functional areas of: land use and zoning; development; water, energy; public safety; transportation; food supply; healthcare.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
1.3 Capture, publication and sharing of data	1.3.1 Extent to which data on the city's resilience position is shared with other organizations involved with the city's resilience.	Availability of a single "version of the truth" – a single integrated set of resilience data for practitioners.	5 – Full availability of the information listed at right on readiness and risk; fully shared with other organizations.. 4 – Some minor gaps, or the information is in more than one place – but it is shared and it is at least linked to enable navigation. 3 – Some more significant gaps, for example on readiness; other organizations may have to "hunt around" to create a complete picture for themselves. 2 – Some significant information on readiness and risk is withheld from other organizations or is missing and/or badly fragmented across multiple websites. 1 – Information provision to other organizations on readiness and risk is rudimentary at best. Not possible to for those organizations to derive specific conclusions for themselves. 0 – No information.	Information to consider making open for public access might include: - A summary of readiness – perhaps the LG SAT. - The outcomes of this scorecard; - An explanation of the hazards and perils that the city is thought to face, and probabilities; - A hazard-map based summary (see Essential 2) of at-risk areas; - A description of what building codes will protect against, and where these have been applied; - A full set of disaster response plans and known issues; - Key roles and accountabilities; - Planned investments that will affect the city's resilience position. - Further resources and contact details.
	1.3.2 Extent to which data on the city's resilience position is shared with the community organizations and public.	Availability of a single "version of the truth" – a single integrated set of resilience data for citizens and community organizations containing at least the items shown at right.	5 – Full availability of the information listed at right on readiness and risk; fully shared with other community organizations and available to	Information to consider making open for public access might include: - A summary of readiness – perhaps the LG SAT or a summary of the outcomes of this scorecard;

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			the public via website, mobile device etc. 4 – Some minor gaps, or the information is in more than one place – but it is shared and it is at least linked to enable navigation. 3 – Some more significant gaps, for example on readiness; other organizations or citizens may have to "hunt around" to create a complete picture for themselves. 2 – Some significant information on readiness and risk is withheld from other organizations or is missing and/or badly fragmented across multiple websites. . 1 – Information provision to other community organizations and to citizens on readiness and risk is rudimentary at best. Not possible to for those organizations or citizens to derive specific conclusions for themselves or their neighbourhoods. 0 – No information.	- An explanation of the hazards and perils that the city is thought to face, and probabilities; - A hazard-map based summary (see Essential 2) of at-risk areas; - A description of what building codes will protect against, and where these have been applied; - A full set of disaster response plans and known issues; - Key roles and accountabilities; - Planned investments that will affect the city's – or a neighbourhood's - resilience position. - Further resources and contact details.

Essential 2: Identify, Understand and Use Current and Future Risk Scenarios

City Governments should identify and understand their risk scenarios, and ensure that all stakeholders both contribute to, and recognize, these. Risk scenarios should identify hazards, exposures and vulnerabilities in at least the "most probable" and "most severe" ("worst-case") scenarios, paying particular attention to the following:

- How hazards might change over time, given the impact of factors such as urbanization and climate change;
- How multiple hazards might combine, and how repeated small scale disaster events (if there is a relevant risk of these) might accumulate in their impact over time;
- Geographic areas exposed and territorial impact;
- Population segments, communities and housing exposed;
- Economic assets and activities exposed;
- Critical infrastructure assets exposed, the consequent risk of cascading failures from one asset system to another (for example where loss of power prevents water being pumped or weakens the hospital system);
- Timescales over which risks, vulnerabilities and impacts occur and responses are required.
- Creation and publication of risk and exposure maps detailing the above.

Scenarios should be:

- The means for current and future investment decisions;
- Based on participatory processes that seek input from the full range of stakeholders (including ethnic and social groupings);
- Regularly updated;
- Widely communicated and used for decision-making purposes, and for updating of response and recovery plans.

Note that actions to address the hazards in each scenario are covered in other sections of the scorecard.

Data you will need to complete this section of the scorecard will include: *documentation of hazards, exposures and vulnerabilities; identification of critical assets and dependencies between these.*

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
	2.1.1 Knowledge of hazards (also called perils) that the	Existence of recent, expert-reviewed estimates of	5 – Comprehensive estimates exist, were updated in last 3 years and	Cities need to have a view of the hazards or perils that they face – what specific hazards

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
2.1 Risk assessment	city faces, and their likelihood.	probability of known hazards or perils and their extents.	reviewed by a 3rd party. "Most severe" and "most probable" hazards are generally accepted as such. 4 – Estimates exist but have minor shortcomings in terms of when updated, level of review, or level of acceptance. 3 – Estimates exist but with more significant shortcomings in terms of when updated, level of review or acceptance. 2 - Some estimates exist but are not comprehensive; or are comprehensive but more than 3 years old; or are not reviewed by a 3rd party. 1 – Only a generalized notion of hazards, with no attempt systematically to identify probability. 0 – No estimates.	(tsunami, hurricane, earthquake, flood, fire etc) exist and how severe might they be? For each hazard there needs to be identified, as a minimum: - a "most probable" incident; - a "most severe" incident. Hazards may be identified from probability distributions, specifically conducted for the purpose of assessing disaster resilience: "most probable" would be at the midpoint of the range of hazards that need to be addressed and "most severe" would be from the top 10% of the probability range. Alternatively, they may be approximated from such sources as: - General hazard assessments for the region - Assumptions created as an input to land zoning, planning discussions or permitting; - Insurance industry risk assessments; - Expert opinion as to "typical" hazards; - Prior experience or historical records of disasters in the region. However, if these levels of knowledge are not available, cities should still try to assemble a picture from prior experiences and/or estimation of the general level of hazard that they face. Sophisticated cities may also attempt to estimate the impact of multiple consecutive

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
				smaller hazards, or combinations of hazards (a hurricane and accompanying storm surge, for example). It is important to note that hazards may change over time as a consequence of urbanization and land use (for example where deforestation increases propensity for flash flooding), climate change (for example, changing rainfall or storm patterns), or better knowledge (for example, understanding of seismic threats or likely storm tracks). Thus, hazard estimates need to be updated regularly.
	2.1.2 Knowledge of exposure and vulnerability	Existence of scenarios setting out city-wide exposure and vulnerability from each hazard level (see above).	5 – Comprehensive scenarios exist city-wide, for the "most probable" and "most severe" incidence of each hazard, updated in last 18 months and reviewed by a 3rd party. 4 – Scenarios have minor shortcomings in terms of coverage, when updated, level or thoroughness of review. 3 – Scenarios have more significant shortcomings in terms of coverage, when updated, level of review, thoroughness. 2 – Partial scenarios exist but are not comprehensive or complete; and/or are more than 18 months old; and/or are not reviewed by a 3rd party. 1 – Only a generalized notion of exposure and vulnerability, with no attempt systematically to identify impacts.	Exposure may be thought of as who or what (people, land, ecosystems, crops, assets, infrastructure, economic activity) is potentially in harm's way as a result of a hazard. Vulnerability may be thought of as the potential consequences of that exposure (loss of life, property or service; physical damage; health impact, economic impact; environmental impact and so on). Different exposures and/or vulnerabilities may combine, for example where the tsunami generated by the Tohoku earthquake in Japan in 2011 badly damaged the Fukushima nuclear power plant – generating a whole additional set of exposures and vulnerabilities. Exposures and vulnerabilities may be assessed from sources such as regional flood maps or earthquake hazard maps, or from expert estimation. Hazards, exposures and vulnerabilities need to be assembled into "scenarios". Scenarios are comprehensive pictures of the total impact of

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			0 – No risk assessment.	the hazard (if any) across all neighborhoods and all aspects of the city, and will include: - Exposure and vulnerability of neighborhoods and economic zones; - Exposure and vulnerability of critical infrastructure items, with and without alternatives (see below); - Benefit from, and status of ecosystem services, where applicable; - Estimates of recovery time, given estimated benefit of mitigation measures, if any. Scenarios will ideally have been for reviewed for thoroughness and plausibility by a 3rd party and updated in last 18 months. This is more frequently than the reviews of hazards, above, as land use and development that may affect exposure and vulnerability happens on a faster time-scale.
	2.1.3 Understanding of critical assets and the linkages between these.	All critical assets are identified (see Essential 8) and relationships between them are identified in the form of potential "failure chains". This is used to frame disaster plans and triage (se essential 9) and also retrofits and upgrades to improve the capability of the infrastructure to withstand disasters.	5 – Critical assets are identified city-wide and systematically linked into failure chains as applicable. The city has a retrofit and triage strategy that allows it to prioritize upgrades and repairs. 4 – Critical assets and failure chains are generally identified with some minor gaps and omissions. A retrofit and triage strategy exists but it may also have gaps.	As identified above, critical assets are equipment, facilities, infrastructure or computer systems/data that are critical to the functioning of the city, maintenance of public safety or disaster response. While many cities will identify these, at least to some degree it is much rarer to identify how they are linked and the "failure chains" that may exist. A failure chain is a set of linked failures spanning critical assets in multiple infrastructure systems in the city. As an example – loss of an electricity substation may stop a water treatment plant from

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			3 = Critical assets and failure chains identified to some degree but some significant known omissions; or 3 = Critical assets are identified but failure chains are not. No triage or strategy is therefore possible and retrofits are prioritized, if they happen at all, by individual city departments. 1 – Identification of critical assets is patchy at best – significant gaps exist by area, or by infrastructure system. No triage strategy. 0 – No identification of critical assets.	functioning; this may stop a hospital from functioning; and this in turn may mean that much of the city's kidney dialysis capability (say) is lost. This is a failure chain that spans energy, water and healthcare systems.
	2.1.4 Hazard maps	Presence of hazard maps	5 – Fully comprehensive, detailed and up to date hazard maps exist for the entire city, covering perils, assets and populations at risk, and are known to be accurate. 4 –Hazard maps exist for the entire city but with some minor omissions of content or detail, perhaps because an update is due. 3 – Hazard maps exist but with more significant omissions or known inaccuracies. 2 – Hazard maps are partial in coverage and fragmented: – exposure and vulnerability data for key assets or areas in particular may be entirely lacking.	(Publication of maps to other organizations and to the public – see Essential 1)

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			1 – Hazard maps are old, incomplete and known to be unsound as a basis for decision making. 0 – No maps.	
2.2 Update process	2.2.1 Process ensuring frequent and complete updates of scenarios.	Existence of a process agreed between all relevant agencies to: - Update hazard estimates every 3 years or less; - Update exposure and vulnerability assessments and asset inventory every 18 months or less.	5 – Update processes exist, are proven to work at required frequency and thoroughness, and are accepted by all relevant agencies; 4 – Processes exist with some minor flaws in coverage, date slippage or less important agencies being bought in. 3 – Processes exist, but with at least 1 major omission in terms of frequency, thoroughness or agency buy-in. Risk identification may be compromised in some areas, accordingly. 2 – Processes have some major flaws to the point where overall value is impaired and original risk assessments are becoming significantly obsolete. 1 – Processes are rudimentary at best. A complete risk assessment – even if elderly – has yet to be achieved. 0 – No processes.	Updates are essential because hazards may change over time (especially if weather or sea-level related); and because land use, population and economic activity patterns may also change as cities grow. Updates need to address: - Hazard patterns - Dwellings - Businesses - City infrastructure and facilities (see essential 8), including critical assets and failure chains. - Critical computer systems and data (see essential 8) - Schools and healthcare facilities (see essential 8) - Ecosystem services (see essential 5) The focus here is on the process itself and its ability to ensure continued and complete updating of scenarios. Updates may be by means of a regular updating exercise that captures all changes for the preceding period, or by means of an

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
				incremental update process that reliably captures changes as they occur.

Essential 3: Strengthen Financial Capacity for Resilience

Understand the economic impact of disasters and the need for investment in resilience. Identify and develop financial mechanisms that can support resilience activities. Key actions might include:

- Understand and assess the significant direct and indirect costs of disasters (informed by past experience, taking into account future risk); and the relative impact of investment in prevention rather than incurring more significant costs during recovery.
- Assigning a ring-fenced capital budget for any major works found to be necessary to improve resilience.
- Including risk management allocations in operating budget as required to maintain the required state of resilience over time.
- Assessing disaster risk levels and implications from all planning, permitting and capital spending decisions, and adjusting those decisions as needed.
- Creating incentives for homeowners, low-income families, communities, businesses and public sector to invest in reducing the risks they face (e.g. business continuity planning, redundancy, building upgrades).
- Applying (if necessary, generating) insurance coverage for lives, livelihoods, city and private assets.
- Exploring as needed innovative financing mechanisms such as specialised bonds, specialised insurance, tax efficient finance, development impact bonds etc.

Data you will need to complete this section of the scorecard will include*: budget and capital plan documentation; documentation of any incentives or financing schemes (for example, loans for seismic upgrades) with a disaster resilience impact, together with take-up statistics for each area of the city; insurance coverage statistics*.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
3.1 Financial plan and Budget	3.1.1 Adequacy of financial planning for all actions necessary for disaster resilience.	Presence of financial (capital and operating) plan(s) with a reasoned set of priorities, based on disaster resilience impact achieved, and keyed to "most probable" and "most severe" scenarios in Essential 2. Priorities for disaster resilience investment $$ are clear and defensible, based	5 – A coherent city-wide set of priorities exists that covers all identified needs, is argued coherently and assembled into a coherent set of 5 year plans (there may be multiple responsible agencies). Plans are protected from political change. 4 – Single 5 year set of priorities and plans exist but with some minor omissions and inconsistencies. Political continuity may be an issue.	If (as is likely) funding comes from several sources, the combined funding needs to be adequate for the city's disaster resilience needs, and also coherently deployed "as if" there was a single source and a single plan. Thus, if there are separate subsidiary plans (for example, transportation or sustainability plans), these need also to be coordinated, complete and mutually consistent.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
		on a view of most beneficial impact. Priorities are assembled into 5 year plan that integrates spending by all key organizations and will meet scenarios in Essential 2.	3 – Plans exist but longer than 5 years and may have some gaps and inconsistencies. Political continuity is a known issue, 2 – Multiple plans from different agencies – these have never been coordinated and it is unclear whether they are consistent or not or will together deliver the required level of disaster resilience. 1 – Plans exist but with substantial gaps. 0 – No prioritization – spending, if any, is haphazard. No plan	Plans also need to persist, even if changed or updated, through changes in the political leadership of the city.
	3.1.2 **Capital** funding for long run engineering and other works that address scenarios and critical asset identification in Essential 2 and Essential 8.	Funding for capital elements of plan(s) relative to estimated cost. Degree of protection ("ring-fencing") from cuts or from being taken away to be used for other purposes.	5 – Plans are 100% funded and protected. 4 – Plans are 75-100% funded and protected. 3 – Plans are 50-75% funded, and may be liable to funds being diverted for other purposes. 2 – Plans are 25-50% funded, and liable to funds being diverted for other purposes. 1 – Plans are 0-25% funded, and routinely diverted for other purposes. 0 – No plan.	If capital funds are spread across separate sources and/or organizations, the deployment of the combined funding needs to be coordinated and mutually consistent in line with the plan above.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
	3.1.3 O**perating** funding to meet all operating costs of disaster resilience activities.	Funding for operating expenses relative to estimated costs: presence of separately delineated budget line item(s). Degree of protection ("ring-fencing") from cuts or from being taken away to be used for other purposes.	5 – Budget exists, is 100% adequate and is protected. 4 – Budget exists, is 75-100% adequate, and is protected. 3 – Budget exists, is 50-75% adequate but is liable to diversion for other purposes. 2 – Budget exists, is 25-50% adequate but is liable to diversion for other purposes. 1 – Budget exists, but is only 0-25% adequate and is routinely diverted for other purposes. 0 – No budget.	If operating funds are spread across separate sources and/or organizations, or separate budget line-items, the deployment of the combined funding needs to be coordinated and mutually consistent in line with the plan above.
3.2 Contingency funds	3.2.1 Contingency fund for post disaster recovery (may be referred to as a "rainy-day fund"). .	Existence of fund(s) capable of dealing with estimated impacts from "most severe" scenario (See Essential 2). Degree of protection ("ring-fencing") of contingency fund(s) from being taken away to be used for other purposes	5 – Contingency fund (and insurance as applicable) exists to rectify impacts from "most probable" scenario, is 100% adequate and protected. 4 – Fund exists, is 75-100% adequate and protected. 3 – Fund exists, is 50-75% adequate but may be liable to funds being diverted for other purposes. 2 – Fund exists, is 25-50% adequate, and liable to funds being diverted for other purposes.	Include impact of insurance coverage where applicable (see below). Include money also available form other agencies, different levels of government etc.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			1 – Fund exists is only 0-25% adequate, and routinely diverted for other purposes. 0 – No fund.	
3.3 Incentives and financing for businesses, community organizations and citizens.	3.3.1 Affordability of, and help with achieving safe housing.	Existence of incentives and affordable financing to help owners and tenants of all sub-standard buildings bring them to a standard to deal with the "most severe" scenario (Essential 2).	5 – Incentives/financing exist, to address all known issues, for all segments of the city's population. 4 – Incentives/financing exist for most of the population with minor gaps in coverage of issues. 3 = Incentives/financing exist for most neighborhoods but gaps in issue coverage exist. 3 = Incentives exist for some issues but neighborhood coverage gaps exist. 1 – Significant weakness in coverage of the city, coverage of issues or in level of adequacy. 0 – No incentives.	Incentives and financing may come from multiple sources.
	3.3.2 Domestic insurance coverage	Extent of coverage of domestic housing. (Personal or life coverage is not assessed).	5 – 75 - 100% of likely housing losses from "most severe" scenario are covered city-wide by insurance. 4 – 75-100% of likely losses from "most probable" scenario are covered city-wide. 3 – 50-75% of likely losses from "most probable" scenario are covered city-wide.	This assessment covers insurance on domestic dwellings. Personal or life coverage is excluded. Governmental, industrial and commercial insurance is covered below. Insurance may come from multiple public or private providers.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			2 – 25-50% of likely losses from "most probable" scenario are covered city-wide. 1 – 0-25% of likely losses from "most probable" scenario are covered city-wide. 0 – No cover.	
	3.3.3 Incentives to businesses organizations to improve disaster resilience – disaster plans, premises etc.	Existence of incentives to help business owners take steps to improve disaster resilience to a standard to deal with the "most severe" scenario (Essential 2).	5 – Incentives are visibly achieving (or have achieved) required results evenly with businesses across the city. 4 – Incentives are generally effective but with some minor shortcomings perhaps in some areas. 3 = Incentives have larger gaps in coverage of the economic base. 3 = Incentives have larger gaps in coverage of the required issues. 1 – Incentives have major weaknesses and have so far failed to achieve their purpose 0 – No incentives.	Incentives and financing may come from multiple sources.
	3.3.4 Incentives to non-profit organizations to improve disaster resilience – disaster plans, premises etc.	Existence of incentives to help non-profits take steps to improve disaster resilience to a standard to deal with the "most severe" scenario (Essential 2).	5 – Incentives are visibly achieving (or have achieved) required results evenly with non profits across the city. 4 – Incentives are generally effective but with some minor shortcomings perhaps in some areas.	Incentives and financing may come from multiple sources. Non profits may be directly concerned with disaster resilience issues (for example, emergency response groups, neighborhood watch, food kitchens); or indirectly (for

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			3 = Incentives have larger gaps in coverage of the non-profit base. 3 = Incentives have larger gaps in coverage of the required issues. 1 – Incentives have major weaknesses and have so far failed to achieve their purpose 0 – No incentives.	example, churches, environmental watch or similar).
	3.3.5 Non-domestic insurance coverage	Extent of insurance coverage of non-domestic property, infrastructure and assets.	5 – 75 - 100% of likely losses from most severe scenario are covered city-wide by insurance. 4 – 75-100% of likely losses from "most probable" scenario are covered city-wide. 3 – 50-75% of likely losses from "most probable" scenario are covered city-wide. 2 – 25-50% of likely losses from "most probable" scenario are covered city-wide. 1 – 0-25% of likely losses from "most probable" scenario are covered city-wide. 0 – No cover.	This question covers insurance to commercial, industrial property and assets, as well as to NGO-, government- or city-owned buildings, assets and infrastructure. Domestic insurance is covered above. Insurance may come from multiple providers. Some governments and agencies and some businesses may self-insure. It will be necessary to confirm that funds exist to meet the likely needs.
3.4 Financing of resilience expenditures.	3.4.1 Pursuit of all possible methods of financing and funding, as required.	Where a city has outstanding resilience expenditure needs (revenue or capital) – the extent to which it has pursued all possible financing	5 – The city has a systematic inventory of financing methods and all potential sources of funds for different resilience expenditures, and a strategy	(If no additional financing needs apply, omit this assessment).

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
		strategies and funding sources.	for using them in ways that complements its own resources. 4 – The city knows of many funding methods and uses them, but not necessarily systematically or as part of an overall strategy. 3 – The city has a good range of funding sources and financing methods but uses them in an ad hoc way – some opportunities may be missed or sometimes external funds duplicate internal activity. 2 – The city knows of some funding sources and alternative financing strategies, and uses these from time to time, but some needed expenditures are not made when in fact funds might have been available. 1 – The city has only just begun to explore alternative financing methods and funding sources – it may have used them once. 0 – No exploration of financing methods and funding sources.	Alternative financing methods and sources may include, but are not restricted to: - Leasing; - Government grants, including matching grants; - Social impact or resilience bonds (payment for results achieved); - Development banks and aid organizations; - Foundations that may have a direct interest in some aspect of resilience – for example where a conservation NGO might support restoration of ecosystem services, or an education NGO might support awareness and training; - Other government agencies that may have a direct interest in some aspect of resilience – for example where a transportation agency finances a new bridge that may also improve evacuation capacity; - Crowd-funding; - Development fees; - Public-private partnerships; - Taxes and surcharges.

Essential 4: Pursue Resilient Urban Development

The built environment needs to be assessed and made resilient as applicable. Building on the scenarios and risk maps from Essential 2, this will include:

- Land zoning and management of urban growth to avoid or exacerbating resilience issues – identification of suitable land for future development taking into consideration of how low-income groups can access suitable land;
- Risk-aware planning, design and implementation of new buildings, neighbourhoods and infrastructure, using innovative or existing/traditional techniques as applicable;
- Addressing needs of informal settlements including basic infrastructure deficits such as water, drainage and sanitation
- Development and implementation of appropriate building codes, and using these to assess existing structures for resiliency to potential hazards, incorporating appropriate retro-fitting of prevention measures;
- Maximizing use of urban design solutions such as impermeable surfaces, green areas, shadowing, water retention areas, ventilation corridors etc) that can cope with risks and also reduce the dependency on technical infrastructure like sewage systems, dikes etc.
- Engaging affected stakeholders in appropriate and proportional participatory decision-making processes when making urban development decisions
- Incorporating exemplary sustainable design principles into new development. Link to other existing standards where appropriate (BREEAM, LEED, Greenstar, etc).
- Updating building regulations and standards regularly (or periodically) to take account of changing data and evidence on risks.

In addition, it will be necessary to assess infrastructure for resiliency to potential hazards: this is covered in Essential 8.

***Data you will need to complete this section of the scorecard will include**: land use, population, income levels and economic activity by segment of the city; and also relevant building codes and their application on a property-by-property basis.*

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
4.1 Land use – effectiveness of land use zoning in preventing exposure build-up (See also essential 5 on ecosystem services)	4.1.1 Agricultural land at risk.	% of agricultural land at risk	5 – No loss of agricultural land from "most severe" scenario. 4 – No loss of agricultural land from "most probable" scenario. 3 – <2.5% of agricultural land at risk from "most probable" scenario.	This assessment is intended to focus on agricultural land required to feed the city, excluding imported food from other regions or countries. Loss is for 6 months or longer. Effectiveness of zoning should ideally be independently validated (see also Essential 2).

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			2 – 2.5-5% of agricultural land at risk from "most probable" scenario. 1 – 5-7.5% of agricultural land at risk from "most probable" scenario. 0 - >7.5% of agricultural land at risk from "most probable" scenario.	
	4.1.2 Economic activity at risk.	% of employment at risk	5 – No loss of employment from "most severe" scenario. 4 – No loss of employment from "most probable" scenario 3 – <2.5% of employment at risk from "most probable" scenario 2 – 2.5-5% of employment at risk from "most probable" scenario 1 – 5-7.5% of employment risk from "most probable" scenario 0 - >7.5% of employment at risk from "most probable" scenario	Employment is at risk from damage to farmland, factories, offices, and so on. Loss is for 3 months or longer. Effectiveness of zoning should ideally be independently validated (see also Essential 2).
		% of business output at risk	5 – No loss of business output from "most severe" scenario. 4 – No loss of business output from "most probable" scenario. 3 – <2.5% of business output at risk from "most probable" scenario. 2 – 2.5-5% of business output at risk from "most probable" scenario.	Business output measured in financial terms. This assessment also includes loss through business being forced to relocate elsewhere, even if only temporarily, due to loss of premises or facilities, loss of markets, loss of services from the city or loss of workforce through inability to reach their place of work. Loss is for 3 months or longer.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			1 – 5-7.5% of business output risk from "most probable" scenario. 0 - >7.5% of business output at risk from "most probable" scenario.	Effectiveness of zoning should ideally be independently validated (see also Essential 2).
	4.1.3 Potential population displacement.	% of population at risk of displacement	5 – No population displacement from "most severe" scenario. 4 – No population displacement from "most probable" scenario. 3 – <2.5% population displacement from "most probable" scenario. 2 – 2.5-5% population displacement from "most probable" scenario. 1 – 5-7.5% population displacement from "most probable" scenario. 0 - >7.5% population displacement from "most probable" scenario.	Displacement for 3 months or longer as a consequence of housing being destroyed or rendered uninhabitable, or the area in which it is located being rendered uninhabitable. This assessment also needs to cover informal and unplanned settlements. Effectiveness of zoning should ideally be independently validated (see also Essential 2).
4.2 Building codes	4.2.1 Existence of building codes designed to address risks identified in Essential 2.	Existence of applicable codes to all physical assets.	Codes exist that will ensure: 1– Zero damage (to the point safety risk) from "most severe" scenario. 4 – Zero damage (to the point of safety risk) from "most probable" scenario. 3 – Damage to <5% of all physical structures and assets to the point safety risk in the "most probable" scenario. 2 – Damage to 5-10% of all physical structures and assets to the point of	Building codes should be specifically evaluated for ability to deal with "most probable" and "most severe" scenarios in Essential 2. It may make sense to subdivide the city by region or neighborhood. Effectiveness of codes should ideally be independently validated (see also Essential 2).

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			safety risk in the "most probable" scenario. 1 - Damage to 10-20% of all physical structures and assets to the point of safety risk in the "most probable" scenario. 0 - Damage >20% of all physical structures and assets to the point of safety risk in the "most probable" scenario.	
	4.2.2 Application of building codes.	Implementation of building codes on relevant structures.	5 – Codes are 100% implemented on applicable structures 4 - Codes are 90-100% implemented on applicable structures 3 – Codes are 80-90% implemented on applicable structures. 2 – Codes are 70-80% implemented on applicable structures. 1 – Codes are 70-80 % implemented on applicable structures. 0 – Codes are <70% implemented on applicable structures	Effectiveness of codes should ideally be independently validated (see also Essential 2). Application of codes will be a particular issue in unplanned settlements.
	4.2.3 Updates to building codes.	Conformity of statutory codes with latest standards in building practice and with perils faced.	5 – Codes are or will be reviewed for suitability for "most severe" scenario and updated every 5 years or more frequently. They embody the latest standards in building practice. 4 – Codes are or will be reviewed for suitability for the "most probable"	Codes may be updated as building practice evolves or as new needs (for example an increased storm risk) dictate.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			scenario every 10 years. They may not embody the very latest standards in building practice. 3 – Codes are or will be reviewed for suitability for the "most probable" scenario every 10 years. They probably do not embody the very latest standards in building practice. 2 – Codes are or will be reviewed for suitability for the "most probable" every 15 years or longer. They are known to be obsolete in significant respects. 1 – Codes exist, but are not reviewed at all, and no there are no plans for this. They are wholly obsolete. 0 – No codes.	
4.3. New development	4.3.1 Urban design solutions that increase resilience.	Use of urban design solutions to improve resilience, often by maximizing the extent and benefit of ecosystem services within the city (see also Essential 5).	5 – Systematic use of design solutions to improve resilience throughout the city, enforced by codes. Assumed to be "the norm". 4 – Widespread use of urban design features but some missed opportunities. Proposals to use urban design solutions are likely to be favourably received but not mandated.. 3 – Some use of urban design features – perhaps in some areas, or perhaps concentrating on one or two solutions. Their use is not assured but the	Urban design solutions that can improve resilience will include, but are not limited to: - soakaways and porous pavement used to deal with urban storm-water run-off and replenish ground water; - underground parking garages used as holding tanks for storm water, and parks that function as flood zones; - green roofs to help cool buildings and reduce storm run-off; - trees and greenery to reduce heat-island effects, or stabilize hillsides;

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			argument for using them can be made depending on each case. 2 – Scattered use of urban design solutions, but interest in expanding this. 1 – Little use and little interest. 0 – No use and no interest.	- neighbourhood micro-grids or roof-top generation as back-up to the main energy supply.
	4.3.2 Sustainable building design standards	Use of sustainable building design standards such as LEED, GreenStar and BREEAM to improve resilience.	5 – Systematic specification of meaningful green building standards for all new-build or retrofit, enforced by codes. Assumed to be "the norm". 4 – Widespread use of green building standards, but some missed opportunities. Proposals to use such standards are likely to be favourably received but not mandated. 3 – Some use of green building standards – perhaps in the downtown area. Their use is not assured but the argument for using them can be made depending on each case. 2 – Scattered use of green building standards developing on the developer's interest, but interest in expanding this. 1 – Little use and little interest. 0 – No use and no interest.	Sustainable building designs can improve resilience by: - reducing demand for energy and water; - dealing better with heat events; - incorporating features such as green roofing that also helps to control storm water runoff;

Essential 5: Safeguard Natural Buffers to Enhance the Protective Functions Offered by Natural Ecosystems

Essential 5 addresses the identification, monitoring and protection of critical ecosystem services that confer a disaster resilience benefit. Relevant ecosystem services may include, but are not limited to: water retention or water infiltration; afforestation; urban vegetation; floodplains; sand dunes; mangrove and other coastal vegetation; and pollination. Many ecosystem services that are relevant to the city's resilience may be provided well outside its geographical area.

The essential includes:

- Recognising value and benefits from ecosystem services for disaster risk prevention, protecting and /or enhancing them as part of risk reduction strategies for cities.
- Considering also natural buffers in the rural hinterland of the city and wider region, and cooperation with municipalities there to establish a regional approach of land use planning to protect the buffers.
- Anticipating changes from climate trends and urbanization and planning to enable ecosystem services to withstand these.

Integration of ecosystem services for more urban resilience into urban land use management, urban design and into relevant investment projects, is covered in Essential 4.

Note that ecosystem services that benefit a city may be located many miles away (for example, where upstream forests may manage floodwater run-off to the benefit of cities on downstream floodplains). Ecosystem services may not be recognized or even suspected, and you may require external expertise to identify them. But if there really are no ecosystem services that affect your city's disaster resilience, omit this section. Ecosystem services that offer a generalized, planetary benefit (for example, polar icecaps) are excluded.

Data you will need to complete this section of the scorecard will include: *land use and zoning documentation, plus data on the extent and health of relevant ecosystems as measured by applicable indicators*.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
5.1 Ecosystem services	5.1.1 Awareness of the role that ecosystem services may play in the city's disaster resilience.	Ecosystem services are specifically identified, and managed as critical assets.	5 - Critical ecosystem services identified and monitored annually on a defined set of key health/performance indicators. 4 – Critical ecosystem services identified and monitored annually, but less systematic use of metrics. 3 – Critical ecosystem services identified but have ad hoc monitoring – no real attempt to track health over time. 2 – Some key ecosystem services omitted from monitoring altogether. 1 – Identification and monitoring of ecosystem services is formative at best, or is seriously deficient. 0 - No monitoring.	Ecosystem services may include: - Sand dunes, coastal wetlands, mangroves or reefs that protect against storm surges and tsunamis; - Forestation that protects against flash flooding, landslides; - Natural overflow channels, sandy soil soak-zones, and marshes that can protect against river flooding and storm water run-off; - Lakes, rivers and aquifers that supply water; - Water-tables that, if lowered, may cause low-lying or reclaimed land to shrink to below sea level; - Trees and greenery that reduce urban heat-island effects or enable urban soak-way zones for flood management. The location of the ecosystem service may be many miles from the city, but still relevant to its disaster resilience: for example, mountain forestation can reduce flood crests that affect cities on floodplains hundreds of miles away. Many ecosystem services also relieve chronic stresses – for example, wetlands help to remediate water pollution; forests help to remediate air pollution, and so on. Where those chronic stresses degrade the city's disaster resilience (for example, where pollution reduces water available in a drought or where lack of pollinating insects reduces

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
				food supply) then the ecosystem services concerned should also be monitored.
	5.1.2 Ecosystem health	Change in health, extent or benefit of each ecosystem service in last 5 years.	5 - Improved health and performance across the board for critical eco-system services' 4 – At least neutral status across the board, with some improvements in some cases. 3 – Neutral status on average – some improvements offset by some declines. 2 – Generalized decline in ecosystem service status. 1 – Generalized severe degradation in status known or suspected. 0 – Potentially fatal damage to some or many key eco-system services.	Measures will include extent, health (perhaps captured as species diversity) and buffering capacity. Measures will be specific to each ecosystem and may need to be derived by scientists or technical experts practicing in the relevant areas.
	5.1.3 Impact of land use and other policies on ecosystem services	Absence of policies or land uses liable to weaken ecosystem services.	5 - Land use policies are strongly supportive of critical ecosystem services and are fully enforced.	This assessment complements the assessment of land use zoning in Essential 4.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			4 - Land use policies are strongly supportive of critical ecosystem services and are generally enforced. 3 - Land use policies are broadly supportive but are not fully enforced. 2 – Land use policies (or lack thereof) may lead or have led to damage to one or more critical ecosystem services. 1 – Land use policies (or lack thereof) inflict generalized degradation on ecosystem services. 0 – Land use policies (or lack thereof) may lead or have led to complete destruction of critical ecosystem services.	

Essential 6: Strengthen Institutional Capacity for Resilience

It is important ensure that all institutions relevant to a city's resilience have the capabilities they need to discharge their roles. "Institutions" include, as applicable, central, state and local government organizations; private sector organizations providing public services; (depending on locale, this may include phone, water, energy, healthcare, road operations, waste collection companies and others as well as those volunteering capacity or equipment in the event of a disaster); industrial facility owners and operators; building owners (individual or corporate); NGOs; professional, employers' and labor organizations; and cultural and civil society organizations (see Essential 7).

Capacity should be developed across the five key DRR areas of understanding, prevention, mitigation, response and recovery planning. Factors affecting capacity will include:

- Skills, including but not limited to: hazard/risk assessment, risk-sensitive planning (spatial and socio-economic), integrating disaster and climate risk considerations in project evaluation/design (including engineering design) , co-ordination, communication, data and technology management, and disaster management, response, recovery, assessment of structures post disaster; business and services continuity planning).
- Training, based ideally on case studies of how DRR can be implemented and what business continuity requires.
- Creating and implementing information and data frameworks for resilience and disaster risk reduction that build consistency in data capture and storage and enable data access, use and re-use by multiple stakeholder groups for regular development processes.

Shared understanding of roles and responsibilities, and a framework of shared and open information on resilience in the city are also important to capacity – these are covered in Essential 1.

Data you will need to complete this assessment include*: training curricula; training records for those trained, courses run; school and university curricula; survey and market research data on effectiveness*.

Subject/Issue	**Item measured**	**Indicative Measurement**	**Indicative Measurement Scale**	**Comments**
6.1 Skills and experience	6.1.1 Availability of skills and experience in disaster resilience – risk identification, mitigation, planning, response and post event response.	Known (ie inventoried in last 1 year) availability of key skills, experience and knowledge.	5 – Skills inventory carried out in last year and all key skills and experience are available in required quantities for all organizations relevant to city disaster resilience. 4 – Inventory carried out - shows with minor gaps in	Skills will include: land planning, energy, environmental, water and structural engineering, logistics, debris disposal, healthcare, law and order, project planning and management **[others tbd].** Knowledge refers to operating knowledge of city government and city infrastructure(s): the

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			quantity or skill type in some organizations. 3 – Inventory carried out but each organization has at least one skill or experience type in short supply. 2 – Inventory may not have complete coverage, but known widespread lack of multiple skill or experience types in many organizations. 1 – Rudimentary and partial inventory. Suspicion of complete or almost complete lack of skills available across the city. 0 – No inventory.	energy, water, sanitation, traffic and other critical city systems at risk.(see Essential 8) Experience refers to experience of the types of perils the city faces (see Essential 2) (Some skills, knowledge or experience may be purchased from specialist consultancies, or supplied on a one-time basis by aid agencies). (First responders – see essential 9)
6.2 Public education and awareness	6.2.1 Exposure of public to education and awareness materials/messaging.	Coordinated public relations and education campaign exists, with structured messaging, channels, and delivery.	5 - Systematic, structured campaign exists using at least 6 of the media at right, via neighborhood mobilization (see essential 7), and schools outreach. 4 – Campaign uses at least 5 of the media/channels above, including 1 of neighborhood mobilization and schools outreach. 3 - Campaign uses at least 4 of the media/channels above; also	Likely to be based on information made public – see Essential 1. Media may include: - Print – books, newspapers, leaflets, fliers; - School and college teaching material; - TV – advertisements. Documentaries, news features; - Radio – as for TV; - Web – websites, advertisements, content on city web-sites;

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			weighted to least informative such as radio and poster ads. 2 – Campaign uses 3 of the media/channels above; also weighted to least informative such as radio and poster ads. 1 – Ad hoc – no structured education and awareness campaign as such. 0 - No education work.	- Mobile – as for web but also social media – Twitter, Facebook, Weebo etc; Possibly also create specialist app for city's disaster resilience information; - Posters – on buildings, busses, trains, city offices. Material may come from multiple agencies and sources, but should have coordinated messages. Schools and colleges may be an especially important channel; also churches, neighborhood groups, libraries.
		Exposures per member of the public, per month to messaging	5 - Average 1 or more exposures per person per week, city-wide. 4 - Average 1 exposure per person per two weeks, city-wide. 3 - Average 1 exposure per person per month, city-wide. 2 - Average 1 exposure per person per quarter, city-wide. 1 - Average 1 exposure per person per six months, city-wide. 0 - Average 1 exposure per person per year or worse.	Exposures established, for example, via traffic counts (web sites, mobile), audience figures (TV, radio), road traffic counts (ie, road traffic past posters), and so on. If funds permit exposures could also be validated via survey.
	6.2.2 Validation of effectiveness of education.	Knowledge of "most probable" risk scenario and knowledge of key response and preparation	5 – "Most probable" scenario, and applicable response and preparation, appears to be generally known by >90% of	Survey can be delivered to different samples via phone; surveys in school classes; mail-

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
		steps is widespread throughout city. Tested by sample survey.	respondents as verified by opinion poll. 4 – 75–90% known. 3 – 50-75% known. 2 – 25-50% known. 1 – 10-25% known. 0 – <10% known, or no poll.	shot; as an add-on to city meetings; as a fill-in portion for leaflets and print-media; and so on.
6.3 Training Delivery	6.3.1 Availability, take-up of training.	Training offered and available to all population (from city government, voluntary or other sources)	5 – Full training curriculum is available for all, derived from known or anticipated needs. 4 – Full training curriculum is available but not fully known about. 3 – Training curriculum available but has some gaps and may not be fully deployed across the city. 2 - Ad hoc training classes address some issues for some area of the city. 1 – Material is known to be dated or inaccurate and not in process of being updated. 0 - No training.	Important to build training into school and college curricula. (See also drills – Essential 9)
		% of population trained in last year.	5 - 5% or better in all neighborhoods	Effectiveness of training validated via drills – see Essential 9

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			4 – 2.5-5% in all neighborhoods 3 – 1-2.5% in all neighborhoods 2 – 0.5-1% in all neighborhoods 1 – <0.5% in all neighborhoods 0 - No training.	
		Frequency of repeat training	5 – 6 monthly refreshers and emergency drills city-wide for all trained participants. 4 – Annual refreshers and emergency drills city-wide for all trained participants. 3 – Annual refreshers and emergency drill cycle but may not be city-wide or reach all participants. 2 – Two-yearly refreshers and emergency drill cycle but may not be city-wide or reach all participants. 1 – Ad hoc refreshers and emergency drills – timing, attendance and content depends on enthusiasm of local organization. 0 - No refreshers or emergency drills.	See also Essential 9.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
6.4 Languages	6.4.1 Accessibility of education and training to all linguistic groups in the city.	Availability of all education and training in all languages spoken in the city.	5 – Available for 100% of linguistic groups and 100% of the population. 4 – Available for 95% of the population irrespective of language. 3 – Available for 90% of the population irrespective of language. 2 – Available for 85% of the population irrespective of language. 1 – Available for 80% of the population irrespective of language. 0 – Available for <80% of the population irrespective of language.	Cities with high numbers of different languages may need to settle for a selection of languages that reaches everyone as a first or second language. Validation will be required that 100% of population is being reached in this way.
6.5 Learning from others	6.5.1 Effort taken to learn from what other cities, states and countries (and companies) do to increase resilience	Learning activities executed with other cities and other practitioners.	5 – Regular (say, annual) exchanges with other cities and regions, specifically to share understand and capture resilience best practices, issues, responses; and examples exist of changes made in the city as a result. Supplemented by regular peer-to-peer contacts with practitioners in other organizations. 4 – Regular exchanges but may be in the context of other meetings with sharing of best	These activities are focused on learning and improving – actual coordination of response management and resilience planning is covered in Essential 1.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			practices as a side-effect. Outcomes are captured and some impact may be identified on how the city prepares for disasters. 3 – Reliance only on networking by individual practitioners in the organization with their peers in other organizations. These can be frequent, and there will be some attempt to capture and implement learnings. 2 – Occasional exchanges of a more one-off or ad hoc nature. Impact on/benefit for the city is diffuse and harder to identify 1 – Even networking is limited and learning potential is therefore also limited. 0 – No attempt to learn from others.	

Essential 7: Increase societal and cultural resilience

Social "connectedness" and a culture of mutual help has a major impact on the actual *outcomes* of disasters of any given magnitude. These can be encouraged by measures that include:

- Establishing and maintaining neighbourhood emergency response groups and training;
- Engaging and co-opting civil society organizations – churches, youth groups, clubs, advocacy groups (for example for the disabled);
- Providing community groups with "unvarnished" data on risk scenarios, the current level of response capabilities and thus the situation they may need to deal with;
- Formulation of neighbourhood plans by reference to such groups (see Essential 9);
- Offering education, training and support to such groups;
- Undertaking formal or informal censuses of those who may be vulnerable and less able to help themselves, in each neighbourhood, and understanding from them what their needs are;
- Using government "touch-points" with the public such as welfare or social services visits and offices, police, libraries and museums to build awareness and understanding;
- Engaging with employers as a communications channel with their workforces for disaster awareness, business continuity planning and training;
- Engage local media in capacity building (TV, print, social media, etc);
- Mobile (phone/tablet) and web-based "systems of engagement" (for example, crowdsourcing or disseminating data on preparedness).
- Translation of all materials into all languages used in the city.

Ensuring that the education curriculum within schools, higher education, universities and the workplace includes disaster awareness and training is a key element of social resilience – this is covered in Essential 6.

Data you will need to complete this assessment include*: list of grass-roots organizations and information on their size, roles and how they operate; details of how the city works with disadvantaged groups – for example, those in areas of high poverty; transient or nomadic communities; slum/favela residents; the elderly; physically or mentally sick or disabled; children; non-native language speakers*.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
7.1 Grass roots organizations	7.1.1 Coverage of grass roots organization(s) throughout the city.	Presence of at least one non-government body for pre and post event response for each neighborhood in the city.	5 – Grass roots organization(s) addressing full spectrum of disaster resilience issues exist(s) for every neighborhood, irrespective of wealth, demographics etc. . 4 - >75% of neighborhoods covered. 3 - >50 -75% of neighborhoods covered 2 - >25-50% of neighborhoods covered 1 – Plans to engage neighborhoods and maybe one or two initial cases. 0 – No engagement.	Grass roots organizations may include: - Those set up specifically for disaster resilience management (for example, community emergency response organizations). - Those serving some other purpose but willing and able to play a disaster resilience role: for example, churches, business Round Tables, youth organizations, food kitchens, neighborhood watch, day centers and so on. Grass roots organizations should be willing and able to contribute to disaster resilience plans for their area based on the input of their members. They need to be seen as legitimate, and to cooperate with each other and the city government. (Event response element is regularly tested at least in simulation exercises – see Essential 9)
	7.1.2 Effectiveness of grass roots network	Grass roots organization meeting frequency and attendance.	5 – For >75% of neighborhoods, one meeting per month, all personnel roles staffed and 10x formal role-holder numbers in regular attendance. 4 – For 50-75% of neighborhoods, one meeting per quarter – all roles staffed and 5 x role-holder numbers in attendance. No meetings in the rest.	Grass roots organizations defined as above.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			3 – For 25-50% of neighborhoods, semi-annual meetings, but with some gaps in roles and less than 3x role-holders in attendance. No meetings in the rest. 2 – For 25-50% of neighborhoods, annual meetings but with significant gaps in roles and less than 3x formal role-holders in attendance. No meetings in the rest. 1 – Ad hoc meetings in less than 25% of neighborhoods of a few "enthusiasts". 0 - No meetings.	
		Clear identification and coordination of pre and post-event roles for grass-roots bodies, supported by training. Roles agreed and signed off, preferably via MOU or similar.	5 – For >75% of neighborhoods, roles are defined and filled, coordination is effective within and between grass-roots bodies, and full training is both provided and attended. 4 – For 50-75% of neighborhoods, roles are defined and agreed, but some minor deficiencies in these or in training, or incomplete staffing in some cases. Coordination generally good but some lapses. No roles defined in the rest. 3 – For 25-50% of neighborhoods, most roles defined, but with more	One key issue is ensuring that there is a clear differentiation of roles between grass-roots organizations and between them and other entities such as city government – who is responsible for what? See also information sharing framework in Essential 1.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			significant omissions; some training but with gaps in coverage; coordination adequate but could be improved. No roles defined in the rest. 2 – For 25-50% of neighborhoods, a few key roles defined, but coordination is absent or poor and training notably incomplete. No roles defined in the rest, 1 – Plans in place to define roles and develop coordination mechanisms. 0 – No roles defined and no coordination.	
	7.1.3 Social connectedness and neighborhood cohesion.	Likelihood that residents will be contacted immediately after an event, and regularly thereafter to confirm safety, issues, needs etc.	5 – Sufficient volunteers are available from grass-roots organizations to give “reasonable confidence” that 100% of residents will be contacted within 12 hours of an event. 4 – 90% of residents within 12 hours 3 – 80% of residents 2 – 70% of residents 1 – 50% or less of residents 0 – No volunteers.	Social connectedness has been shown to have a major impact in reducing fatalities from disasters, and also in reducing opportunistic crime following an event. Connectedness is however difficult to measure directly. This assessment is written in terms of specifically identified volunteers and grass-roots organizations, taking these as a proxy measurement for connectedness. In addition, the “reasonable confidence” standard is inherently subjective. As well as this proxy measurement, therefore, other factors that you may also wish to take into account will include:

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
				- A history of people in each neighborhood meaningfully helping each other after previous events; - A strong fabric of community organizations in general, even if not focused on disaster resilience in the first instance.
	7.1.4 Engagement of vulnerable segments of the population.	Evidence of disaster resilience planning with or for the relevant groups covering the span of the vulnerable population. Confirmation from those groups of effective engagement.	5 – All groups are regularly engaged on disaster resilience issues and they or their representatives confirm as such. 4 – All major groups (measured by membership % of those defined as vulnerable in the city as a whole) are engaged – some minor gaps. 3 – One or more major gaps in coverage or effective engagement. 2 – Multiple major gaps in coverage or effective engagement 1 – Generalized failure to engage. 0 – No groups specifically identified.	Vulnerable segments of the population might include, as examples: - Those in areas of high poverty; - Transient or nomadic communities; - The elderly; - Physically or mentally sick or disabled; - Children; - Non-native language speakers. Engagement may be through neighborhood organizations or via specialist government organizations, charities, NGOs etc. These may also function as "grass roots" organizations (see above) (Public awareness, education and training materials – see Essential 7)
7.2 Private sector / employers	7.2.1 Extent to which employers act as a channel with employees.	Proportion of employers that pass resilience communications to employers, and allow limited time off for resilience volunteer activities.	5 – 50% of employers with more than 10 employees takes part in communicating with their workforce about resilience issues/ 10% take part in	Employees can act as an important communications conduit to employees on resilience issues, especially in the area of hazards faced and preparation – which are

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			resilience training and allow small amounts of time off for resilience volunteer activities. 4 – 40%/8%... 3 – 30%/5%... 2 – 20%/3%... 1 – 10%/1%... 0 – 0%/0%...	also likely to benefit them in the form of better continuity of operations after an event.
	7.2.2 Business continuity planning	Proportion of business with a solid business continuity plan	5 – All employers with more than 10 employees have some form of business continuity plan based on a planning assumptions validated by the city. 4 – 80%... 3 – 50%... 2 – 30% 1 – 10% or less 0 – 0% or don't know.	While business continuity plans are the concern of each business, their presence and effectiveness will play a major role in how rapidly the city's economy restarts after a disaster. Therefore cities need to be proactive in persuading businesses to undertake continuity plans, based on a shared view of the hazards and issues likely to arise.
7.3 "Systems of Engagement"	7.3.1 Use of mobile and e-mail "systems of engagement" to enable citizens to receive and give updates before and after a disaster	Use of mobile and social computing-enabled systems of engagement (supported by e-mail).	5 – All information before, during and after an event is available on mobile devices; this is supported by alerts on social media; this is also used to enable an in-bound "citizen to government" flow allowing	"Systems of engagement" is the term given to mobile device/social media and e-mail-based systems to pass information to individuals and also to capture information from them. They are usually paired with "systems of record" which are back-office and enterprise systems (such as the emergency management system).

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			crowd sourcing of data on events and issues. 4 – Extensive use is made of systems of engagement, with a few minor omissions. 3 – Some use is made, but there are larger gaps in the information available by this means and the in-bound flow works only via direct communication rather than mining of data generally. 2 – As for 3 but with no inbound flow. 1 – Only rudimentary use of systems of engagement – perhaps only via mobile access to the existing website which may not have been optimized for smartphones etc – but interest in expanding this. 0 – No use of systems of engagement.	Data capture may be directly, where a citizen directly contacts the city government, or via a data-mining – for example where some governments in Australia mine data from Twitter and SMS to gain an extra source of intelligence on wildfire outbreaks and status.

Essential 8: Increase Infrastructure Resilience

This essential addresses understanding how critical infrastructure systems will cope with disasters the city might experience (see essential 2) and developing contingencies to manage risks caused by these outcomes. This should be addressed through measures including, but not limited to:

- Assessment of capacity and adequacy in the light of the scenarios in Essential 2. Consider: possible damage to parallel infrastructure (for example, impact on evacuation capacity if one of two roads out of a city is blocked); and consider linkages between different systems (for example, impact if a hospital loses its power or water supply)
- Liaising with, and building connections between infrastructure agencies (including those that may be in the private sector) to ensure resilience is considered appropriately in project prioritization, planning, design, implementation and maintenance cycles.
- Tendering and procurement processes that to include resilience criteria agreed upon by the city and stakeholders and is consistent throughout.
- For emergency management infrastructure, assessment of "surge" capacity – ability to deal with suddenly increased loadings from law and order issues, casualties, evacuees, and so on.

Systematically triaged processes are also required for prioritization of retrofit or replacement of unsafe infrastructure. These are covered in Essential 2.

Critical infrastructure includes that required for the operation of the city and that required specifically for emergency response, where different. Infrastructure required for operation includes but is not limited to:

- transport – roads, rail, airports and other ports
- vehicle and heating fuel supplies
- telecommunication systems
- utilities systems (water, wastewater, electricity, gas, waste disposal)
- health care centres, hospitals
- schools and educational institutes
- community centres, institutions
- school facilities
- healthcare facilities
- food supply chain
- police and fire services
- jails
- "back office" administration – welfare payments, housing
- computer systems and data supporting the above

- (as resources allow, safety and survivability of cultural heritage sites and artifacts).

Infrastructure required for disaster response may include the above, plus (as examples):

- emergency or incident command centers, and associated communications and monitoring/situation awareness systems – these may include cameras, sensors and crowdsourcing mechanisms such as reading of SMS and Twitter feeds
- additional fire, police and ambulance vehicles
- national guard or other military services
- earth and debris-removing equipment
- pumps
- generators
- sports facilities, school buildings and so on that provide places of shelter
- mortuaries
- back-up computing facilities

Data you will need to complete this section of the scorecard will include*: disaster resilience plans for each infrastructure system (each may be owned by one or more separate agencies), and data on execution of those plans; location of, and relationship between, critical assets, the populations they serve, and documentation linking their loss or damage to the scenarios in Essential 2. This data is likely to come from multiple organizations and completion of this section of the scorecard will probably require engineering input.*

Subject/Issue	**Item measured**	**Indicative Measurement**	**Indicative Measurement Scale**	**Comments**
8.1 Protective Infrastructure	8.1.1 Adequacy of protective infrastructure (Ecosystem services offering protection or mitigation – see Essential 5)	Protective infrastructure exists or is in the process of construction – capabilities known to match hazards envisioned in "most probable" and "most severe" scenarios in Essential 2.	5 – Protective infrastructure fully in place designed to deal with "most severe" scenario with minimal economic or humanitarian impact. 4 – Protective infrastructure has some deficiencies relative to "most severe" scenario but designed to deal with "most probable" scenario. 3 – Protective infrastructure would mitigate most of "most likely" scenario but some impacts would be felt; deficiencies relative to "most severe" are more serious; 2 - Protective infrastructure would allow significant damage/impact from "most possible", and potentially catastrophic damage from "most severe". 1 - Protective infrastructure would mitigate some impacts but would still allow potentially catastrophic damage from "most probable" scenario. 0 –No protection in place.	Examples of protective infrastructure: - Levees and flood barriers; - Flood basins; - Sea walls (where used); - Shelters, such as tornado/hurricane shelters; - Storm drains; - Shock absorption capabilities fitted to infrastructure to deal with earthquakes.
	8.1.2 Effectiveness of maintenance	Processes exist to maintain protective infrastructure and ensure integrity and operability of critical assets.	5 – Audited annual inspection process and remediation of issues found. 4 – Audited inspections but remediation of minor items may be delayed by funding issues.	Examples of processes: - Levee maintenance; - Clearing storm drains; - Maintenance of emergency response equipment

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			3 – Audited inspections every 2 years or more; remediation may be delayed by funding issues. 2 – Non-audited inspections every 2 years or more – backlog of remediation issues. 1 – Haphazard inspections in response to incidents or reports from the public. Significant known backlog of maintenance issues such that effectiveness of infrastructure may be impaired. 0 – No regular inspections and backlog/maintenance status is unknown.	- Maintenance of back up and stand-by power or communications systems or other critical assets
8.2 Communications	8.2.1 Service days at risk of loss	"Communications loss factor". If a = estimated # of days to restore regular service area-wide b = % of user accounts affected … then communications loss factor = a x b (Example – 1.5 day's loss of service for 10% of user accounts in city = loss factor of 15%; 3 days' loss of service for 50% of user accounts in city = loss factor of 150%)	5 – No loss of service even from "most severe" scenario 4 – No loss of service from "most probable" scenario 3 – Loss factor of 1-25% from most probable" scenario 2 – Loss factor of 25-100% from "most probable" scenario 1 – Loss factor of 100-200% from "most probable" scenario 0 – Loss factor >200% from "most probable" scenario	Communications are arguably the most critical infrastructure of all, because all other infrastructures (as well as factors such as emergency response and public awareness) are likely to depend on them.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
	8.2.2 Designated critical asset service days at risk of loss from communications failure.	"Communications critical asset (CCA) loss factor". If a = estimated # of days to restore regular service area-wide b = % of critical assets affected … then CCA loss factor = a x b (Example – 1.5 day's loss of service for 10% of critical assets in city = loss factor of 15%; 3 days' loss of service for 50% of critical assets in city = loss factor of 150%)	5 – No loss of service even from "most severe" scenario 4 – No loss of service from "most probable" scenario 3 – Loss factor of 1-25% from most probable" scenario 2 – Loss factor of 25-100% from "most probable" scenario 1 – Loss factor of 100-200% from "most probable" scenario 0 – Loss factor >200% from "most probable" scenario	Critical communications assets might include, for example: - Police or armed forces communications systems - Water and energy sensing systems - Traffic control systems - Communication towers, transmitters, switches and other nodal components of public phone systems - Data- and switching-centers routing internet traffic. Service may be provided either from the asset itself or via a designated alternative/back-up.
	8.2.3 Cost of restoration.	Likely cost of loss of service and restoration of communications system(s) as % of annual billed revenue	5 – No loss of service. 4 - 10% of annual billed revenue 3 – 10-15% 2 – 15-25% 1 – 25-50% 0 - >50% of annual billed revenue.	This assessment is designed to help establish the return on investment from investing in hardening the relevant infrastructure, in reducing the burden of restoring the city to normal life after a disaster. If a communications system does not have billed revenue (for example a private radio network), calculate cost to replace as % of initial installation cost of entire system. Use same thresholds as shown left.
8.3 Electricity	8.3.1 Customer service days at risk of loss.	"Electrical energy loss factor". If : a = estimated # of days to restore regular service area-wide	5 – No loss of service even from "most severe" scenario 4 – No loss of service even from "most probable" scenario	Loss of service refers to service from the main electricity supply. It excludes the use of back up generators.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
		b = % of user accounts affected … then electrical energy loss factor = a x b (Example – 1.5 day's loss of service for 10% of user accounts in city = loss factor of 15%; 3 days' loss of service for 50% of user accounts in city = loss factor of 150%)	3 – Loss factor of 1-25% from most probable" scenario 2 – Loss factor of 25-100% from "most probable" scenario 1 – Loss factor of 100-200% from "most probable" scenario 0 – Loss factor >200% from "most probable" scenario	Loss of service should be assessed relative to the "normal" state: - If "normal" service is electricity 24 hours a day then loss of service is anything that reduces this; - If "normal" service is electricity for less than 24 hours per day, then loss of service is anything that reduces this still further.
	8.3.2 Designated critical asset service days at risk of loss from energy failure.	"Electricity critical asset (ECA) loss factor". If a = estimated # of days to restore regular service area-wide b = % of critical assets affected … then ECA loss factor = a x b (Example – 1.5 day's loss of service for 10% of critical assets in city = loss factor of 15%; 3 days' loss of service for 50% of critical assets in city = loss factor of 150%)	5 – No loss of service even from "most severe" scenario 4 – No loss of service even from "most probable" scenario 3 – Loss factor of 1-25% from most probable" scenario 2 – Loss factor of 25-100% from "most probable" scenario 1 – Loss factor of 100-200% from "most probable" scenario 0 – Loss factor >200% from "most probable" scenario	Critical electrical assets are those that are either: - Essential for the operation of some part of the energy grid for the city; - Essential for the functioning of some other critical asset (say, a water treatment plant or a rail line). Loss of service refers to service from the main electricity supply. Service may be provided either from the asset itself or via a designated alternative/back-up.
	8.3.3 Cost of restoration	Likely cost of lost service and restoration as % of annual billed revenue	5 – No loss of service. 4 - 10% of annual billed revenue 3 – 10-15% 2 – 15-25%	This assessment is designed to help establish the return on investment from investing in hardening the relevant infrastructure, in reducing the burden of restoring the city to normal life after a disaster.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			1 – 25-50% 0 - >50% of annual billed revenue	
8.4 Water, sanitation	8.4.1 Customer service days at risk of loss.	"Water/sanitation loss factor". If a = estimated # of days to restore regular service area-wide b = % of user accounts affected … then water/sanitation loss factor = a x b (Example – 1.5 day's loss of service for 10% of user accounts in city = loss factor of 15%; 3 days' loss of service for 50% of user accounts in city = loss factor of 150%)	5 – No loss of service even from "most severe" scenario 4 – No loss of service even from "most probable" scenario 3 – Loss factor of 1-25% from most probable" scenario 2 – Loss factor of 25-100% from "most probable" scenario 1 – Loss factor of 100-200% from "most probable" scenario 0 – Loss factor >200% from "most probable" scenario	Loss of service refers to service from the main water or sanitation system for the neighborhood or city, if present. It excludes the use of back up supplies or portable sanitation systems. If the *main* supply is a localized water supply or sanitation system (eg well or septic tank), this may in fact prove more disaster-resilient than a city-wide system. Loss of service needs to be assessed relative to the "normal" state. For example: - If "normal" service is potable running water in every house, 24 hours a day - then loss of service needs to be assessed as the removal or diminution of this service; - If "normal" is running water for washing but not drinking, 24 hours a day - then loss should be assessed relative to this; - If "normal" is either of the above but only for some hours a day, then the loss is relative to the "normal" number of hours – ie, where user accounts have even fewer hours a day of availability until service is restored; - If "normal" is standpipes or communal toilets, then loss is relative to this - the loss factor will be calculated by

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
				reference to the estimated numbers of households using the standpipes or communal toilets affected. - If "normal" for a neighborhood includes no sanitation at all, then focus on water alone and score that. Note – storm water systems are covered under "protective infrastructure", above.
	8.4.2 Designated critical asset service days (for example, service to hospitals or other critical assets) at risk of loss from water or sanitation failure.	"Water/sanitation critical asset (WCA) loss factor". If : a = estimated # of days to restore regular service area-wide b = % of critical assets affected … then WCA loss factor = a x b (Example – 1.5 day's loss of service for 10% of critical assets in city = loss factor of 15%; 3 days' loss of service for 50% of critical assets in city = loss factor of 150%)	5 – No loss of service even from "most severe" scenario 4 – No loss of service even from "most probable" scenario 3 – Loss factor of 1-25% from most probable" scenario 2 – Loss factor of 25-100% from "most probable" scenario 1 – Loss factor of 100-200% from "most probable" scenario 0 – Loss factor >200% from "most probable" scenario	Critical water or sanitation assets are those that are either: - Essential for the operation of some part of the water or sanitation systems for the city; - Essential for the functioning of some other critical asset (say, a hospital). Loss of service refers to service from the main water or sanitation system for the neighborhood or city, as above. Service may be provided either from the asset itself or via a designated alternative/back-up.
	8.4.3 Cost of restoration of service	Likely cost of lost service and restoration as % of annual billed revenue	5 – No loss of service. 4 - 10% of annual billed revenue 3 – 10-15% 2 – 15-25% 1 – 25-50%	This assessment is designed to help establish the return on investment from investing in hardening the relevant infrastructure, in reducing the burden of restoring the city to normal life after a disaster.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			0 - >50% of annual billed revenue.	
8.5 Gas (if applicable)	8.5.1 Safety and integrity of gas system (if applicable)	Use of fracture resistant gas pipes in seismic or flood zones, and installation of automated shut-off capabilities.	5 – Full use: automated shut-offs on every property and 100% fracture resistant pipe. 4 – >90% of properties; 90% fracture resistant pipe if applicable.. 3 – 75-90% in both cases; 2 – 50-75% in both cases 1 – 1-50% in both cases 0 – 0% in both cases.	Fracture resistant pipe: PVC pipe or similar. If no mains gas system present – omit this assessment.
	8.5.2 Customer service days at risk of loss.	"Gas loss factor". If a = estimated # of days to restore regular service area-wide b = % of user accounts affected … then gas loss factor = a x b (Example – 1.5 day's loss of service for 10% of user accounts in city = loss factor of 15%; 3 days' loss of service for 50% of user accounts in city = loss factor of 150%)	5 – No loss of service even from "most severe" scenario 4 – No loss of service even from "most probable" scenario 3 – Loss factor of 1-25% from "most probable" scenario 2 – Loss factor of 25-100% from "most probable" scenario 1 – Loss factor of 100-200% from "most probable" scenario 0 – Loss factor >200% from "most probable" scenario.	Loss of service refers to those customer premises where mains (piped) gas is available. If the main form of gas supply is bottles, this may prove more disaster-resilient than a piped (mains) supply. Bottled gas is dealt with under fuel supply, below. "Loss of service" needs to be assessed relative to the "normal" state – for example, a significant drop in gas pressure relative to normal levels. .
	8.5.3 Designated critical asset service days at risk of	"Gas critical asset (GCA) loss factor". If :	5 – No loss of service even from "most severe" scenario	Critical gas assets are those that are either:

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
	loss from gas supply failure.	a = estimated # of days to restore regular service area-wide b = % of critical assets affected … then GCA loss factor = a x b (Example – 1.5 day's loss of service for 10% of critical assets in city = loss factor of 15%; 3 days' loss of service for 50% of critical assets in city = loss factor of 150%)	4 – No loss of service even from "most probable" scenario 3 – Loss factor of 1-25% from most probable" scenario 2 – Loss factor of 25-100% from "most probable" scenario 1 – Loss factor of 100-200% from "most probable" scenario 0 – Loss factor >200% from "most probable" scenario	- Essential for the operation of some part of mains gas system for the city; - Essential for the functioning of some other critical asset (say, a power-station). Service may be provided either from the asset itself or via a designated alternative/back-up.
	8.5.4 Cost of restoration of service	Likely cost of lost service and restoration as % of annual billed revenue	5 – No loss of service. 4 - 10% of annual billed revenue 3 – 10-15% 2 – 15-25% 1 – 25-50% 0 - >50% of annual billed revenue.	This assessment is designed to help establish the return on investment from investing in hardening the relevant infrastructure, in reducing the burden of restoring the city to normal life after a disaster.
8.6 Transportation	8.6.1 Road – service from road system at risk of loss	Road loss factor – if: a = miles of major road network for city and surrounding area at risk of becoming impassable to any type of vehicle after event b = likely number of days estimated before reopening,	5 – No loss of service even from "most severe" scenario 4 – No loss of service even from "most probable" scenario 3 – Loss factor of 1-25% from most probable" scenario 2 – Loss factor of 25-100% from "most probable" scenario	Loss of service refers to general road mobility. It primarily refers to damage to road surfaces or bridges and tunnels, or from fallen debris from buildings, cliffs etc.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
		c = total of major roads in the city and surrounding area lost for one day …then road loss factor = (a/c) x b as a % (Example - 10 miles of major road likely to be lost for two days, out of total of 100 miles of major road = road loss factor of 20% ((10/100) x 2)	1 – Loss factor of 100-200% from "most probable" scenario 0 – Loss factor >200% from "most probable" scenario	
	8.6.2 Road – survival of critical access and evacuation routes	Road critical asset (RCA) loss factor. If: a = carrying capacity (vehicles per hour) of evacuation/emergency supply routes to and from the city at risk of becoming impassable after event. b = # of days estimated before reopening c = carrying capacity (vehicles per hour) of all designated critical evacuation/emergency supply routes … then RCA loss factor = (a/c) x b as a % (Example –route with carrying capacity of 1,000 vehicles per hour likely to be closed for 3 days, out of a total carrying capacity on all evacuation/	5 – No loss of service even from "most severe" scenario 4 – No loss of service even from "most probable" scenario 3 – Loss factor of 1-25% from most probable" scenario 2 – Loss factor of 25-100% from "most probable" scenario 1 – Loss factor of 100-200% from "most probable" scenario 0 – Loss factor >200% from "most probable" scenario	Loss of service on critical access and evacuation routes should if possible also include an estimate of the likely impact of traffic gridlock on access or evacuation rates.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
		supply routes of 2,000 vehicles per hour = RCA loss factor of 150% ((1000/2000 x 3)		
	8.6.3 Rail/metro (if applicable) – service from rail system at risk of loss	Rail loss factor (for rail, use tons; for metro, use passengers). If: a = carrying capacity (tons or passengers per day) of affected rail lines to the city b = # of days estimated before reopening c = carrying capacity (tons per day per hour) of all rail links to the city. … then RCA loss factor = (a/c) x b as a % Example –rail line with carrying capacity of 10,000 tons or passengers per day likely to be closed for 2 days, out of a total carrying capacity on all rail lines of 15,000 tons or passengers per day = RCA loss factor of 133% ((10000/15000 x 2).	5 – No loss of service even from "most severe" scenario 4 – No loss of service even from "most probable" scenario 3 – Loss factor of 1-25% from most probable" scenario 2 – Loss factor of 25-100% from "most probable" scenario 1 – Loss factor of 100-200% from "most probable" scenario 0 – Loss factor >200% from "most probable" scenario.	Electrified rail lines are susceptible to energy outages (see above); and diesel lines are susceptible to fuel shortages (see below). If no rail lines, omit this assessment.
	8.6.4 Air (if applicable)	Airport loss factor. If: a = estimated # of flights in and out per day possible after the disaster	5 – No loss of service even from "most severe" scenario 4 – No loss of service even from "most probable" scenario	If no airport, omit this assessment. If multiple airports, combine capacities and scores. Airports should be capable of admitting commercial airliners or military transport aircraft - omit minor airfields.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
		b = max # of flights per day in normal operations c = # of days estimated before restoration of full capacity, then Airport loss factor = (a/b) x c as a % Example if 80 flights in and out per day are possible after a disaster, compared with a normal maximum of 100, and it takes 2 days to restore full capacity, then the airport loss factor is 160% ((80/100) x 2).	3 – Loss factor of 1-25% from most probable" scenario 2 – Loss factor of 25-100% from "most probable" scenario 1 – Loss factor of 100-200% from "most probable" scenario 0 – Loss factor >200% from "most probable" scenario.	
	8.6.5 River/Sea (if applicable)	River/seaport loss factor. If: a = estimated # of dockings per day possible after the disaster b = max # of dockings per day in normal operations c = # of days estimated before restoration of full capacity, then River/seaport loss factor = (a/b) x c as a % (Example if 5 dockings per day are possible after a disaster, compared with a normal maximum of 8, and it takes 2 days to restore full capacity, then the airport loss factor is 125% ((5/8) x 2).	Per port: 5 – No loss, even from "most severe" scenario 4 – No loss, even from "most probable" scenario 3 – 0.1-1 day from "most probable" scenario 2 – 1-2 days from "most probable" scenario 1 – 2-5 days from "most probable" scenario 0 - > 5 days	If no river or seaports, omit this assessment.

Subject/Issue	**Item measured**	**Indicative Measurement**	**Indicative Measurement Scale**	**Comments**
	8.6.6 Other public transport (if applicable)	(Buses and taxis effectively captured in road measures above).	5 – No loss of service even from "most severe" scenario 4 – No loss of service even from "most probable" scenario 3 – Loss factor of 1-10% from most probable" scenario 2 – Loss factor of 20% from "most probable" scenario 1 – Loss factor of 30% from "most probable" scenario 0 – Loss factor >30% from "most probable" scenario	Omit if not applicable.
8.7 Law and Order, First responders	8.7.1 Protection of critical law and order/responder assets.	"Law & Order critical asset (LOCA) loss factor". If a = estimated # of designated critical law and order assets rendered inoperable by the event b = total # of designated critical law and order assets … then LOCA loss factor = a/b expressed as % (Note – days loss of use is not relevant here as these are assets are most likely to be needed right after the event)	5 – No loss of service even from "most severe" scenario 4 – No loss of service even from "most probable" scenario 3 – Loss factor of 1-10% from most probable" scenario 2 – Loss factor of 20% from "most probable" scenario 1 – Loss factor of 30% from "most probable" scenario 0 – Loss factor >30% from "most probable" scenario	Critical law and order/responder assets include such items as: - Vehicles (fire-fighting, ambulances, police vehicles) - Helicopters and aircraft - Emergency food and first aid stocks/supplies; - Shelters; - Back-up generators; - (Communications systems – see above) - (Operations centers – see below) - (Key buildings – see below);

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
				- (Critical IT systems – see below). Service may be provided either from the asset itself or via a designated alternative/back-up.
	8.7.2 Disaster resilience of prison system	Ability of prison system to survive "most probable" and "most severe", scenarios, without releasing or harming inmates.	Under "most severe" scenario: 5 – No loss 4 – Some minor damage to facilities is probable – no less of life or loss of custody 3 – Significant damage to facilities is probable but no loss of life or custody. 2 – Significant damage to facilities and possible risk of loss of life or custody 1 - Significant damage to facilities and possible significant risk of loss of life or custody 0 – Widespread generalized failure to keep inmates in place, safely,	Includes police station cells or other detention facilities blocks as well as prisons.
8.8 Education facilities	8.8.1 Structural safety of education facilities	% of education structures at risk of damage from "most probable" and "most severe" scenarios	5 – No teaching facilities at risk even from "most severe" 4 – No teaching facilities at risk from "most probable" 3 – 1-5% of teaching facilities at risk from "most probable" 2 – 5-10% of teaching facilities at risk from "most probable"	Some schools may be assessed as critical assets as they provide shelter – see Essential 9.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			1 – 10-15% of teaching facilities at risk from "most probable" 0 – >15% of teaching facilities at risk from "most probable"	
	8.8.2 Loss of teaching time	Number of teaching days lost as % of total in academic year.	5 – No loss of teaching days 4 – 1% of annual teaching days lost from "most severe"; 0.5% from "most probable". 3 – 5% of annual teaching days lost from "most severe"; 2.5% from "most probable". 2 – 10% of annual teaching days lost from "most severe"; 5% from "most probable". 1 – 20% of annual teaching days lost from "most severe"; 10% from "most probable". 0 – > 20% of annual teaching days lost from "most severe"; >10% from "most probable".	Teaching may continue to be provided in the original facilities or in designated alternative facilities. However, this assessment needs to include an estimate of the impact of teachers either injured or unable to get to work.
	8.8.3 Education data	% of critical education data and associated applications imaged at remote site.	5 – All critical education data and associated apps routinely backed up and processable within 24 hours at a remote site not known to be vulnerable to any events affecting the city 4 – 90% or more of critical education data, with associated apps…	(Communications disaster resilience – see above).

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			3 – 80% or more of critical education data, with associated apps… 2 – 70% or more of critical education data, with associated apps… 1 – 60% or more of critical education data, with associated apps… 0 – Less than 60% of critical education data, with associated apps…	
8.9 Healthcare	8.9.1 Structural safety and disaster resilience of health care and emergency facilities (Staffing/ first responders – see essential 9)	"Bed days lost" – estimated # of beds at risk x number of days' loss under "most probable" and "most severe" scenarios.	5 – No bed days lost even under "most severe" scenario. 4 – No bed days lost under "most probable" scenario. 3 –1-5% of annual bed days lost from most probable" scenario. 2 – 5-10% of annual bed days lost from "most probable" scenario . 1 – 10-15% of annual bed days lost from "most probable" scenario. 0 –>15% of annual bed days lost from "most probable" scenario.	Healthcare may continue to be provided at the original facilities if they are sufficiently disaster resilient, or in designated alternative facilities (although moving patients is usually undesirable and the feasibility of this after a disaster needs to be considered).
		"Critical bed days lost: estimated # of bed days for designated critical services (eg ER, dialysis, intensive care – TBD) at risk under "most probable" and "most severe" scenarios.	5 – No critical bed days lost even under "most severe" scenario 4 – No critical bed days lost under "most probable" scenario 3 – <2.5% of critical annual bed days lost from most probable" scenario	Healthcare may continue to be provided at the original facilities or in designated alternative facilities (although moving patients is usually undesirable, especially for those with critical injuries and the feasibility of this after a disaster needs to be considered).

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			2 – 2.5-5% of critical annual bed days lost from "most probable" scenario 1 – 5-7.5% of critical annual bed days lost from "most probable" scenario 0 –>7.5% of critical annual bed days lost from "most probable" scenario	
	8.9.2 Health records and data	% of patient and health system data and associated apps stored and processable at location unlikely to be affected by the event.	5 – All critical healthcare data and associated apps routinely backed up and processable within 1 hour at a remote site not known to be vulnerable to any events affecting the city 4 – 95% or more of critical healthcare data, with associated apps. 3 – 90% or more of critical healthcare data, with associated apps. 2 – 85% or more of critical healthcare data, with associated apps. 1 – 80% or more of critical healthcare data, with associated apps. 0 – Less than 80% or more of critical healthcare data, with associated apps.	Healthcare data covers: - Personal medical records and histories - Dental records (may be needed for identification of victims); - Critical operating data for healthcare facilities. (Communications disaster resilience – see above). Loss of data needs to be assessed relative to what pre-existed the disaster.
	8.9.3 Availability of emergency healthcare including facilities and urgent medical supplies for acute needs.	Sufficient acute healthcare capabilities exist to deal with expected major injuries.	5 – 100% of major injuries in "most probable" scenario; and 90% of major injuries in "most severe" scenario, can be treated within 6 hours. 4 – 100% of major injuries in "most probable" scenario; and 90% of major	This assessment needs to take into account estimated losses in critical bed days, above.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			injuries in "most severe" scenario, can be treated within 12 hours. 3 – 100% of major injuries in "most probable" scenario; and 90% of major injuries in "most severe" scenario, can be treated within 18 hours. 2 – 100% of major injuries in "most probable" scenario; and 90% of major injuries in "most severe" scenario, can be treated within 24 hours. 1 – 100% of major injuries in "most probable" scenario; and 90% of major injuries in "most severe" scenario, can be treated within 36 hours. 0 – Longer than 36 hours, or no emergency healthcare capability.	
8.10 Administrative operations	8.10.1 Assurance of continuity of all critical administration functions.	Estimated # of days disruption to critical administration services under "most probable" and "most severe" scenarios, given availability of redundant facilities, support staff etc.	5 – No disruption to services even under "most severe" scenario 4 – No disruption to services under "most probable" scenario 3 - Minor disruptions (few hours or less) under "most probable" scenario 2 – Some significant disruptions for up to 48 hours or less under "most probable" scenario 1 – Significant disruptions for 48 hours – 5 days under "most probable" scenario	Critical administration functions will include those that directly affect the well being of the public or individuals. For example: - Payment of food-stamps or unemployment benefit; - Housing offices; - Reporting of damage after the disaster; - Trash collection and disposal (impacts from road closures are covered above). (Healthcare and education – see above). (Critical IT systems – see below)

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			0 – Generalized failure of services for > 5 days	The assessment of disruption is intended to apply at the neighborhood level, for example with closure of or damage to neighborhood offices.
8.11 Computer systems and data	8.11.1 Assurance of continuity of computer systems and data critical to government continuity.	% of critical applications and associated data (to include social services and other personal records) imaged at, and accessible from, remote site.	5 – All critical apps and data routinely backed up and processable within 1 hour at a remote site not known to be vulnerable to any events affecting the city 4 – 90% or more of critical apps, with associated data… 3 – 80% or more of critical apps, with associated data… 2 – 70% or more of critical apps, with associated data… 1 – 60% or more of critical apps, with associated data… 0 – Less than 60% of critical apps, with associated data…	This assessment is focused on the computer systems required for the critical administration functions identified above. (Communications disaster resilience – see above). (Health and Education data – see above)
	8.11.2 Assurance of continuity of computer systems and data critical to	% of critical applications and associated imaged at, and accessible from, remote site.	5 – All critical apps and data routinely backed up and processable within 15 minutes at a remote site not known to	This assessment is focused on the SCADA systems, PLCs, control rooms, logistics and planning systems and so on that are required

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
	any of the above infrastructure.		be vulnerable to any events affecting the city 4 – 90% or more of critical apps, with associated data… 3 – 80% or more of critical apps, with associated data… 2 – 70% or more of critical apps, with associated data… 1 – 60% or more of critical apps, with associated data… 0 – Less than 60% of critical apps, with associated data…	to maintain the operation of the infrastructure items above. (Communications disaster resilience – see above). (Health and Education data – see above)

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Essential 9: Ensure Effective Disaster Response

Building on the scenarios in Essential 2, ensure effective disaster response, for example by:

- Creating and regularly updating contingency and preparedness plans, communicated to all stakeholders through the structure in Essential 1 (especially including other levels of government and adjacent cities, infrastructure operators, community groups). Contingency plans to include law and order, providing vulnerable populations with food, water, medical supplies, shelter, and staple goods (e.g. for housing repairs).
- Developing and installing detection and monitoring equipment and early warning systems and effective associated communication systems to all stakeholders and community groups.
- Ensuring interoperability of emergency response systems adjacent countries, between agencies and with neighbouring cities.
- Holding regular training, drills/tests and exercises for all aspects of the wider emergency response "system" including community elements and volunteers.
- Integration of risk reduction and emergency response with engineers, contractors, et al to be able to effectively and efficiently engage in preparedness, response and recovery operations.
- (Coordinating and managing response activities and relief agencies' inputs).
- Ensuring in advance that a viable mechanism will exist for the rapid, rational and transparent disbursement of funds after a disaster (Essential 10).
- Assigning and ring-fencing adequate contingency funds for post event response and recovery (Essential 3).

Data you will need to complete this section of the scorecard (potentially from multiple organizations and agencies) will include: *which warning systems exist and whom they will reach; emergency management plans and procedures that specifically consider the impact of the scenarios in section 3; documentation of first responder – staffing and equipment - capabilities; records of drills and practices; identification of systems where interoperability with other agencies is critical and of the standards adopted; and records of evaluations, learning points and improvements enacted.*

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
9.1 Early warning	9.1.1 Existence and effectiveness of early warning systems.	Length and reliability of warning – enabling practical action to be taken.	5 - Warnings exist for all hazards known to be relevant to the city, and will allow time for reaction (as far as technology permits). Warnings are seen as reliable and specific to the city.	The technology of disaster warnings is rapidly evolving, both in the long-term assessment of risk (for example weather risk in the coming season) and the notification period and update frequency for a specific event (for example

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			4 – Warnings exist but warning time maybe less than technology currently permits. Warnings are seen as reliable and specific. 3 - Some hazards, especially earthquakes, are excluded and warning time may be less than technology permits. (If earthquakes are the only hazard for your city, score 0). 2 – Warning time is less than technology permits and there may also be some false positives: reliability of warnings may therefore be perceived as questionable. 1 – Warnings seen as ad hoc and unreliable. Likely to be ignored. 0 - No warnings.	the progress of a flood crest down a river, or landslide risk, or tornado warnings). Improved warning may enable an improved risk assessment in Essential 2, for example, by enabling better preparation or enabling more people to move from harm's way. However, while they are the focus of much research currently, meaningful earthquake warning systems do not currently exist for practical purposes. If earthquakes are the only hazard for your city, score 0.
		Reach of warning – will 100% of population receive it?	5 - 100% reached. 4 – 90-100% reached. 3 – 80-90% reached. 2 – 70-80% reached. 1 – 50-70% reached.. 0 - <50% reached (or no warnings – see above).	Warnings should be delivered over the maximum possible notice period via multiple media, including phone, TV, radio, web, as well as sirens.
9.2 Event management plans	9.2.1 Existence of emergency response plans that integrate professional	Existence of plans formulated to address "most likely" and "most severe" scenarios, shared and signed	5 - Complete plans exist, keyed to scenarios referenced in Essential 2.	Emergency management plans will need to cover:

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
	responders and grass roots organizations. (For post-event response - see Essential 10)	off by all relevant actors (including citizen organizations	They have been tested in real emergencies. 4 – Complete plans exist as above, but may not have been fully tested. 3 - Plans exist but are not keyed to scenarios referenced in Essential 2. 2 – Plans exist are known to be incomplete or otherwise deficient. 1 – Plans exist but are known to have major shortcomings. 0 - No plans.	- Command and control - coordination with other agencies and cities, roles, responsibilities (see Essential 1); - Evacuations (including hospitals, jails, etc.); - Communication systems; - Critical asset management (including likely “failure chains” – see Essential 8); - Medical response; - Law and order response; - Fire and rescue response; - Public information; - Triage policies; - Incorporation of contributions from citizen/grass roots organization. Elements of emergency management plans may be linked to, and tested through, plans for “regular” events such as sporting fixtures, carnivals or parades (see below).
9.3 Staffing/responder needs	9.3.1 ‘Surge” capacity of police also to support first responder duties	Sufficient back-up or para-professional capacity to maintain law and order in “most severe” and “most probable” scenarios, in addition to supporting burden of first responder duties.	5 – Surge capacity exists and is tested either via actual events or practice drills for scenarios in Essential 2 – coverage of all neighborhoods will be possible within 4 hours. 4 – Adequate surge capacity nominally exists but is untested.	This capacity may come from other agencies such as the Army or civil defense force but needs to be confirmed via MOU or similar.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			3 – Surge capacity exists but is known or suspected to have minor inadequacies, perhaps in location, numbers. Coverage of all neighborhoods within 4-12 hours. 2 – Coverage of all neighborhoods within 12-48 hours. 1 – Coverage of all neighborhoods within 48-72 hours. 0 – No surge capacity identified.	
	9.3.2 Definition of other first responder and other staffing needs, availability – including fire, ambulance, healthcare, neighborhood support etc.	Staffing needs are defined for "most probable" and "most severe" scenarios.	5 – Needs defined, either from actual events or from practice drills for scenarios in Essential 2, taking into account the role of volunteers. 4 – Needs defined independently of latest scenarios. 3 – Some needs defined but with some gaps for specific professions or for specific areas of the city. 2 –Needs definition has more serious shortcomings. 1 –Needs definition is essentially nominal or guesswork. 0 - No needs defined (or no plan – see above).	Different national response standards may apply in this area. Parts of this capacity may come from other agencies such as the Army or civil defense force.
		Estimated shortfall in staff/responders per defined needs – potentially from multiple sources. MOUs	5 - Staffing and responders known to be available either from actual events or practice drills for scenarios in	Different national response standards may apply in this area.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
		exist for non city sources, especially from private sector.	Essential 2, in line with defined needs for "most severe" scenario. 4 - Staffing and responders known to be available in line with defined needs for "most probable" scenario. 3 – Shortfall of <5% of ideal staff numbers from "most probable". 2 – Shortfall of 5-10% of ideal staff numbers. 1 – Shortfall of >10% of ideal staff numbers. 0 - No definition of needs – see above.	
9.4 Equipment and relief supply needs	9.4.1 Definition of equipment and supply needs, and availability of equipment.	Equipment and supply needs are defined for "most probable" and "most severe" scenarios in essential 2	5 – Needs defined, keyed to scenarios from essential 2, and take into account the role of volunteers. 4 – Needs defined independently of latest scenarios 3 – Some needs defined but with some gaps for specific professions or for specific areas of the city. 2 –Needs definition has more serious shortcomings. 1 –Needs definition is essentially nominal or guesswork. 0 - No needs defined (or no plan).	Equipment includes: - Police, fire and ambulance vehicles, and fuel; - Helicopters, planes as applicable, and fuel; - Rescue equipment; - Medical supplies; - Bulldozers, excavators, debris trucks (may be supplied by private organizations); - Local emergency response IT systems, hand-held devices. (Medical/hospital needs – see Essential 8)

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
		Estimated shortfall in available equipment per defined needs – potentially from multiple sources. MOUs exist for non city sources, especially from private sector.	5 – Equipment known to be available in line with defined needs for "most severe" scenario. 4 – Equipment known to be available in line with defined needs for "most probable" scenario. 3 – Shortfall of <5% of ideal equipment numbers for key items. 2 – Shortfall of 5-10% of ideal equipment numbers for key items. 1 – Shortfall of >10% of ideal equipment numbers for key items. 0 - No definition of needs – see above.	Equipment defined as above.
9.5 Food, shelter, staple goods and fuel supply.	9.5.1 Likely ability to continue to feed population	"Food gap" - # of days that city can feed all segments of its population likely to be affected minus # of days' disruption estimated under those scenarios.	Under "most severe" scenario: 5 – Positive outcome – days of emergency food available exceeds estimated days disruption to regular supply 4 – Even – days of food available equals estimated days' disruption to regular supply. 3 - Negative outcome – estimated food gap is 24 hours. 2 - Negative outcome – estimated food gap is 48 hours. 1 - Negative outcome – estimated food gap is 72 hours.	Food = food and water Needs to include certainty that food from other agencies is available, via MOU or similar.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			0 - Negative outcome – estimated food gap is more than 72 hours.	
	9.5.2 Likely ability to meet needs for shelter/safe places	"Shelter gap" – numbers of displaced persons minus shelter places available within 24 hours.	Under "most severe" scenario: 5 – Positive outcome – shelter places available within 12 hours exceeds estimated need; 4 – Even – shelter places available equal to estimated need; 3 - Negative outcome – shelter places available less than estimated need (shelter gap) by 5%. 2 - Negative outcome – estimated shelter gap is 10%. 1 - Negative outcome – estimated shelter gap is 15%. 0 - Negative outcome – estimated shelter gap is 20%. or more	Shelter may include existing structures likely to resist the disaster in question, by virtue of their strong construction and/or their location – sports stadia, school halls, shopping malls, parking garages and so on. Shelters need to take account of separate needs of men, women, children, disabled. Signage to, and for use within, shelters is also likely to be required. Third-party owners of shelter facilities/safe places should be engaged via MOUs or similar.
		"Shelter gap" – ability of shelters to withstand disaster events and remain safe and usable.	Under "most severe" scenario: 5 – All designated shelter places are assessed as likely to safely withstand a "most severe" event. 4 – 90% of shelter places are assessed as likely to safely withstand a "most severe" event. 3 - 80% of shelter places are assessed as likely to safely withstand a "most severe" event.	This applies to shelters in which people may have taken refuge prior to an event (for example a hurricane, where there will be some hours warning); or shelters to which people may be directed after the event.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			2 - 70% of shelter places are assessed as likely to protect users in "most severe" event. 1 – 50% of shelter places are assessed as likely to safely withstand a "most severe" event. 0 – Less than 50%, are assessed as likely to withstand a "most severe "event.	
	9.5.3 Ability to meet likely needs for staple goods.	"Staples gap" - % shortfall in supply within 24 hours relative to demand	Under "most severe" scenario: 5 – Positive outcome – supply of staples available within 12 hours exceeds estimated demand. 4 – Even – supply equals estimated demand. 3 - Negative outcome – supply of five or more critical staples less than estimated demand (staples gap).by 5% 2 - Negative outcome – estimated staples gap is 10%. 1 - Negative outcome – estimated staples gap is 15% 0 - Negative outcome – estimated staples gap is 20% or more.	Cities will need to compile lists of critical staple items, as these are to some extent culturally or population-dependent. But they are likely to include: - Sanitation; - Personal sanitary supplies and diapers; - Medications and first aid supplies; - Batteries; - Clothing; - Bedding; - Bottled gas for cooking, heating; - Materials for immediate repairs or weather-proofing of housing. In some countries these may be provided via private sector retailers, operating under MOU with the city or other government agency.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
	9.5.4 Likely availability of fuel.	"Fuel gap" - # of days that city can meet fuel requirements, minus # of days disruption to regular supply..	Under "most severe" scenario: 5 – Positive outcome – days of fuel available exceeds estimated days disruption to supply. 4 – Even – days of fuel available equals estimated days disruption to supply. 3 - Negative outcome – estimated disruption exceeds days of fuel available (fuel gap) by 24 hours. 2 - Negative outcome – estimated fuel gap is 48 hours. 1 - Negative outcome – estimated fuel gap is 72 hours. 0 - Negative outcome – estimated fuel gap is more than 72 hours.	Fuel – gasoline, diesel, as required for emergency vehicles, back up equipment, and personal and business transportation.
9.6 Interoperability and inter-agency compatibility	9.6.1 Interoperability with neighboring cities/states and other levels of government of critical systems and procedures.	Ability to cooperate at all levels with neighboring cities and other levels of government.	5 – Proven interoperability of all key systems and procedures. 4 – Interoperability in theory of all key systems but yet to be tested in practice. 3 – Some minor incompatibilities exist but are being addressed. 2 – Major incompatibilities but plan exists to address them. 1 – Major incompatibilities but no plan.	Critical first response systems and procedures will include those in the areas of communications, law and order, fire, first responder, food distribution, etc). Interoperability needs to be assessed at multiple levels, including: - Communications systems; - Data; - Emergency management applications;

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			0 – Interoperability never assessed.	- Assumptions, rehearsed procedures and priorities; - Accountabilities (see Essential 1); - Territorial coverage; - Physical asset characteristics (for example, fire hose widths for neighboring fire departments; fuel compatibility for vehicles).

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
	9.6.2 Emergency operations center	Existence of emergency operations center with participation from all agencies, automating standard operating procedures specifically designed to deal with “most likely” and “most severe” scenarios. .	5 – Emergency operations center exists with hardened communications and camera-enabled visibility of whole city, and with SOPs designed and proven to deal with “most severe” scenario; all relevant agencies participate. 4 – Emergency operations center exists with hardened communications and camera-enabled visibility of whole city, and with SOPs designed and proven to deal with “most probable” scenario; all relevant agencies participate. 3 – Emergency operations center exists with SOPs designed for “most probable” scenario (but may not be proven), most agencies participating but incomplete camera visibility or communications. 2 – Emergency operations center exists but SOPs unproven, participation incomplete and poor camera visibility. 1 – Emergency operations center designated but with significant generalized shortcomings. 0 – No emergency operations center.	Operations center needs itself to be highly disaster-resilient! SOP = Standard operating procedures – pre-rehearsed processes and procedures for emergency response.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
9.7 Drills	9.7.1 Practices and rehearsals – involving both the public and professionals.	Testing of plans annually, by reference to simulated emergency and actual non-emergency events. .	5 - Annual suite of drills validated by professionals to be realistic representation of "most severe" and "most probable" scenarios. 4 – Annual suite of drills broadly thought to be realistic. 3 – Annual suite of drills but not realistic in some significant respects. 2 – Less than annual drills. 1 – Ad hoc partial exercises – not all scenarios tested, not realistic. 0 – No exercises (or no plans – see above).	Drills to include use of/response to education and healthcare facilities. Drills linked to public engagement and local training – see essential 6. Specific emergency drills may be supplemented by use of sporting events, rallies, parades and other local activities, and also minor versions of the disaster event (eg minor flooding, weaker earthquakes) to: - Practice aspects of emergency response such as crowd management; - Test carrying capacity of potential evacuation routes; - Evaluate response and access times, etc. (These may also be used for disaster awareness).
	9.7.2 Effectiveness of drills and training	Level of effectiveness of drills	5 – All professional and public participants in drills show strong evidence of having absorbed training. 4 – Most participants show evidence of having absorbed training, with some minor issues. 3 – One or more issues with training evident from outcome of drills. 2 – Several significant skills or knowledge gaps revealed.	Requires evaluation of every drill after completion. Training delivery and level of participation – see essentials 6 & 7.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			1 – Drills indicate that city is broadly unprepared for disaster in terms of training and skills. 0 – No drills.	

Essential 10: Expedite Recovery and Build Back Better

After any disaster there will be a need to:

- Ensure that the needs of the survivors and affected community are placed at the centre of recovery and reconstruction with support for them and their community organizations to design and implement rebuilding shelter, assets and livelihoods at higher standards of resilience.
- Planners should ensure that the recovery programmes are consistent and in line with the long-term priorities and development of the disaster affected areas.

Recovery, rehabilitation and reconstruction can to a considerable degree be planned ahead of the disaster. This is critical to building back better and making nations, cities and communities more resilient to disasters than they were before the event. Pre-disaster plans for post-event recovery should cover the following and with necessary capacity building, where relevant:

- Providing shelter, food, water, communication, addressing psychological needs, etc.
- Limiting and planning for any use of schools as temporary shelters
- Identifying the dead and notifying next of kin
- Debris clearing and management;
- Taking over abandoned property
- Management of local, national and international aid and funding, and coordination of efforts and prioritizing and managing resources for maximum efficiency, benefit and transparency.
- Integration of further disaster risk reduction in all investment decisions for recovery and reconstruction.
- Business continuity and economic reboot.
- Learning loops: undertake retrospective/post-disaster assessments to assess potential new vulnerabilities and build learning into future planning and response activities.

Data you will need to complete this section of the scorecard will include: *post–event plans, potentially from multiple organizations and agencies*.

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
10.1 Post event recovery planning – pre event!	10.1.1 Planning for post event recovery and economic reboot.	Existence of comprehensive post event recovery and economic reboot plans.	5 – Fully comprehensive plans exist addressing economic, infrastructure and community needs after "most probable" and "most severe" scenario.	Comprehensive post event recovery plans will need to detail (not an exhaustive list): - Interim arrangements for damaged facilities and homes anticipated from

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			4 – Fully comprehensive plans exist addressing economic, infrastructure and community needs after "most probable" scenario. 3 – Plans exist for post "most probable" event but with some shortfalls. 2 – Plans exist for post "most probable" event but with more significant shortfalls 1 – Plans exist for post "most probable" event but with generalized inadequacy. 0 – No plan.	"most probable" and "most severe" scenarios; - Locations and sources of temporary housing (if different from emergency shelters – see Essential 9); - Triage policies for repairs and debris removal and preferred contractors; - Counseling and personal support arrangements; - Community support arrangements – re-initiation of social security, food and other benefits payments; - Economic "re-boot" arrangements – interim tax relief, incentives, etc etc; - Improvements to city layout and operations sought as rebuilding takes place, to reduce future risk; - Arrangements to ensure social equality – equality of attention, inputs, funding, priority across all neighborhoods. Plans may be from several organizations, but these should be reviewed for consistency of assumptions and priorities. (Post event organization structures – see Essential 1) (Funding – see Essential 3)

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
	10.1.2 Shadow financial arrangements for processing incoming aid and disbursing funds.	Post event arrangements exist for dealing with incoming financial aid and disbursements	5 – Arrangements exist and are believed to be workable. 4 – Arrangements have some minor gaps but are believed to be workable. 3 – Arrangements have one or more significant gaps that may compromise aspects of workability. 2 – Arrangements have more significant shortfalls that place overall workability in doubt. 1 – Partial or incomplete arrangements only. Unlikely to be workable. 0 – No plan.	May be provided by national government, if still functional, or by a private sector organization such as an accounting firm.
	10.1.3 Learning loops	Existence of a process and format for "post-mortems" on what went well and less well in the event response and post-event phases.	5 – Comprehensive plans exist that are shared by all stakeholder, and they have in fact been used after a disaster – changes have been made to plans and practices. 4 – Comprehensive plans exist but have not been used in live situations – only after drills. 3 – The need to learn is acknowledged and some attempt is planned to share learnings, but it is not systematic - there are gaps. 2 – Post event learning is planned in some stakeholders, but to varying degrees and it is not planned to be shared.	This process could be the process used for usual learning and review after drills and practices – the difference being that this is "for real".

Subject/Issue	Item measured	Indicative Measurement	Indicative Measurement Scale	Comments
			1 – Any provision for post event learning is rudimentary at best. 0 – No plans.	

UNISDR
The United Nations Office for Disaster Risk Reduction

Appendix 1: Glossary of Terminology as Used in the Scorecard

Acute Stress	Some natural or man-made event that causes a *disaster*. Acute stress is the direct focus of this scorecard – but the resulting disasters may be made more severe, or more frequent, or the city may be rendered less able to respond, by underlying or *chronic stress*. Acute stress is one end of a continuum – the other being *chronic stress*
Chronic stress	Environmental degradation and other natural or man-made factors that cause underlying damage without directly leading to a full blown *disaster*. Examples might include issues such as over-use of groundwater, pollution or deforestation. Chronic stresses are not directly the focus of this scorecard. They may however make disasters more likely, or more severe, or reduce the ability of the city to respond to them. Chronic stress is one end of a continuum – the other being *acute stress*.
Critical administration functions	Critical administration functions will include those that directly affect the well being of the public or individuals. For example: payment of food-stamps or unemployment benefit; housing offices; reporting of damage after the disaster; trash collection and disposal.
Critical asset	Equipment, facility infrastructure or computer system/data that is critical to the functioning of the city, maintenance of public safety or *disaster* response. Critical assets are frequently interlinked and may form *failure chains* that need to be identified and managed.
Disaster	An event leading to major loss of life or damage to assets, property or economic activity. Disasters may be man-made or natural – the latter are the primary focus of the scorecard, but it is applicable also to the former.
Disaster Resilience	The ability to mitigate and recover from *disaster* events. A subset of the wider concept of *resilience*.
Exposure	Who or what (people, land, ecosystems, crops, assets, infrastructure, economic activity) is potentially in harm's way as a result of a *hazard*. Different exposures and/or *vulnerabilities* may combine, for example where the tsunami generated by the Tohoku earthquake in Japan in 2011 badly damaged the Fukushima nuclear power plant – generating a whole additional set of exposures and vulnerabilities.
Failure chain	A failure chain is a set of linked failures spanning *critical assets* in multiple infrastructure systems in the city. As an example – loss of an electricity substation may stop a water treatment plant from functioning; this may stop a hospital from functioning; and this in turn may mean that much of the city's kidney dialysis capability (say) is lost. This failure chain would therefore span energy, water and healthcare systems.
Grass roots organizations	Organizations that exist to create *disaster resilience* at the local level, whether set up specifically for the purpose (for example, community emergency response organizations), or serving some other purpose but willing and able to play a disaster resilience role: for example, churches, business Round Tables, youth organizations, food kitchens, neighborhood watch, day centers and so on.

Hazard	Some event or phenomenon (for example, hurricane, flood, fire, earthquake, tsunami) that may lead to a *disaster*. Hazards may change over time as a consequence of urbanization and land use (for example where deforestation increases propensity for flash flooding), climate change (for example, changing rainfall or storm patterns), or better knowledge (for example, understanding of seismic threats or likely storm tracks). Thus, hazard estimates need to be updated regularly.
Peril	See *hazard*.
Resilience	The ability to mitigate and adapt to both *chronic* and *acute stresses*.
Risk Assessment	The process and outcome of compiling *scenarios* of natural *hazards* that could cause a *disaster* in the city, and the city's *exposure* and *vulnerability* to these.
Scenario	A comprehensive assessment of the severity, probability of a *hazard* and its total impact – the *exposure* and *vulnerability* of the city to loss of life, damage or other adverse impact in the resulting *disaster*. As a minimum cities will ideally have two scenarios – one for *the "most probable"* event and one for the *"most severe"*
Single point of coordination	Person or group/committee (with subgroups or sub committees as required) from which all organizations with any role in the city's disaster resilience accept direction or guidance in resilience matters, and to which they report on such matters.
Standard operating procedure (SOP)	Pre-rehearsed processes and procedures for emergency response.
Vulnerability	The potential consequences of *exposure* to some *hazard* (loss of life, property or service; physical damage; health impact, economic impact; environmental impact and so on). Different *exposures* and/or vulnerabilities may combine, for example where the tsunami generated by the Tohoku earthquake in Japan in 2011 badly damaged the Fukushima nuclear power plant – generating a whole additional set of exposures and vulnerabilities
"Most Probable"	A *disaster*-causing hazard and its severity computed to be at the midpoint of a probability distribution (preferred) or assessed as "typical;" through expert judgment and other ad hoc estimation.
"Most Severe"	A *disaster*-causing hazard and its severity computed to be in the top 10% of a probability distribution (preferred) or assessed as "worst case" through expert judgment or other ad hoc estimation.