BUROHAPPOLD ENGINEERING

Climate Risk and Vulnerability Assessment (CRVA) Methodology

The purpose of the Climate Risk and Vulnerability Assessment (CRVA) is to develop an understanding of the current and future climate risks facing the region. The CRVA will inform the inclusion of adaptation goals and actions in the regional climate action plan, which is a required deliverable as a member of the Global Covenant of Mayors (GCoM). As such, the methodology described herein has been developed according to GCoM guidance.

Key Definitions

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. The term hazard usually refers to climate-related physical events or trends or their physical impacts (GCoM, 2019).

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, resources, infrastructure or economic, social or cultural assets in places and settings that could be adversely affected (GCoM, 2019).

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (GCoM, 2019).

Resilience: The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation (GCoM, 2019).

Adaptive Capacity: The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences (GCoM, 2019).

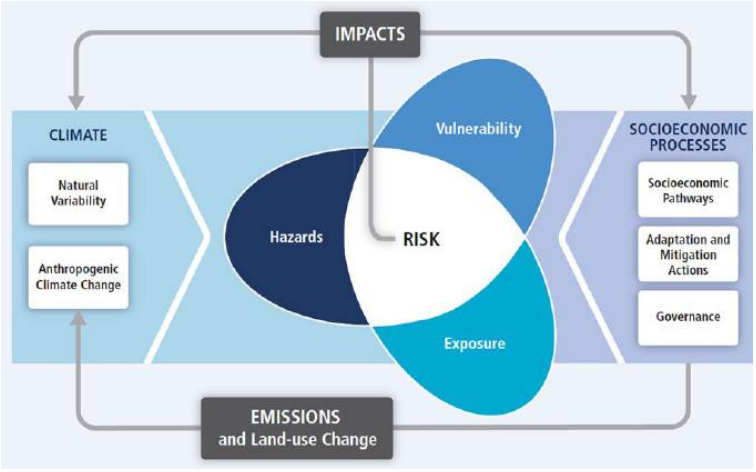

Figure 1: Climate risk is a function of hazards, exposure, and vulnerability (IPCC, 2012)

Climate risk arises as a result of the confluence of hazards, exposure, and vulnerability. In other words, a climate hazard becomes a climate risk when inhabitants and/or assets are exposed to the particular hazard and if those exposed inhabitants or assets are vulnerable to it. The region can improve its resilience and adaptive capacity to climate-related shocks and stresses by implementing climate adaptation actions. However, it is necessary to develop a sound understanding of context-specific climate risks before developing such actions.

Initial Steps and Documentation

1. An internal team will be identified to lead data collection and reporting.

    1.1. An Advisory Group of relevant experts and stakeholders may be convened to help construct indicators and select the best scale of analysis (this may include representatives from academia, non-governmental organizations, citizens, city governments, and the private sector).

2. The boundary of assessment will be defined according to the region's jurisdictional boundary.

3. Data sources will be identified, documented, and mapped, where applicable.

    3.1. A database of documentation and datasets will be created (potentially including reports, spreadsheets, and databases maintained by the State, counties, public institutions, analysis and modelling performed by others, and GIS databases and maps).

4. A glossary of key terms and definitions will be created, consistent with those established by GCoM and the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5).

5. The CRVA's update and revision process will be established and included in the final report.

Hazard Assessment

The hazard assessment is intended as an opportunity to identify the climate hazards faced by the region. Hazards that occurred in the past and their associated impacts will be considered in this assessment. How these hazards are expected to change in the future and what impacts can be expected from them will also be evaluated. Field work will not be required to collect hazard data.

1. Previous plans and documentation on regional hazards will serve as a starting point, particularly for identifying past and current climate hazards (flooding, drought, heat waves, etc.).

2. A technical workshop session will be convened consisting of local staff, practitioners, and key stakeholders, as well as representatives from GCoM, International Urban Cooperation North America (IUC-NA), and BuroHappold Engineering. This workshop will inform the completion of Steps 3 & 4 below, as well as Step 1 of the Vulnerability Assessment.

    2.1. Workshop participants will be provided with an overview of the Climate Risk and Vulnerability Assessment reporting framework. A workshop discussion will address current and future climate hazards, current and future climate risks, and factors influencing adaptation within the region.

3. Past climate hazards and their associated impacts will be identified.

    3.1. Types of climate hazards that occurred in the past, the intensity and frequency of these hazards, and their associated impacts will be identified using findings from previous studies, the aforementioned technical workshop, as well as desktop-based research and literature reviews.

4. Current (last 5 to 10 years) and future (mid-century) climate hazards and their impacts will be identified.

    4.1. The most significant climate hazards, their expected change in intensity and frequency (as well as timescale of expected changes), and their associated impacts will be identified using climate projections and research available from resources such as the U.S. Climate Resilience Toolkit,[1] The Climate Explorer,[2] and the Fourth National Climate Assessment.[3] Current (last 5-10 years) and future (mid-century) hazards will be identified. CDP's list of climate hazards will be used as guidance (see Appendix A).

    4.2. Per GCoM guidance, timescales of expected changes will be categorized as: (1) immediately = hazard is already taking place; (2) short term = by 2025; (3) medium term = 2026 - 2050; (4) long term = after 2050; and, (5) not known = no information available on when this hazard will occur or if hazard has already occurred.

Hazards	**Frequency**	**Intensity**	**Timescale**
Drought	Increase	Increase	Medium-term
Extreme heat days	Increase	Increase	Medium-term
Flash/surface floods	Increase	No change	Medium-term
Extreme cold days	Decrease	Decrease	Not known
Water-borne disease	Increase	Not known	Long-term

Table 1: Example hazard identification

    4.3. Where feasible, current and projected climate hazards could be mapped for the region (availability and granularity of data will vary for each hazard).

    4.4. When available, more applicable, regional data from down-scaled climate modeling could be used to identify climate hazards. Furthermore, two future climate change scenarios (e.g. RCP 4.5 and RCP 8.5),

[1] U.S. Climate Resilience Toolkit. https://toolkit.climate.gov/tools

[2] The Climate Explorer. https://crt-climate-explorer.nemac.org/

[3] Fourth National Climate Assessment. https://nca2018.globalchange.gov/

for current (last 5-10 years), future (mid-century), and distant future (end of century) could be used, where relevant.

Vulnerability Assessment

Vulnerability is a function of exposure, sensitivity, and adaptive capacity. The region will identify critical assets, sectors, and populations vulnerable to climate hazards. The adaptive capacity of these assets and population groups to climate change will be evaluated.

1. Critical assets, sectors, and services will be identified, organized, and mapped.

    1.1. A working group discussion at the technical workshop session will address: (1) critical regional assets, sectors, and services (see Appendix B for the CDP guidance); (2) at-risk facilities and infrastructure; and, (3) community and environmental assets.

    1.2. Where feasible, identified critical assets, sectors, and services will be organized and mapped using GIS.

        1.2.1. A more detailed list of critical assets could be identified and mapped via desktop research and GIS, using the Federal Emergency Management Agency (FEMA) classifications as guidance (see Appendix C).

2. Vulnerable populations will be identified and mapped using census data and previous studies. This may also involve engaging with community members, vulnerable groups, and climate experts.

    2.1. An indicator-based social vulnerability assessment will be conducted and may consider (but will not be limited to) the Center for Disease Control and Prevention (CDC)'s Social Vulnerability Index (SVI) and sub-indicators (see Appendix D).

3. A vulnerability assessment will be conducted, taking into account the exposure, sensitivity, and adaptive capacity of assets and groups.

    3.1. Exposure is the extent to which a hazard may impact an asset or group. The exposure of assets and groups and how well they can function during a shock or stress event will be assessed. To this end, a risks and vulnerabilities map will be created to help identify vulnerable areas and the assets and sectors that will be impacted by climate hazards.

    3.2. Sensitivity is the magnitude of the losses associated with hazard exposure. A score between 0 and 4 will be allocated for the sensitivity of assets and groups to hazards. Quantitative and qualitative criteria used to determine the score will be defined and may include: (1) lives lost; (2) monetary value lost; (3) structural integrity; or, (4) hours of interruption.

    3.3. Adaptive capacity is an indication of the redundancy, flexibility, and robustness of an asset or group.

        3.3.1. Various social, economic, and political factors influence the adaptive capacity of a jurisdiction. Per GCoM guidance, the region will identify the most relevant factors and indicate the extent to which they challenge the jurisdiction's adaptive capacity and climate resilience efforts. Factors will be

classified according to "high," "moderate," "low," "do not know," and "no concern." CDP's list of factors affecting adaptive capacity will be used as guidance (see Appendix E).

3.3.2. A score between 0 and 3 will be allocated for the adaptive capacity of an asset or group. Quantitative and qualitative criteria used to determine the score will be defined and may include: (1) ability of an asset to cope with a loss of its original function; or, (2) a system's recovery time.

3.4. The product of the sensitivity and adaptive capacity scores will be indicative of overall vulnerability.

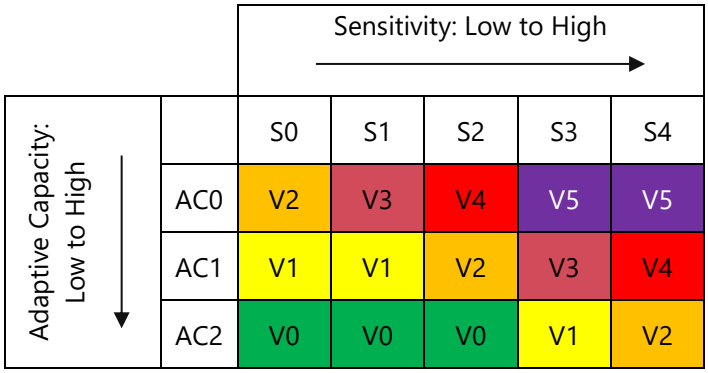

Figure 2: Example vulnerability scoring matrix

Risk Assessment

Risk is a function of the probability of a hazard impact and the overall consequence of the impact (Risk = Probability x Consequence). This formulation allows for the prioritization of the most at-risk assets, systems, and groups, focusing on the most vulnerable ones identified in the Hazard and Vulnerability Assessments.

1. Per GCoM guidance, the region will indicate the probability and consequence of each reported climate hazard. The probability will be based on the outcome of the hazard assessment, and the consequence will be based on the outcome of both the hazard and vulnerability assessments. Both will be classified according to the following qualitative descriptors: "high"; "moderate"; "low"; "do not know" in accordance with CDP and GCoM guidance (see Appendix F).

2. The product of probability and consequence scores will be indicative of the overall climate risk level of a given hazard, where high risk scores (R4 and R5) are to be prioritized and "Do not know" scores indicate where the region is not able to accurately report the information based on evidence or data.

2.1. Per GCoM guidance, this analysis will be conducted for all past, current, and future climate hazards identified in the Hazard Assessment.

		Probability			
Consequence		Do Not Know	Low	Moderate	High
	High	R1	R3	R4	R5
	Moderate	R1	R3	R4	R4
	Low	R1	R2	R3	R3
	Do Not Know	R1	R1	R1	R1

Figure 3: Example risk scoring matrix

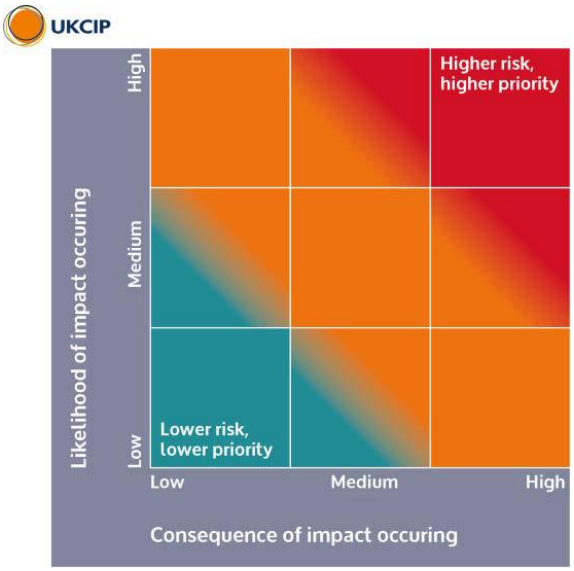

Figure 4: Example risk scoring graph (UKCIP)

Appendix A – CDP Climate Hazards[4]

Rain storm	Land fire
Monsoon	Flash/surface flood
Heavy snow	River flood
Hail	Coastal flood
Severe wind	Groundwater flood
Tornado	Storm surge
Cyclone (Hurricane/Typhoon)	Permanent inundation
Extratropical storm	Salt water intrusion
Tropical storm	Ocean acidification
Lightning / thunderstorm	Atmospheric CO2 concentrations
Fog	Landslide
Extreme winter conditions	Avalanche
Cold wave	Rockfall
Extreme cold days	Subsidence
Heat wave	Water-borne disease
Extreme hot days	Vector-borne disease
Drought	Air-borne disease
Forest fire	Insect infestation

[4] CDP, CDP Cities 2018 Reporting Guidance, Hazards and Adaptation: https://guidance.cdp.net/en/guidance?cid=4&ctype=theme&idtype=ThemeID&incchild=1&microsite=0&otype=Guidance&tags=TAG-637%2CTAG-638

Appendix B – CDP Assets and Services

Energy	Commercial
Water Supply & Sanitation	Residential
Transport	Education
Waste Management	Public health
Information & Communications Technology	Community & Culture
Food & Agriculture	Law & Order
Environment	Emergency Management
Industrial	

Appendix C – FEMA Critical Infrastructure and Key Resources Sectors

Agriculture and Food	Energy
Banking and Finance	Government Facilities
Chemical	Information Technology
Commercial Facilities	National Monuments and Icons
Communications	Nuclear Reactors, Materials, and Waste
Dams	Postal and Shipping
Defense Industrial	Public Health and Healthcare
Drinking Water and Water Treatment Systems	Transportation Systems
Emergency Services	

Additional critical asset examples:

Asset Type	**Examples**
Critical Facilities	Hospitals, schools, emergency shelters, emergency response services
Built Environment and Infrastructure	Houses, offices, non-critical public facilities and utilities, industrial facilities, roads, railways, harbors, ports and marinas, other coastal infrastructure such as breakwaters, seawalls, jetties
Environmental Assets	Vulnerable natural resources such as reefs, wetland areas, endangered or threatened species, groundwater resources
Economic Sectors	Major economic sectors and main employers within a community or study area
"Soft Infrastructure"	Indicators of social resilience and cohesion, such as non-profit organizations and other community infrastructure

Appendix D – CDC Social Vulnerability Index (SVI)

Type	**Indicator**
Aggregated	Social Vulnerability Index (SVI)
Socioeconomic	Below Poverty
	Unemployed
	Income
	No HS Diploma
Household composition & disability	Aged 65 & Older
	Aged 17 or Younger
	Civilian with a Disability
	Single-Parent Household
Minority status & language	Minority
	Speak English “less than well”
Housing & transportation	Multi-Unit Structures
	Mobile Homes
	Crowding
	No Vehicle
	Group Quarters

Appendix E – CDP Factors Affecting Adaptive Capacity

Access to basic services	Budgetary capacity
Access to healthcare	Migration; Safety and security
Access to education	Economic health
Cost of living	Economic diversity
Housing	Rapid urbanization
Poverty	Resource availability
Inequality	Environmental conditions
Unemployment	Infrastructure conditions / maintenance
Public health	Infrastructure capacity
Political stability	Land use planning
Political engagement / transparency	Community engagement
Government capacity	Access to quality/relevant data

Appendix F – CDP Hazard Probability and Consequence

Probability of Hazard	
High	Extremely likely that the hazard will occur (e.g. greater than 1 in 2 change of occurrence over the next five years)
Medium high	Highly likely that the hazard will occur (e.g. between 1 in 2 and 1 in 20 chance of occurrence over the next five years)
Medium	Likely that the hazard will occur (e.g. between 1 in 20 and 1 in 200 chance of occurrence over the next five years)
Medium low	Somewhat likely that the hazard will occur (e.g. between 1 in 200 and 1 in 2,000 chance of occurrence over the next five years)
Low	Not likely that the hazard will occur (e.g. between 1 in 2,000 and 1 in 20,000 chance of occurrence over the next five years)
Do not know (GCoM, 2019)	City has not experienced or observed climate hazards in the past or has no ways of accurately reporting this information based on evidence or data.

Consequence of Hazard	
High	The hazard represents the highest level of potential concern for your jurisdiction. You anticipate that should it occur, the hazard would result in extremely serious impacts to your city and catastrophic interruption to day-to-day life.
Medium high	The hazard represents a high level of potential concern for your jurisdiction. You anticipate that should it occur, the hazard would result in serious impacts to your jurisdiction and interruption to day-to-day life.
Medium	The hazard represents a medium level of potential concern for your jurisdiction. You anticipate that should it occur, the hazard would result in impacts to your jurisdiction, but that these would be moderately significant to day-to-day life.
Medium low	The hazard represents a lower level of potential concern for your jurisdiction. You anticipate that should it occur, the hazard would result in impacts to your jurisdiction, but that these would be less significant to day-to-day life.
Low	The hazard represents the lowest level of potential concern for your jurisdiction. You anticipate that should it occur, the hazard would result in impacts to your jurisdiction, but that these would be insignificant in day-to-day life.
Do not know (GCoM, 2019)	City has not experienced or observed climate hazards in the past or has no ways of accurately reporting this information based on evidence or data.

Appendix G – Additional Resources

Type	Source	URL
Climate data	Fourth National Climate Assessment (U.S. Global Change Research Program)	https://nca2018.globalchange.gov/
	State Climate Summaries (NOAA-NCICS)	https://statesummaries.ncics.org/
Risk assessment	Climate Change Risk Assessment Guidance (C40)	https://resourcecentre.c40.org/resources/assessing-risks-in-cities