City Disaster Vulnerability Index (CDVI) – Concept Note

1. Purpose and Objectives

The City Disaster Vulnerability Index (CDVI) was developed to provide a holistic representation of the multiple factors of vulnerability in a small urban area, identify concentrations of vulnerabilities and subsequently support the targeting and prioritisation of cross-sector interventions. The index provides a method to quantitatively assess sub-city areas in terms of their vulnerability to a variety of shocks and stresses. The multiple attributes and detailed scale of data within the CDVI enables a range of insights for different decision and policy makers at the City, regional and national level, including:

- Identifying areas of risk and vulnerability concentration during response and recovery efforts, along with for scenario planning exercises for preparation and planning activities
- Understanding how these risks can become worse and potential compounding impacts, along with the factors that drive and create vulnerability in certain areas
- Exploring where the risk can go in the future with the ability to perform what-if analysis
- Identifying where interventions should be targeted, on what sectors, and what the relative benefits can be.

2. The Index

The index was based on a range of research on urban vulnerability and disaster risk[1] indices along with input from subject-matter experts. Figure 1 details the index and how it is divided across four key pillars – Urban Fabric, Public Administration & Governance, Enterprise and People. These pillars represent the key elements of a city – where people live and work and how services enable that in a resilient manner.

The specific indicators used within each pillar and component was also determined based on known available datasets within Latin American cities – where the tool was trialled. This iterative process of assessing data availability against component and pillar focus ensured that the index was robust across cities while still capturing the diversity of information required to support multi-sectoral interventions.

For each city, a final step of Principal Component Analysis (PCA) was conducted to ensure the data used captured different aspects of vulnerability and was not simply repeating the same information in different metrics. In general, this was not the case, with the PCA not leading to the removal of any metrics given the highly selective and iterative nature of indicator selection. The PCA results were also used as an exploratory tool on the input data itself, helping to establish whether there were any errors in data collection or processing by highlighting outliers to explore.

The index therefore represents a comprehensive overview of different indicators of urban vulnerability. To enable effective targeting of interventions from a sectoral perspective. For the initial

[1] Power, C. et. al., (2015). Social and economic vulnerability global indicator database handbook. CEDIM Research Report.
Khazai, B., et. al., (2015) A guide to measuring urban risk resilience: principles, tools, and practice of urban indictors. First edition. Earthquake Megacities Initiative.
Daniell, J. E., et. al., (2018). Indirect loss potential index for natural disaster for national and subnational analysis. Risk modeling for hazards and disasters. http://dx.doi.org/10.1016/B978-0-12-804071-3.00006-9.

set up of the CDVI it was applied to four different sectors through the use and weightings applied to each of the indictors, components and pillars. The four sectors were:

- Public health
- Poverty and social protection
- Civil protection and disaster risk management
- Economic development

There was also consideration of the temporal dimension:

- Before an event (shock or stress) – vulnerability that exists in society and leads to increased negative consequences
- During, including the immediate response to an event
- Long term recovery from an event – building back better and reducing vulnerability moving forward

Figure 1 - Overview of City Disaster Vulnerability Index (CDVI)

The CDVI therefore represents vulnerability holistically across the four pillars while still enabling decision makers and planners to focus on specific sectoral and temporal perspectives, critical for planning and prioritising interventions.

3. Weighting

To initialise the index default weights were determined by expert elicitation. The Analytic Hierarchy Process (AHP) was used for the elicitation processed. The process is used extensively due to its ability to decompose a problem into a hierarchical structure especially when applied to decision contexts such as the CDVI that is designed to support the prioritisation of areas or concentrations of vulnerability for intervention. AHP supports this by extracting information through systematic pairwise comparisons, and the weights therefore represent a trade-off across indicators, or a willingness to forego a given variable in exchange for another[2].

As described in Forman[3], a foundational paper by one of the developers:

> AHP is a compensatory decision methodology because alternatives that are efficient with respect to one or more objectives can compensate by their performance with respect to other objectives. AHP allows for the application of data, experience, insight, and intuition in a logical and thorough way within a hierarchy as a whole. In particular, AHP as a weighting method enables decision-makers to derive weights as opposed to arbitrarily assigning them.

The essence of the comparison is that for a given objective i.e. improving public health through intervention, which indicator is more important and by how much. The response is a semantic scale between 1 and 9 where 1 indicates equality between two individual indicators, while a preference of 9 indicates that the individual indicator is 9 times more important than the other one.

To determine the initial weights six subject matter experts responded to the AHP for each of the sectors and then each of the time dimensions. The weights were averaged across respondents for each sector and then distribution for temporal dimension was applied to the weights per sector. It is important to remember though that the implementation of the index means the weights are transparent and variable meaning they can be tailor based on more local understanding of the application area.

4. Decision Support Tool

The CDVI has also been built into a geospatial decision support tool (DST) to enable more effective visualisation, useability and engagement at the city-level. The DST was implemented within QGIS, an open source geographic information system that enables viewing, editing and analysis of geospatial data, and operates as a plugin. The tool allows users to make specific selections – sector, and context / temporal dimension, based on these selections the index is initialised using appropriate default weights.

To guide the user in understanding the richness of the datasets available the DST, after user selection of sector and context, the Tool loads pre-selected key datasets for the city region. For example, in the health sector the location of health facilities, demographic profiles, and representation of existing medical conditions are loaded into the map window. This allows the user to begin explore dimensions of vulnerability prior to loading the full CDVI. Within the plugin the user can then ' Calculate Vulnerability', that loads the full database of CDVI information for the urban region. This consists of:

- Initial vector data for key indicators and data based on sector selection.
- A shapefile per CDVI pillar including unweighted indicator values for the respective pillar and key contextual data, such as total population or number of dwellings. This data is at a small administrative boundary based on data availability per urban region of application.
- CDVI shapefile, at the same spatial resolution as the pillar data, showing the weighted and normalized components and pillars, along with integrated CDVI value. This is based on the weights – either defaulted based on sector and context selection, or edited by the user within the DST.

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[2] OECD (2008). Handbook on constructing composite indicators – methodology and user guide.

[3] Forman E.H. (1983). The analytic hierarchy process as a decision support system, Proceedings of the IEEE Computer society.

This implementation within QGIS enables users to explore the CDVI data at multiple levels of detail, along with how changing weights influences understanding of vulnerability spatially. It can also be intersected against other spatial data, imported into the map, such as a flood or earthquake scenario. This simple analysis with a spatial tool can support decision makers analyse a range of questions, for example:

- Where are there shortages of public services relative to total and vulnerable population groups, and how much investment is required to make this more equitable?
- Where are informal workers concentrated and how exposed are they to disasters that affect a particular area in the city or transportation routes for that area?
- Where do lock downs (through pandemic counter-measures, or natural hazard impacts) have greatest impact to place-based workers – how does this change household income and wellbeing & remittances?
- Using a what-if scenario of conflict driven migration what areas are capable of supporting IDPs or refugees, how does this influx change the relative vulnerability of that area and how does the community compare to others across the city (or broader region) to learn what programs and resourcing are effective?
- Where should a risk mitigation scheme (e.g. flood defence) be placed to support the most economically fragile populations of the city, what benefits would it have in terms of reduced workforce interruption?
- What level of cash-transfer and shock responsive social protection is required in this area following a disaster impact? Can this understanding support the development adaptive social protective in advance?

Further enhancements of the tool with further enable analytical support to complex public policy and investment decisions. However, the flexible implementation of the CDVI, within a GIS platform with a range of existing tools is a significant step forward in more easily integrated risk and vulnerability analytics into decision making processes making them more transparent, efficient and equitable.