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MEASURING AND MANAGING URBAN DISASTER RESILIENCE

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ABSTRACT

Making a city disaster-resilient means understanding the capacity of communities and decision-makers to actively adapt to, cope with, and transform in view of potential threats. Urban resilience needs to be considered a multi-dimensional concept, visible at multiple levels, and highly dynamic. Various indicator frameworks rely on pre-arranged indicator sets and beneficiaries to measure resilience neglecting the need to dynamically adjust indicators to the context of specific places or sub-city levels of geography. The purpose of this paper is to introduce an approach for measuring and monitoring resilience within cities. The Disaster Risk and Resilience Index (DRRI) approach has been developed over the last 15 years and implemented in various cities around the world with the aim of supporting practitioners in their Disaster Risk Management decision making. The DRRI is based on a combination of the Urban Disaster Risk Index (UDRI) and Resilience Performance Scorecard (RPS) methodologies to work hand-in-hand as a set of indicators to establish both an initial diagnostic of integrated urban risk as well as a benchmark and track progress (or lack of progress) on the mainstreaming of risk reduction approaches in the city's organizational, functional, operational and development systems and processes.

Keywords: Urban Resilience, Scorecard, Indicators, Participatory Decision Making, Governance, Disaster Risk Management

1. INTRODUCTION

Following the axiom that "what gets measured gets managed," the ability to measure resilience is increasingly being identified as a key step towards reducing disaster risk. Measurement is vital not only to evaluate and benchmark the baseline conditions of what makes communities resilient, but also to help communities to understand the factors that can lead to adverse impacts and the diminished capacity to respond to an event. To this end, various indicator frameworks have been developed to benchmark resilience, e.g. the Baseline Resilience Indicators for Communities (Cutter et al. 2010), IBM-AECOM Resilience Scorecard (UNISDR 2017a, UNISDR 2017b), Torrens Scorecard (Arbon et al. 2012, TRI 2012, TRI 2015), or the City Resilience Framework (da Silva et al., 2014). These tools often rely on pre-arranged indicator sets and pre-defined beneficiaries neglecting the need to dynamically adjust indicators to the context of specific places or to sub-city levels of geography. Most feature a prescribed approach that gives a broad picture of performance along a set of questions or resilience dimensions that neglect community and grassroots level perspectives.

No single model or approach for measuring disaster resilience has been universally accepted, and the diversity and unique requirements of different organizations and stakeholders suggest that no one-size-fits-all approach will ever do the job. To capture local processes for decision-making and the production of relevant indicators and targets for producing actionable information, different types of

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indicators that are representative of the local knowledge, conditions, and context are needed. These types of indicators cannot be computed from publically available databases and require the design of targeted surveys with a specific audience in mind.

2. URBAN RESILIENCE

Resilience to natural hazards and disasters has been defined as the ability of communities exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential structures and functions (UNISDR 2009). Resilience has become the *de facto* framework for decreasing disaster risk and enhancing community-level disaster preparedness, response, and recovery capacities (Cutter et al. 2014). Timmerman (1981) was likely the first to describe resilience as a concept in natural hazards and disasters where he described resilience as the measure of the capacity of a social system, or part of a system, to absorb impacts or recover from damaging events. Since the publication of the work of Timmerman, conceptual models used to describe and assess resilience within the disaster risk management literature are plentiful, and range from theoretical frameworks that depict resilience as a set of networked capacities (Norris et al. 2008; Sherrieb et al. 2010, 2012) as well as those that consider resilience to be based on a set of capitals such as social, economic, and community capitals (Chambers 1988, Chambers and Conway 1992, Peacock et al. 2010), to conceptual models that include the description of attributes of particular systems such as the economy (Rose 2007), governance (Tierney 2012) and critical infrastructure (Bruneau and Tierney 2007). Place-based models also occur within the literature (Cutter et al. 2008). They are relevant for integrating information on natural hazard risk into a resilience framework because they consider hazard impact potential from exposure to damaging events coupled with measures of pre-existing social conditions that make people vulnerable. They provide the primary impetus for understanding the drivers and processes of disaster resilience are especially critical for the development of management plans to enhance resilience of communities.

Just as the concept of resilience itself has a long history of use within different disciplines, urban resilience research also draws from diverse research domains: research on urban theory more generally (e.g. Grimm et al. 2008), research on social resilience and social vulnerability (e.g. Cutter, Boruff, and Shirley 2003); research on hazards and disasters (e.g. Godschalk 2003, Pelling 2003); and research on climate change (e.g Leichenko 2011). Meerow et al. (2016) systematically reviewed definitions of urban resilience from various disciplines and found theoretical inconsistencies. For example, definitions vary based on how “urban” is conceptualized; or there are inconsistencies in the literature on pathways to a resilient state (i.e. some definitions of urban resilience focus largely on persistence, while others include transformation and transition). Meerow et al. (2016) argue that given the theoretical inconsistencies in the literature, a definition of urban resilience needs to retain flexibility and allow for the different perspectives to remain. As such, Meerow et al. (2016) define urban resilience as: “the ability of an urban system-and all of its constituent socio-ecological and socio-technical networks across temporal and spatial scales- to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity.” Despite the conceptual inconsistencies, the “malleability” around resilience is an advantage and especially important for work on cities, which are complex systems and therefore require the input and expertise of multiple disciplines and stakeholders.

3. EVOLUTION OF THE DISASTER RISK AND RESILIENCE INDEX

The purpose for the development of the Disaster Risk and Resilience Index (DRRI) approach was to build a monitoring and evaluation tool for benchmarking and measuring progress on disaster resilience in terms of mainstreaming of risk reduction approaches in the city’s development policies and processes (Khazai and Bendimeard, 2009, Khazai et al., 2016,). The first component of the DRRI indicator systems are the quantitatively derived Urban Disaster Risk Indicators (UDRI) which provide a holistic view of disaster risk by capturing the direct physical damages and the aggravating social and economic conditions contributing to total risk. The models and methodology referred to here as the

Urban Disaster Risk Indicators (UDRI) was originally developed for the Inter-American Development Bank through the IDB-IDEA Indicators Program by the Institute of Environmental Studies (IDEA) of the National University of Colombia, Manizales (NUCM) (Cardona et al, 2005, Carreno 2004, Carreno 2007). The UDRI has been adapted and used through a fully participatory process as an innovative risk communication tool to engage stakeholders in understanding their involvement and taking ownership of the risk factors in the city. In the last decade, the UDRI indicator systems was implemented and tested in 16 cities worldwide. Some were applied in Asia by the Earthquake and Megacities Institute (EMI) and the Karlsruhe Institute of Technology (KIT) in cities such as Metro Manila (Fernandez et al., 2006), Istanbul (Khazai et al., 2008; Kilic et al., 2012), Amman (EMI, 2009), Mumbai (Khazai et al.; Bendimerad et al. 2011), Pasig City (EMI, 2011) and Quezon City (Bendimerad et al., 2013), and Dhaka (EMI, 2014). In the Americas and Europe the indicator system was applied by the National University of In the Americas and Europe the indicator system was applied in cities such as Bogota, Medellin, Manizales and Barecelona by the National University of Colombia (UNC/IDEA) at Manizales (IDEA, 2005; Cardona 2006, Suárez and Cardona 2007, Suárez 2008) and by the International Center for Numerical Methods in Engineering (CIMNE) of the Technical University of Catalonia in Barcelona (Marulanda et al., 2013; Salgado-Gálvez et al., 2014a; Cardona et al., 2014; Carreño et al., 2014). The first implementation of the UDRI in Africa is currently being carried out by EMI in Algiers and Dar es Salaam. The collective experience and findings in the application of the UDRI indicator systems and various case studies are presented in the Measuring Urban Risk and Resilience Guidebook (Khazai et al., 2015). Overall, the objective of the UDRI indicator systems and the way that they were applied is to help enhance ownership within city stakeholders with the aim to assist in disaster risk management policy development, decision-making, and monitoring effectiveness of specific DRR options adopted.

A second component – the Resilience Performance Scorecard (RPS) was designed specifically as a participatory tool to be used by public officials and authorities in local, regional and national government agencies to assess a city's risk and resilience at multiple levels of geography from an integrated and qualitative perspective. The antecedent for the RPS is the work of Khazai et al. (2011) and Khazai and Bendimerad (2011) where a qualitative indicator system was developed as a self-assessment of urban resilience of Mumbai as part of the Disaster Risk Management Masterplan. Following a multi-disciplinary research collaboration between the Center for Disaster Management and Risk Reduction Technology (CEDIM) at the Karlsruhe Institute of Technology, the South Asia Institute (SAI) of Heidelberg University and the Global Earthquake Model (GEM) Foundation, the RPS was formulated by the authors progressively through experiences gained in multiple implementations in various urban settings including Lalitpur, Nepal (Anhorn et al. 2014, Burton et al. 2015, Khazai et al. 2018); Quito, Equador (Valcárcel et al. 2016); Addis Ababa, Ethiopia (Musori et al. 2017) and Nablus, Palestine (Cerchiello et al. 2016). The Lalitpur case study is the most comprehensive one as it covers firsthand information from the scorecard development and customization process, employs the most rigorous data collection efforts and covers two timeslots, prior to and after a catastrophically damaging earthquake event. The latter is important because it demonstrates the ability of the RPS to benchmark, track performance and monitor resilience over time.

4. METHODOLOGY

4.1 Urban Disaster Risk Index

The current UDRI methodology is based on Cardona's original model (Cardona, 2001; Barbat and Cardona, 2003; IDEA 2005) accounting for a holistic approach, where the total risk index is obtained by multiplying the direct physical risk index by an indirect impact factor, based on variables that account for the socio-economic fragility and resilience within the city's population and institutions. The indirect impact factor accounts for *Social Fragility Indicators*, which are defined as inherent factors of fragility of a person or group - such as personal attributes, living situations, and economic well-being. At the same time, the Impact Factor will increase if the capacity to overcome vulnerability in face of hazards is not present. Thus, the impact factor also includes *Lack of Resilience Indicators*, such as available means of disaster preparedness and risk mitigation, emergency response capacities, and other buffers and resources for reconstruction and recovery. A standard *additive aggregation* is used to combine the social fragility (F_S) and lack of resilience (F_R) indicators to obtain the Impact Factor (F). Accordingly, the aggravating coefficient, F, for each spatial unit (i) is obtained as the weighted sum of the social fragility indicators (F_{f_k}) and lack of resilience indicators (F_{r_l}), as given by the formula below. The results of the ranking for the aggravating coefficient, F, are shown in the figure below, where it is assumed that both social fragility and lack of resilience contribute equally. Thus, the following weights are used in the calculation for F.

$$F_i = \sum_{k=1}^{n} F_{f_k} \times w_{f_k} + \sum_{l=1}^{n} F_{r_l} \times w_{r_l} \qquad (1)$$

After the weighted aggregation of the indicators to obtain the aggravating coefficient (F) and the additive aggregation to obtain Physical Risk (RF), these two are combined according to the expression below to obtain UDRI.

$$UDRI = \sum_{i=1}^{n} R_{F_i} \times (1 + F_i) \qquad (2)$$

The model of integrated risk proposed developed for the Global Earthquake Model Integrated Risk Toolkit (Khazai et al., 2014; Burton and Silva, 2016) improves methodological aspects of the first proposal of Cardona (2001), turning it into a more versatile tool that can be utilized by local stakeholders for step-by-step development of the UDRI and interactive visualization of risk indicators (Figure 1). The software platform is highly flexible and also allows for different input indicators and weights to be uploaded by users to visualize the sensitivity of the index interactively. The Urban Disaster Risk Index utilizes publically available and multi-hazard risk and damage data, as well as relevant social and economic vulnerability indicators to produce a spatiotemporal diagnostic of integrated urban risk at the sub-city district level. The process of developing the Urban Disaster Risk Index consists of five main steps which will be passed iteratively:

1. **Indicator Framework**: Within the indicator development process the development of the indicator framework will take place through a consultation process with local stakeholders and specify the various dimensions to be covered, i.e. the sub-systems of the built environment and society, and the fragility and resilience factors identified for each sub-system.
2. **Indicator Selection**: The *second step* is defining and populating the indicators for each sub-system according to the framework identified in step 1, and collection of the requisite data. To guarantee the quality of the composite indicator framework, the single sub-indicators should meet some quality standards. For example, indicators used should be relevant, accessible, reproducible, interpretable and reliable. An important criterion in this project will be the repeatability/reproducibility of the indicators. Thus, the indicators will be based on easy to interpret, publically available data, so that the index can be constructed for future time intervals.
3. **Normalization:** Before aggregating the values of the sub-indicators into an overall composite indicator value, the sub-indicator values will be normalized (*step 3*). This is necessary because most of the sub-indicators have different units and cannot be combined into the indicator framework in their original values.
4. **Aggregation**: In the *fourth step*, the sub-indicators are combined as a weighted sum which results in the form of one single aggregated index value, UDRI, and several sub-levels. A simple aggregation scheme will be utilized based on indicator weights that are validated with stakeholders.
5. **Sensitivity Analysis**: The output index can be sensitive top to inherent correlations between some variables as driving factors of vulnerability, intra-model uncertainties associated with the weighting process and the implementation of transformation functions, as well as uncertainties contained within the input-data. Therefore, to analyze the robustness of the methodology, a sensitivity analysis which demonstrates the variability of the results will be conducted as a *final step*.

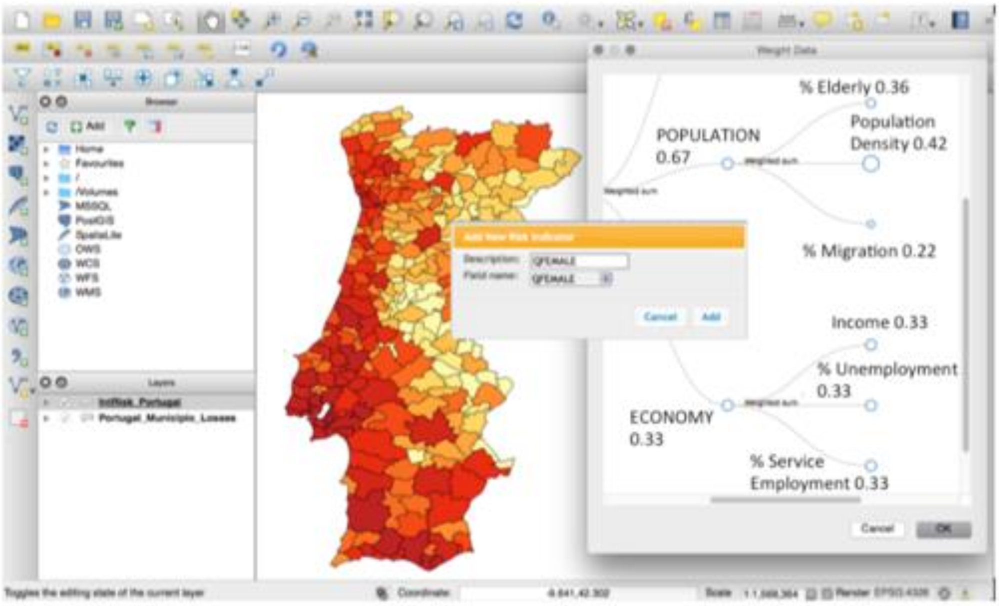

Figure 1 Collapsible tree chart embedded into the Toolkit QGIS dialog to allow users to define their model type, to apply weights, and to aggregate their data.

4.2 Resilience Performance Scorecard (RPS)

The Resilience Performance Scorecard was explicitly designed as a participatory tool to be used by public officials and authorities in local, regional and national government agencies to assess a city's risk and resilience at multiple time intervals from an integrated perspective. The RPS is a multilevel and multi-scale self-evaluation tool that empowers stakeholders to evaluate quantitatively assess resilience parameters for different time periods based on primary source information. The RPS aims to address key functional and operational areas of DRR planning in cities. These consist of strategies, policies, actions, and processes for mainstreaming disaster risk reduction at the local level. The following six dimensions were adapted from the Disaster Risk Reduction Management Planning model (Bendimerad et al., 2016), as overarching areas of emphasis to mainstream disaster risk reduction into planning and decision-making processes in urban environments and applied to the Scorecard (Legal and institutional arrangements: corresponds to the mechanisms available to advocate risk reduction in the city and the formal ability to transform policy respectively:

5. Social capacity: intended to measure the capacities of the population to efficiently prepare, respond and recover from a damaging event;
5. Critical services and public infrastructure resilience: relates to the capacity of lifelines and critical facilities and operators to prepare for, react and respond to hazard impacts;
5. Emergency preparedness, response, and recovery: reflects the effectiveness and performance of the risk management system for response and recovery in case of emergencies;
5. Planning, regulation and mainstreaming risk mitigation: relates to the commitment and mainstreaming of DRR through regulatory planning tools in the city; and
5. Awareness and advocacy: represent the level of awareness and knowledge of hazards and risk, community leaders and public institutions possess.

The dimensions of urban resilience used in the RPS are tied to four Priorities for Action of the *Sendai Framework for Disaster Risk Reduction* (UN 2015) (see Figure 2). These are priority areas for focused actions within and across sectors of governance at state, local, national, regional and global levels. Each of these priority areas corresponds to two key dimensions of urban resilience analyzed in the RPS where key dimensions of the RPS are connected to topical areas of the updated UNISDR 10 Essentials which were developed within the Making Cities Resilient Campaign to accelerate the implementation of the Sendai Framework at the local level.

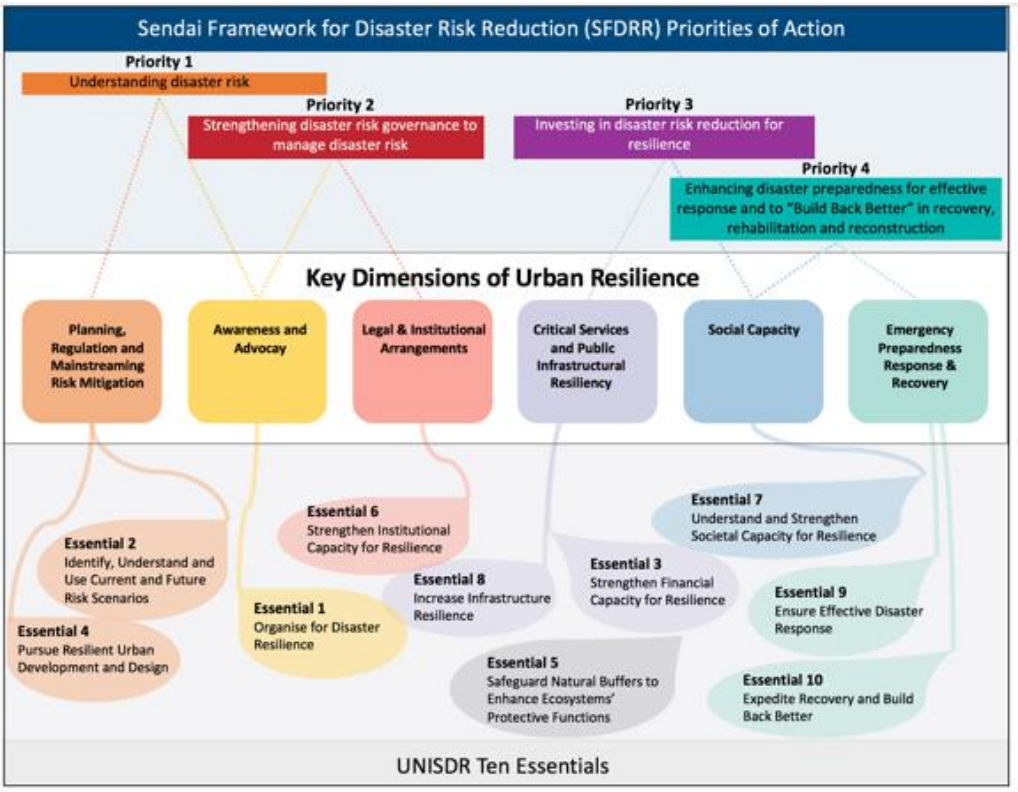

Figure 2. Key Dimensions of Urban Resilience used in the RPS and its links to the Sendai Framework Aim and the UNISDR 10 Essentials (Khazai et al., 2018)

The targets and indicators for measuring urban resilience within each of the six key dimensions of the RPS were developed and contextualized through a participatory process together with city stakeholders in the form of questions and a quantified answer scheme for achieving an understanding of gaps in resiliency along each dimension. This aspect of the methodology is fully customizable. In most applications of the RPS so far, six key localized performance indicators were developed for each of the six dimensions to produce a total of 36 indicators. While the key dimensions of the scorecard are consistent across different scales, the indicators (questions) along each of the themes within the six dimensions can be adjusted to represent the appropriate level of geography. For example, "enforcement and implementation of building codes" is a function at the Municipal and not the Sub-municipal level in some cities, whereas the existence of designated personnel for DRR lies at the lowest administrative level.

The RPS was developed to align with four pre-defined benchmarks and target levels of attainment. Here, we adopted a simple linear scoring methodology for comparative and benchmarking capabilities in which each respective answer to the corresponds to: 1) little or no resilience, 2) emerging resilience, 3) engaged in resilience, 4) full resilience integration. The levels of resilience attainment shown in Figure 4 correspond to the following general categories:

- "Little or no resilience" (Level 1): There is little or no institutional policy, process or culture for incorporating disaster resilience within the functions and operations of the organization.
- "Emerging resilience" (Level 2): The organization has a growing level of awareness, and there is support for disaster reduction among the policy makers. The institution may still have limited capacity in some areas, but overall making investments and taking action to building resilience.
- "Engaged in resilience" (Level 3): There is a high level of engagement and commitment to building resilience by the institutions. There is already an established policy for mainstreaming, an overall institutional process/system, and identifiable actions that render the system sustainable and irreversible.
- "Full resilience integration" (Level 4): Resilience and risk reduction is fully absorbed into

planning and development processes as well as core services of the institutions. The organization places high importance on reducing disaster risks in a sustainable program of action at multiple levels and within multiple sectors, and there is a comprehensive demonstration of practice.

These categories are a generalization of the level of resilience that can be attained based on our scoring system. The RPS breaks down each of these to an answer scheme that corresponds to the indicator. For example, one of the RPS indicators refers to "Coordination" and asks the question: "to what extent are well-defined mechanisms of coordination for disaster preparedness, safety and risk reduction between different agencies and areas of the city?" In this case Level 1, refers simply to the lack of existence of coordination mechanisms. Level 2, is a state where coordination mechanisms exist but cooperation among government agencies is still weak. Level 3 refers to a state where policies are developed to institutionalize the coordination mechanisms; whereas Level 4 or full integration is a state where these policies are fully implemented and coordination and cooperation is 'institutionalized' between the agencies. However, this is not to suggest that an optimum level of attainment has been achieved: usually there is always need for dynamic adjustments. Building resilience is viewed as an open-ended process: while organizations should aim to achieve the highest level of attainment, they should also aim to make continuous improvements to their approach. To clearly differentiate between the four levels of attainment, logical boundaries based on distinctive criterion have to be developed in the answer scheme for each of the questions. As a guiding principle, the authors used a generic three-level scale of distinctive criterion to formulate the attainment degree: namely existence, intensity, and quality (see Figure 3).

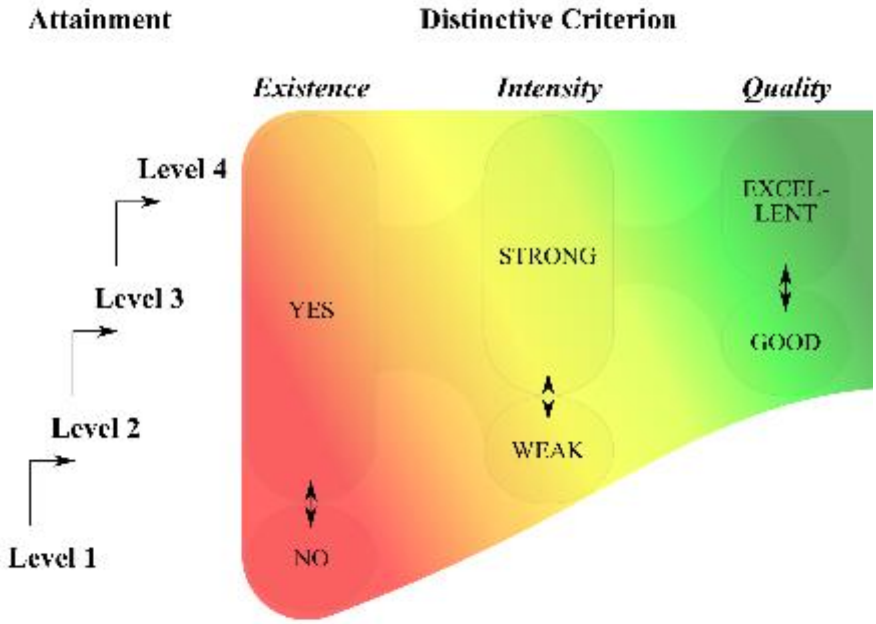

Figure 3. Generic answer scheme.

It is the overriding aim of the RPS development process to contribute to benchmark and track progress on DRM performance in a city over time. An example for the implementation of this methodology is shown in Figure 4 for two different time periods for the Lalitpur Metropolitan Municipality in Nepal in 2014 and 2015 (before and after the 2015 Ghorka earthquake in Nepal).

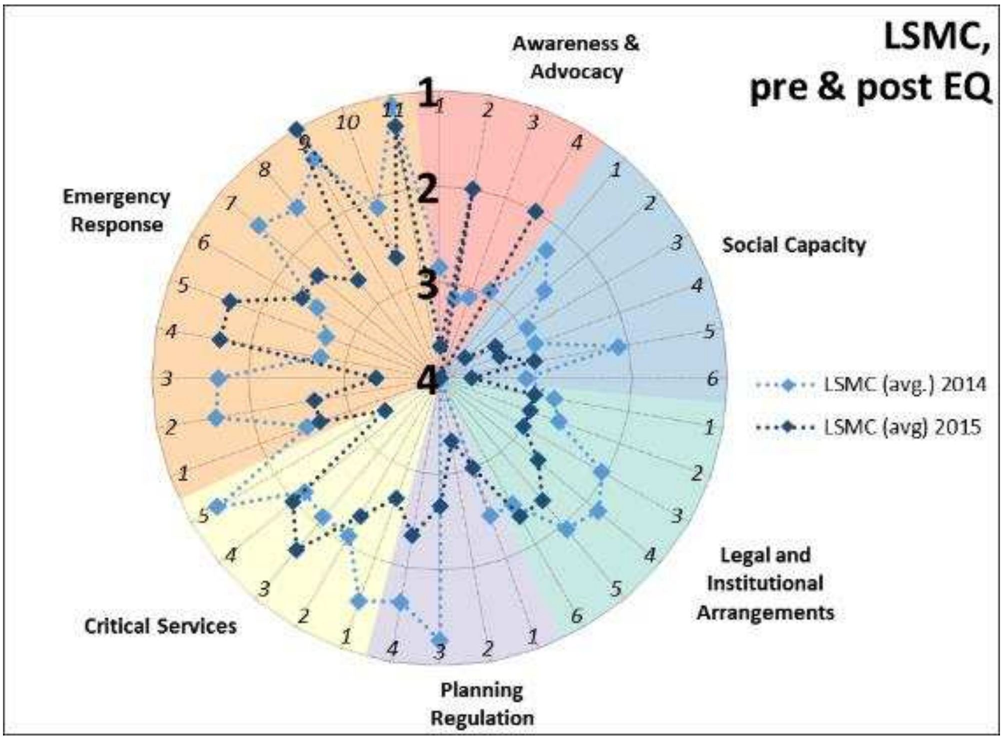

Figure 4. Illustration of implementing the RPS for two different time periods (2014 and 2015, before and after the Ghorka earthquake in Nepal)

4.3 Participatory Approach

In order to move towards the eventual and desirable outcome of stimulating change in stakeholders and to take action towards a more resilient tomorrow, a "localized" understanding of DRR planning is needed through an on-going process of negotiation, participation and learning. The Disaster Risk and Resilience Index (DRRI) is based on a combination of the Urban Disaster Risk Index (UDRI) and Resilience Performance Scorecard (RPS) methodologies to work hand-in-hand as a set of indicators to establish both an initial diagnostic of integrated urban risk as well as a benchmark and track progress (or lack of progress) on the mainstreaming of risk reduction approaches in the city's organizational, functional, operational and development systems and processes. The UDRI will provide an initial diagnostic of integrated urban risk in a city. In future implementations, the value of UDRI changes based on variations in the census data or the risk landscape, however, the UDRI does not provide a direct link to prospective and corrective actions that local authorities might take build resilience and reduce risk. To be able to benchmark and track progress in disaster risk management in a city over time, the RPS is brought in which corresponds to indicators measuring key areas and critical city functions in DRM.

To ensure adaptability and long-term use, the DRRI is designed in each city application to be compatible with local governance systems allowing the indicators to be linked directly to the critical functions performed by local governments as they relate to DRM. This way, the indicators are immediately relevant and easily understood by policy/decision makers, managers, planners and disaster management professionals.

The implementation of the Disaster Risk and Resilience Index (DRRI) requires engagement into a preparatory process where the local context is captured and is comprised of a four-step analysis, which is particularly decision-maker driven and employs institutional learning and adaptive governance as a key concept to ensure sustainable solutions are focused on (Figure 5). Utilizing the latest risk models as an important input, the DRRI advances from the existing hazard, vulnerability and risk knowledge and targets specifically the current lack of knowledge transfer to practice, governmental enforcement, and vision-oriented (spatial) decision-making. The following multi-step process is followed in the implementation of the DRRI through a participatory process:

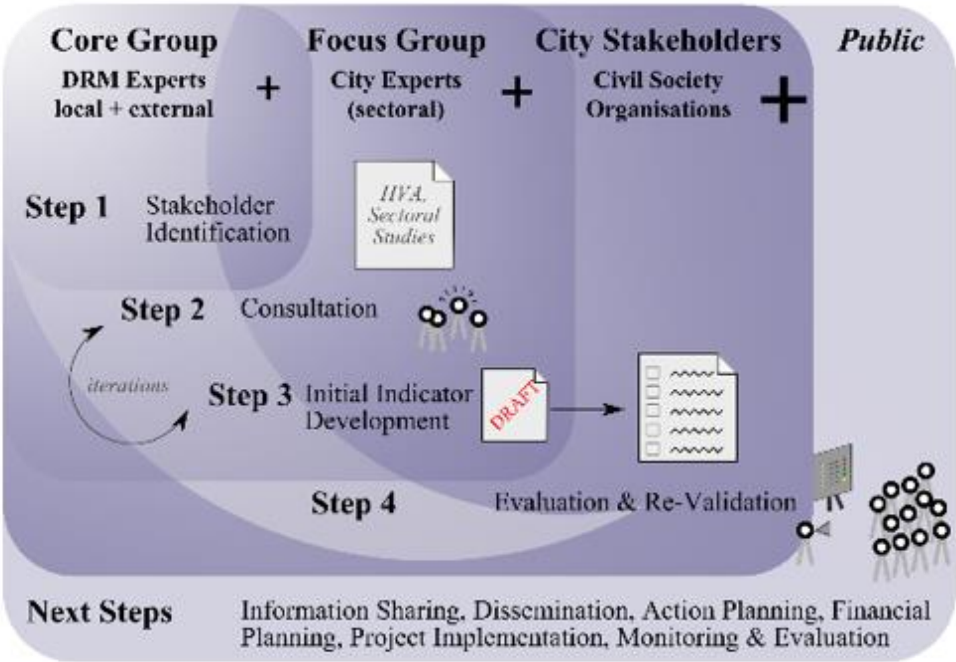

Figure 1. Participatory process for co-developing indicator systems with local stakeholders

Step 1: Stakeholder Identification
Identify a "**Focus Group**" (FG) as key city stakeholders along each of the five themes of the DRRI who will test, monitor, and validate the results of the implementation phase for each of the DRRI. Also, put together a "**Core Group**" (CG) for each implementation of the DRRI. The DRRI "**Core Group**" should be composed of the Focus Group leader for each of the sectors/themes represented in the DRRI, thus ensuring that adequate knowledge regarding each of the 5 sectors is contained. The optimum number of members of the FG will be decided by the CG; in any case it should have at least three members and a maximum of 10 so that the group is easier to handle.

Step 2: Stakeholder Consultations
The Core Group will focus on **contextualizing the selected resilience dimensions/themes** (e.g., emergency response capacities, shelter planning, or legal institutional arrangements) to local needs and consider fully and interactively input through structured interviews with the Focus Group. This step includes engagement with local stakeholders through a process of collectively defining resilience goals (i.e., target performance outcomes) for the city along each of the key dimensions, and specifying the respective monitoring and evaluation indicators according to these goals.

Step 3: Initial Indicator Development
The initial indicators of UDRI - physical risk (damage and loss from hazard available hazard scenarios), social and economic vulnerability and lack of resilience and coping capacities are based on publically available data and will be determined during the preparation phase of the project in consultation with the Core Group. A final selection of indicators and their weights will be validated with the Focus Group and analyzed for sensitivity for the construction of the UDRI.

An initial set of indicators for the DRRI should be agreed upon by the Core and Focus Group. The DRRI advances from the existing hazard, vulnerability and risk knowledge in the UDRI and targets specifically the current lack of knowledge transfer to practice, governmental enforcement, and vision-oriented (spatial) decision-making. The indicators should include guiding questions and expected outcomes and define the five different target levels of attainment according to the context in the city. The DRRI indicators and questionnaires should be validated by selected members from the Focus Group in an interactive workshop setting before using it with the City Stakeholders for evaluation and re-validation. Utilizing the results of the workshops and interactions with the Focus Group members, the key indicators and target performance levels of the DRRI can be improved upon to further refine and contextualize them to the respective city and the social, political, and economic circumstances of its residents. This iterative process of contextualization and validation of the DRRI questionnaire, serves multiple purposes: 1) to identify the current level of understanding of resilience within communities and across sectors of the local government, 2) to better understand existing challenges in the politicized environment of local governments, and 3) to familiarize potential facilitators with the background understanding and concept to ensure proper translation and management of group processes.

Step 4: Validation of the DRRI in Workshops

The indicators and questionnaires should be validated by selected members from the FG in an interactive workshop setting. Utilizing the results of the workshops and interactions with the Focus Group members, the key indicators and target performance levels of the DRRI defined by the “Core Group” are improved upon to further refine and contextualize them. This iterative process of contextualization and validation of the DRRI questionnaire, serves multiple purposes: first to identify the current level of understanding of resilience, second getting to know existing challenges in the politicized environment of local governments, third familiarize potential facilitators with the background understanding and concept to ensure proper translation and management of group processes. The final result of this is a customized questionnaire with a concise set of questions along the key resilience themes. The themes are covered by representative indicators along with precise guide questions with the target performance levels having a defined logic order. Additionally the facilitators are prepared to provide examples and explanations if necessary. In a final participatory workshop the DRRI survey can be administered to the FG individually or in groups. One way of administering the self-evaluation is through an interactive display of results where the participants cast their votes (via remote keypads) for each indicator and discuss their evaluation. Engaging with the participants in such a way helps to reduce initial apprehension by minimizing the fear of data manipulation as well as providing the conditions for communication to take place around key issues. Hence it is possible to discuss relevant matters on the spot, while not imposing pre-existing ideas and concepts.

Figure 6. Key pads to promote communication and discussions in the scoring of the indicators among the Focus Group members (Photo Credit: Christopher Burton)

4. DRRI WEB-BASED PLATFORM

The participatory workshops with the Focus Groups will be the opportunity for the stakeholders to validate the structure of the DRRI and its representation of the disaster risk management practice. Currently a web-based platform is under development to facilitate the implementation of the DRRI with a wide group of stakeholders who will be able to provide their assessment of the DRRI indicators at different stages of the project. The web-based platform is being developed as an interactive audit tool and dashboard designed to help with metric assessment, action planning, and DRM performance monitoring. The following features are integrated into the DRRI Web-based Application (Figure 7):

5 <u>Visualize Integrated Urban Risk</u>: The web-based platform will show the final Urban Disaster Risk Index on interactive maps based on physical loss and damage from multi-hazard scenarios and their interactions with social and economic vulnerability for different administrative areas.

5 <u>Measure DRM Performance:</u> Users go through each of the DRRI indicators and detailed characterizations with guidance to provide an in-depth assessment of their resilience performance. Stakeholders can provide input on their perceived level of DRM attainment along DRM dimensions aligned with their functional and operational areas.

5 <u>Improve DRM Performance</u>: Interactive features will be added to help users collaboratively set resilience goals and objectives, flag areas where action is needed, and help them prioritize and actions that still need to be implemented based on specific information provided by them. A reporting feature in the audit software will enable the user to produce customized reports and visualizations along different DRM dimensions.

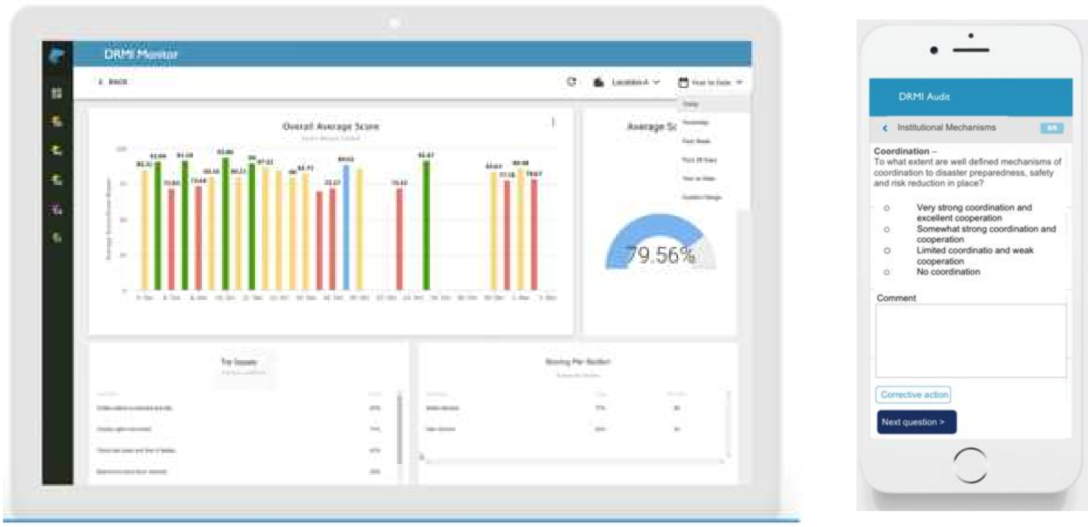

Figure 7. DRRI Web-based application and audit tool

5. CONCLUSIONS

This paper presents the theoretical background, methodology and application of the DRRI indicator systems for measuring and managing urban resilience. The DRRI is useful in evaluating the status, gaps and current achievements of key resilience dimensions and can be applied at multiple levels of geography. The DRRI is implemented through a fully participatory process with local stakeholders, which can be used to engage participants in guided dialogue about their perception of key dimensions of urban resilience. The results are captured and displayed to participants in real time, allowing for discussion to take place about discrepancies in the evaluation and points of views to be expressed with potential to converge towards a group consensus. The tool thereby can be used for getting buy-in among participants on a set of potential activities for increasing the capacity of population and public institutions where the current capacity is revealed low through the scorecard process. In this regard, the DRRI provides a useful diagnosis of the resilience of the city and facilitates the construction, update and prioritization of strategies with the participation of public institutions and community leaders.

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