# DISASTER RISK REDUCTION CONCEPTUAL FRAMEWORK: OPEN DATA FOR BUILDING RESILIENCE IN CRITICAL INFRASTRUCTURE

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Disaster Risk Management (DRM) and Disaster Risk Reduction (DRR) emerged as systematic approaches to reduce the impact of climate change on the built environment. However, post 2015 United Nations (UN) disaster emergency frameworks failed to capture the dynamics of hazards, exposure and vulnerability, due to the lack of accountability and accuracy of disaster data loss. This paper aims to explore the nature and impact of the utilisation of Open Data in DRR to build resilience in critical infrastructure. A historical review of DRM and DRR policies emergence pre-and post the year 2015 is applied. Based on evidence from empirical research and UN global reports, a correlational study between the 2015-2030 Sendai Framework for Disaster Risk Reduction (SFDRR) and Sustainable Development Goals (SDGs) is applied. Using the indicators of (SFDRR) Target D, and (SDGs) Goal 11, terminological analysis is applied for disaster damage, critical infrastructure and disruption of basic services. This paper offers a conceptual framework for building resilience in critical infrastructure across disaster preparedness three-stage process of recovery, rehabilitation and reconstruction. This framework rests on firm theoretical foundations concerning the Open Data for resilience initiative principles, and use case for building resilience in the Kathmandu Valley's, Nepal critical infrastructure.

Keywords: disaster risk management, disaster risk reduction, open data, urban resilience

## INTRODUCTION

The disastrous impact of climate change on urban livelihoods and natural biodiversity systems has long been observed worldwide. Shaped by the type of hazard and degree of exposure, extensive disaster risk derived by urbanisation, environmental degradation, socio-economic inequality, and poor urban governance is witnessed to accumulate larger losses in mortality, economic and physical damage (Shaw *et al.,* 2010:198).

Over the past ten years, approximately 700 thousand people have lost their lives, over 1.4 million have been injured and 23 million have been made homeless because of disasters. At the same time, the Hyogo Framework for Action (HFA) 2005-2015: building the resilience of Nations and communities to disasters was adopted by the World Conference on Disaster Reduction, but the layer of extensive risks was 'not captured by global risk modelling, nor are the losses reported internationally' (UNISDR 2015:90).

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'Climate change may not be responsible for the recent skyrocketing cost of natural disasters, but it is very likely that it will impact future catastrophes' (NASA 2016). The variations of risk drivers between the countries globally reflect the uneven social, economic and governance construction of hazards, risk and vulnerability.

There have been various attempts in the year 2015 to address challenges related to development, climate change and disaster risk losses. The Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 was endorsed by the United Nations (UN) General Assembly, and adopted by 187 countries as a 15-year, voluntary, non-binding agreement with four priorities and global seven targets, which aim at the reduction of disaster risk and losses in lives, livelihoods and health. This was followed with the adoption of the 2030 Agenda for Sustainable Development Goals (SDGs). With 17 Goals and 169 targets, both the SFDRR and SDGs aim to reduce disaster damage to critical infrastructure and disruption of basic services.

On first sight, it might seem plausible to argue that effective monitoring of disaster data loss can help achieve progress in reporting to the SFDRR and the SDGs global targets and associated indicators. However, on closer inspection, Cutter and Gall (2015) indicate that 'existing loss accounting systems vastly underestimate the true burden of disasters, both nationally and globally' (Cutter and Gall 2015). The 2017 Sendai Framework Data Readiness Review - Global Summary Report, gave scope to gaps in loss-data availability, accessibility, quality, applicability and the 'need to be sufficiently consistent and comparable to allow meaningful measurement of progress and impact' (UNISDR, 2017).

Moreover, calls for local solutions (Manyena, 2016:41), and understanding the challenges of DRR multi-level governance (Triyanti and Chu, 2016:1) in developing countries requires addressing data collection approaches at the local level, to help develop and validate reporting for global frameworks at the national and regional levels. In this respect, this study is needed to empirically investigate the use of Open Data in disaster preparedness for building resilience in policy and practice.

Defined as 'the ability of a system, community or society 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 basic structures and functions' (UNISDR, 2016). The term 'resilience' have been explored broadly across different research disciplines, yet all agreed on the role of local communities' social dynamics in understanding the scale of risk and level of vulnerability, to strengthen urban resilience.

Hence, the key question is: How can open data fill the gaps in capturing, sharing and using disaster data losses from underlying risks, and recognising the challenges for achieving the global targets? Based on empirical evidence from UN global reports, literature review of DRM and DRR theories in the context of urban resilience and this paper addresses the gap in disaster data loss, and discusses the implications of building coherence between the 2015-2030 Sustainable Development Goals (SDGs) and the Sendai Framework for Disaster Risk Reduction (SFDRR).

## METHODS

This paper is part of an ongoing PhD that aims to develop an Urban Resilience toolkit to support the implementation of SFDRR in the Middle East and North Africa (MENA) Region. To prepare and validated the elements of the toolkit with a robust methodology, the key objective of this paper is to develop and demonstrate a Disaster Risk Reduction Conceptual Framework, based on the use of open data for building resilience in critical infrastructure. In an attempt to unravel the objectivist ontology of DRR in the contexts of the 2015-2030 SFDRR and SDGs, the literature review includes data from secondary resources, refereed journals and UN policy reports, to undertake an inductive theoretical perspective towards filling the gap in disaster loss databases, and achieve the global targets.

Starting with the historical review of DRM and DRM ideologies emergence in UN frameworks pre-and-post the year 2015, the paper prioritizes investigating a correlational study between SFDRR and SDGs, against the three main constructs of Target D for the SFDRR, and SDG Goal 11- Target 11.5.2 (disaster damage, critical infrastructure and disruption of basic services). In particular, this study analyses the characteristics and constructs of the indicators terminologies, to understand how data losses are collected across disaster risk timeframe, scale, and assessment process.

Using strategic DRR and DRM theory, a conceptual framework is developed to understand how the shared principles of preparedness process of recovery, rehabilitation and reconstruction take place, jointly with the Global Facility for Disaster Risk Reduction (GFDRR) Open Data for resilience initiative principles. It prioritizes understanding the paradigm of risk-resilience in using, sharing and collecting consistent data on extensive hazards, exposure and vulnerability of critical infrastructure.

The paper will then showcase the use of Open Data in mapping critical infrastructure in the case study of Kathmandu, Nepal, building seismic resilience in the Kathmandu Valley's education and health infrastructure. The paper concludes with learning lessons, identifying gaps and future challenges for the interpretation of disaster risk assessments, and hazard impact model in reporting for the 2015- 2030 global indicators.

## HISTORICAL REVIEW

### Disaster Risk Management and Disaster Risk Reduction

The United Nations Office for Disaster Risk Reduction (UNISDR) states that, the term disaster management encompasses several activities of organization, planning and application that address measures for preparing, responding to and recovering from disasters (UNISDR 2016: 14). Prominently, disaster management focuses on implementing strategies that may not lead to eliminating the risk of disasters.

This topic was debated as early as 1961 by Duncan, as cited by Kroll-Smith and Couch, identifying the physical factors of disaster. On the contrary, Quarantelli (1985, 1987) suggested the social norms of disasters in relation to the demand of action and capability of response beyond geophysical terms. (Kroll-Smith and Couch 1991). The UNISDR define disaster as 'a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts'. Notwithstanding, disasters social and physical scopes are recognized in the differentiation between emergency response and recovery actions (UNISDR 2016:13).

Emergency management was first initiated during the First World War in 1935, following the bombing of civilian areas, and the establishment of the Civil Defence Service by the Home Office of the United Kingdom. Brought about protecting the population against nuclear destruction, a shift towards protection against natural hazards such as floods and earthquakes arose by the end of the Cold War 1991.

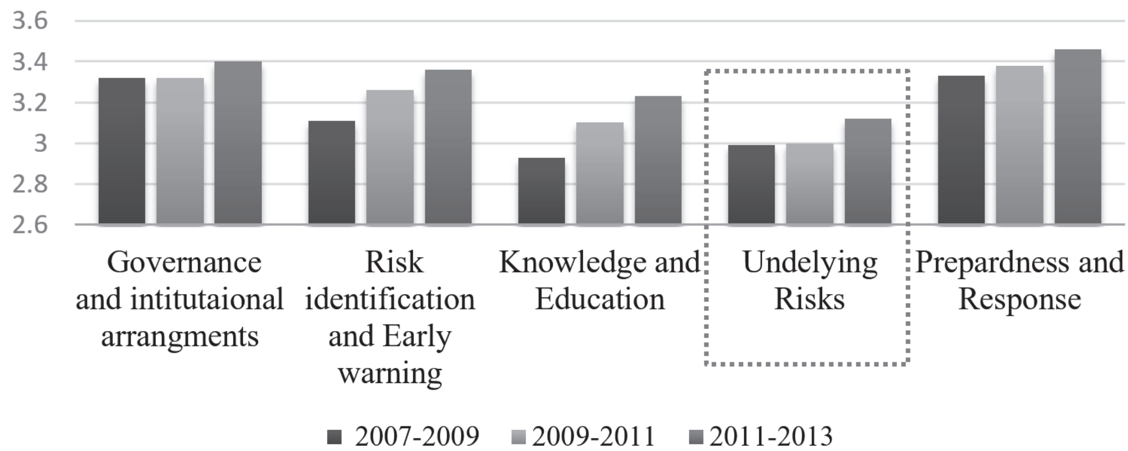
In the early 1960s, The United Nations General Assembly (GA) started adopting measures regarding severe disasters, to inform the Secretary-General of the type of emergency they are in the position to offer. This came into effect when the Buyin-Zara earthquake struck Iran and killed more than 12,000 people. This is followed by the creation of the United Nations Disaster Relief Office (UNDRO), to promote the study, prevention, control and prediction of natural disasters, and assist in providing advice to governments on pre-disaster planning.

Recognised as 'the International Decade for Natural Disaster Reduction', the period 1990-1999 witnessed the GA supremacy of reducing the impact of natural disasters for all people, with focus on developing countries. This was endorsed by Yokohama Strategy and Plan of Action at the World Conference on Disaster Reduction, which was held at Yokohama, Japan from 23 to 27 May 1994 (UNISDR 2017).

The 3rd Millennium witnessed the international community movement towards early warning, to take timely actions in advance of hazardous events. This was triggered with El Niño phenomenon's acute impact and climatic changes affecting the equatorial Pacific region and beyond, aimed to review the Yokohama Strategy, identify gaps and mitigate challenges. The early warning system movement was consolidated with the establishment of the International Strategy for Disaster Reduction (ISDR) and emphasis on shift form Disaster Risk Management (DRM), to Disaster Risk Reduction (DRR).

The ISDR endorsed the Hyogo Framework for Action (HFA) 2005-2015: building the resilience of Nations and communities to disasters, adopted by the World Conference on Disaster Reduction (Kobe, Hyogo- Japan), to facilitate disaster reduction strategy into national plans. Focusing on the reduction of disaster losses, Priority for Action 4 of the HFA calls to 'Reduce the underlying risk factors' (UNISDR 2015).

*Figure 1: Progress in implementing the HFA 2007-2013 (Source: Adapted from the UNISDR 2015 Global Assessment Report on Disaster Risk Reduction), (Part II-p.114)*




Since 2007, 146 governments have participated in at least one cycle of the HFA review using the online HFA Monitor. In 2011-2013, 136 countries submitted reports, and governments have reported growing levels of HFA implementation over time (Figure 1). Nevertheless, HFA monitoring mechanism focused on reporting data losses form large scale intensive disaster (e.g. earthquakes and cyclones), and overlooked the underlying risks of mortality, physical damage and economic losses from small scale extensive disasters (e.g. floods, landslides) derived by poor urban governance and planning. These notions have been elaborated by Dodman *et al.,* (2009), in the light of scale, frequency and impact, divided into biological, chemical, and physical hazards (Dodman, D., Hardoy, J and Satterthwaite 2009).

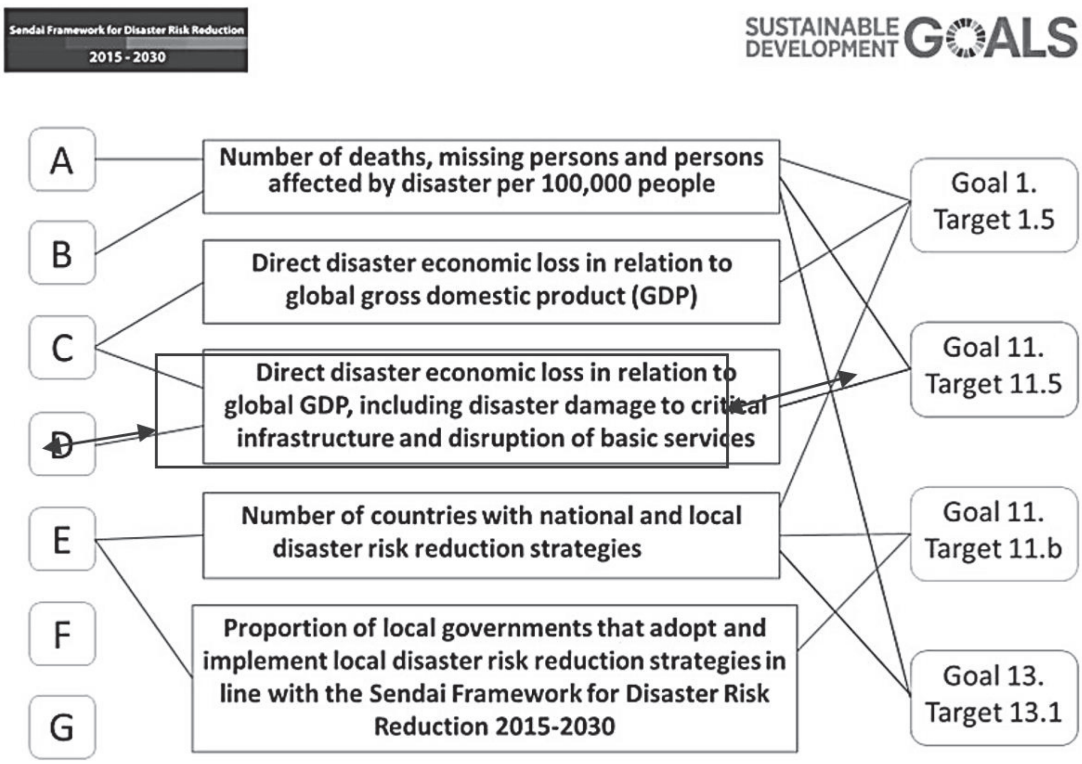
It is often argued by UN reports and policy documents that an evolution from managing disasters to managing risks was affiliated with the launch of the Sendai Framework for disaster risk reduction (SFDRR) 2015-2030. However, evidence from the 2015 Global Assessment Report on Disaster Risk Reduction recognise that 'most resources continue to be invested in strengthening capacities for disaster management, and there has been limited success in applying policies, norms, standards and regulations to manage and reduce risk across development sectors' (UNISDR 2015:118). Hence, there is growing consensus to differentiation between DRR and DRM tools and mechanisms to address the underlying risk drivers, and best utilise Open Data in disaster risk preparedness, beyond tendencies to mitigate challenges in post-disaster recovery only.

## CORRELATIONAL STUDY

### Critical Infrastructure in SFDRR and SDGs

Peters *et al.,* (2016) stated that 'delivering this global vision by 2030 in a sustainable and inclusive way, requires that we act upon all the major frameworks negotiated and agreed throughout 2015 and 2016'. (ODI, 2016:10). Based on the 2017 Integrated Research on Disaster Risk and International Council for Science policy document, Figure 2 highlight the correlation between SFDRR and SDGs global targets through common indicators (UNISDR, 2017).

*Figure 2: Correlation between SFDRR and SDGs global targets through common indicator (UNISDR, 2017)*




As noted by Luiijf *et al.,* (2008), gaps in data losses caused by cascading effects due to infrastructure interdependencies are identified as a key challenge for critical infrastructure protection (Luiijf *et al.,* 2008:303). More to the point is the fact that 'data are typically more available on physical damage and human impact, and less available on economic losses, losses of specific assets and infrastructure' as noted by the Sendai Framework Data Readiness Review (UNISDR, 2017).

Considering that the terms 'damage', 'critical infrastructure', 'disruption' and 'basic services' are addressed coherently across the SFDRR, SDGs, as presented in Table 1, to understand how data losses are collected across disaster risk timeframe, scale, and assessment process. This will help identify the level of interruptions or damages per sector in critical infrastructure and basic service, on extensive and intensive risks for all hazards.

*Table 1: Data disaggregation and statistical processing - SFDRR and SDG indicators*

| | | | |
|---|---|---|---|
| **Target D for the SFDRR Target (d)** 'Substantially reduce disaster **damage** to **critical infrastructure** and **disruption** of **basic services**, among them health and educational facilities, including through developing their resilience by 2030' | | | |
| **SDG Goal 11, Target 11.5.2** 'Direct disaster economic loss in relation to global GDP, including disaster **damage** to **critical infrastructure** and **disruption** of **basic services'** | | | |
| Terminologies | Duration | Assessment Process | Scale |
| Damage | Physical harm, not structural or architectural, which may continue to be habitable, although they may require some repair or cleaning that happen during the event or within the first few hours after the event | Assessed soon after the event to estimate recovery cost and claim insurance payments. | These are tangible and relatively easy to measure. |
| Critical infrastructure | The physical structures, facilities, networks and other assets that support services that are socially, economically or operationally essential to the functioning of a society or community. | Number of times interruption or damage occurs per population and sector | By country, event, hazard type, sub-national administrative unit, asset |
| Disruption | Disturbance and interruption of services, activities, or process that may affect different segments of the population with differing degrees of severity, including cases in which service delivery continues. | Disruptions of services can be measured in smaller units of time, for example hours or even minutes or seconds<br>Duration of service disruption and the number of people who did not receive basic services | Disruption of services may occur at irregular periods of time (or) can also be due to lower levels of quality |
| Basic services | Services that are needed for all of society to function effectively. This include water supply, sanitation, health care, education, housing, and food supply. They also include services provided by critical infrastructure such as electricity, telecommunications, transport, finance or waste management that are needed for all of society to function. | | By destroyed/ damaged, transportation mode, service sector (duration: short, medium and long; an affected scale in terms of household numbers) |

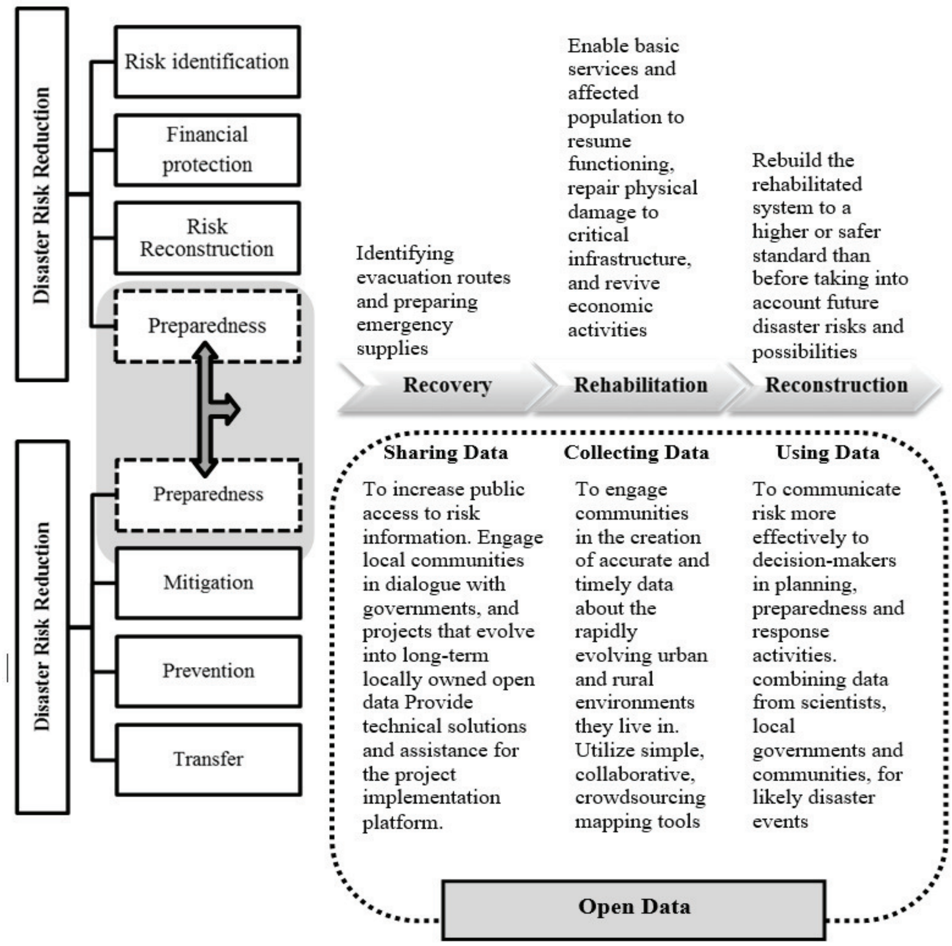
## CONCEPTUAL FRAMEWORK

### Use of Open Data for Critical Infrastructure Preparedness in DRM and DRR

It has been argued by Kirschenbaum (2002), that preparedness elements are driven by social factors that vary according to disaster management agencies, and community based collective behaviours, reflecting the components of 'provisions', 'planning' and 'protection' (Kirschenbaum 2002:14). Notwithstanding, the component of data sharing, using and collecting is missing. This study points towards a more integrated eco-system to use Open Data for preparedness and effective response to "Build Back Better" in recovery, rehabilitation and reconstruction' (UNISDR 2015).

Defined as 'data that is open to anyone free to use, re-use or redistribute", Open Data must be legally open to be placed in the public domain with minimal restrictions, and technically open in formats that are machine readable and usable. In the context of disaster preparedness, Open Data for disaster loss should maintain the standards for relevance, accuracy, reliability, timeliness, punctuality, accessibility and clarity. This allows for developing comparable and coherent data sets that can be 'sufficiently consistent and comparable to allow meaningful measurement of progress and impact' (UNISDR, 2017).

*Figure 3: The interrelationship between DRR and DRM (Preparedness and Open Data)*




Adopting the 2011, Global Facility for Disaster Reduction and Recovery (GFDRR) model (Figure 3), links between DRM and DRR highlights the contrast elements of preparedness, and identify core tools to improve risk information, communication and mitigation.

The indicators addressed here to measure the global progress for the SFDRR and SDGs provide guidelines on how and why the indicators are constructed, but do not identify a cohesive global approach to be adopted for data collection. Within the boundaries of disaster timeframe and level of damage, the terminologies listed under (Direct), (Basic) and (Critical) for basic services and infrastructures cannot be identified in the context of small scale and slow-onset disasters. These disaster-related data gaps overlook the underlying risks associated with socio-economic dimensions at the recovery and rehabilitation phase.

Accordingly, the use case below showcases the use of Open Data through participatory hazard mapping methods for critical infrastructure (schools- hospitals) in Kathmandu, Nepal. This model provides a guide on using Open Data tools to fill the data-loss gap and accommodate the dynamics of all hazards in measuring resilience for the SDGs and SFDRR indicators.

*Table 2: Case study: Kathmandu, Nepal: Open Data for Critical Infrastructure (2012)*

| | |
|---|---|
| **Country:** Nepal<br>**City Profile:** Kathmandu, capital city, is situated in central Nepal bowl-shaped valley between four major mountains, at high elevation (approximately 4600ft or 1400m)<br>**Population**: Exceeding one million<br>**Risk profile:** Earthquakes and landslides | |
| **Objectives:** To build seismic resilience in the Kathmandu Valley's education and health infrastructure | **Expected Outcomes:** The model will be used to prioritize plans for retrofits of schools and health facilities to improve structural integrity in the face of earthquake. |
| **Project:** Critical Health and Educational Sector Infrastructures | **Partnership:** Government of Nepal, the World Bank and GFDRR Open Cities Project |
| **Stakeholders:** Universities, technical communities, community groups, local government, Kathmandu Living Labs (local NGO) | |
| **Method:**<br>• Collect structural data (asset and exposure) for 2,256 schools and 350 health facilities in the Kathmandu Valley urban areas<br>• Engage all stakeholders in order to create a robust asset inventory and expand the OSM (Over 2,300 individuals participated in OSM trainings or presentations during the first year of the project)<br>• Create a disaster risk model to determine the relative vulnerability of the relevant buildings.<br>• Create a comprehensive base map of the valley by digitizing over 100,000 building footprints, mapping the road network, and collecting information on other major points of interest. | |
| **Results:** Kathmandu has to date mapped over 100,000 buildings and collected exposure data for 2256 educational and 350 health facilities within Kathmandu Valley. | |
| **Sustainability Plan:** Kathmandu Living Labs to follow-up OpenStreetMap trainings and mapping. | |

# CONCLUSIONS

Disasters result from a combination of hazard, with their respective to exposure and vulnerability exacerbated with climate change extreme weather events, evidence from previous literature indicate that the severity and frequency of disasters impact are most to be affecting the 'grassroots-level community' (Shaw, Pulhin *et al.,* 2010:116). The subjectivist review of building resilience in DRM and DRR pre-and-post 2015 UN frameworks is challenged in this paper, to identify the gap in disaster data losses database from underlying risks, and aim to explore the nature and impact of the utilisation of Open Data for building urban resilience in DRR.

Due to the lack of multi-level disaster management governance system at the local, national and regional levels, Open Data is indemnified as an ecosystem-based disaster risk management tool responding to Triyanti and Chu recommendations, by developing a conceptual framework the use of Open Data for Preparedness in DRM and DRR shared variables of 'recovery', 'rehabilitation' and 'reconstruction', in conjunction with the Open Data for Resilience initiative three stage process of sharing, collecting and using data for DRR. (Triyanti and Chu, 2016)

With the focus on building resilience, the SFDRR and the SDGs 2015-2030 agendas have the potential to integrate the paradigm of risk-resilience, taking into account the issue of inconsistency in monitoring reliable data of disaster damage to critical infrastructure and disruption of basic services. The correlation study in this paper and analytical outline of the SDG 11.5.2 and SFDRR Target D terminologies, duration, assessment process and scale, engender that the indicators addressed to measure global progress in the implementation of the global targets provide guidelines to the Metadata (describing how and why is the indicators constructed) and Methodology (the Summation of data from National statistics offices) but does not provide mechanism of data collection and tools for analysis to monitor progress and develop DRR resilience plans at the local level. Accordingly, this paper showcases the Kathmandu, Nepal model of using Open Data for mapping critical health and educational infrastructure, and create a disaster risk model to determine the relative hazard, exposure and vulnerability.

In the context of building urban resilience, national and local governments would require identifying local techniques to mitigate climate change impact by reporting on small-scale onset, and frequent hazardous events that are not registered in international disaster loss databases. Lack of transparency, weaknesses of urban governance and limitations in financial and human capacities may cause socio-economic assessment biases, and will remain as challenges for the application of Open Data findings into extensive hazards. It is important to improve human and technical capacities with the use of Open Data tools to obtain a consistent report on data losses for all hazards and underlying risks. This will have be compared to the Hyogo framework of last decade (2005-2015), to develop evidence based record on the implementation of SFDRR and achievement of 2030 SDGs global targets.

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