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Multi-Hazard Vulnerability Assessment of School Infrastructure

The case of Cagayan de Oro - Philippines

SAFER COMMUNITIES THROUGH SAFER SCHOOLS

Arash Nassirpour a.nassirpour@ucl.ac.uk
Carmine Galasso c.galasso@ucl.ac.uk
Dina D'Ayala d.dayala@ucl.ac.uk

1. Introduction

- Philippines, one of the most hazard-prone countries in the world, is regularly subject to various natural disasters such as earthquakes, volcanoes, hurricanes, tsunamis and floods, inflicting loss of lives and costly damage to the country's infrastructure.
- The vulnerability of the school buildings is of high priority as schools play a critical role in the education of the next generation, who are the most vulnerable part of the society due to their age and developmental stage.
- A safer school can save valuable lives of children, provide a safe haven for the local community, serve as a temporary shelter and help to bring normalcy back to the society in times of disaster. However, school buildings constructed prior to adequate building codes, share structural deficiencies. Hence, appropriate tools and approaches are required to address the prevailing vulnerabilities.
- Developing a comprehensive and systematic dataset of schools, including structural and non-structural characteristics, common defects and typical damage associated to multiple natural hazards, will be beneficial as the initial stage of disaster management planning along with prioritization of retrofitting and strengthening programs.

2. Aims & Objectives

The main aim of the SCOSSO (Safer Communities Through Safer Schools) project is to develop an innovative multi-hazard risk assessment framework for school infrastructure in the Philippines.

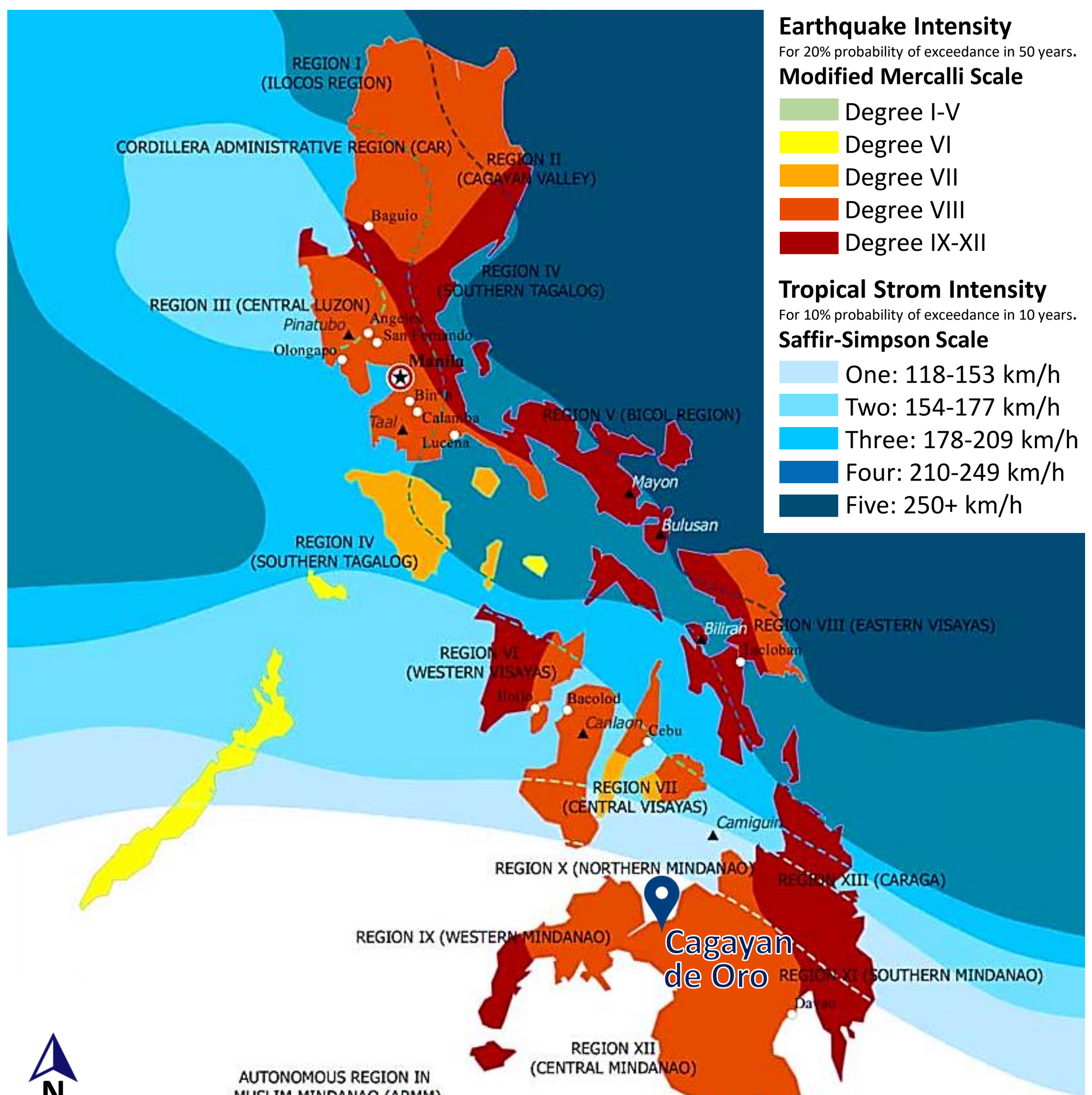


Figure 1 – Phillipiness Natural Hazard Risk; Seismic, Volcanic & Tropical Storm United Nation Office for the Coordination of Humanitarian Affairs (OCHA) [March 2011]

As part of the SCOSSO;

- A methodology is developed for rapid yet reliable visual vulnerability assessment of school infrastructure against Philippine's most common natural hazards, such as earthquakes, hurricanes and floods (Figure 1).
- Utilising the data of rapid visual survey, an investigation is conducted to relate the collected data to vulnerability indices to swiftly determine the safety level of the surveyed schools.
- The proposed framework allows governmental authorities, first responders and decision makers to quickly identify the most vulnerable structures among the surveyed stock and plan further rehabilitation measure or if necessary replacement.

3. Rapid Visual Surveying

The Rapid Visual Surveying procedures are developed to swiftly monitor and identify the hazardous buildings. In this study a Data Collection Form is proposed which the surveyor completes based on visual observation of the school buildings (Figure 2).

The structure may be assessed from its exterior without the benefit of building entry, detailed structural drawings or any analysis. The form includes 94 spaces for documenting information on different aspects including the positioning of the building, general information on the building's occupants and space arrangement, along with detailed structural characteristics and deficiencies.

A preliminary investigation is conducted in the city of Cagayan de Oro, the regional capital of Northern Mindanao - Philippines. This is a highly urbanized first class city with over 675,000 citizens and multi-hazard profile of earthquakes, floods, hurricanes and tsunamis. The city has established a full-time unit in charge of disaster preparedness, response, recovery and mitigation.

To test the feasibility of the proposed method, the campus of 9 elementary schools have been surveyed, resulting in 115 school buildings.

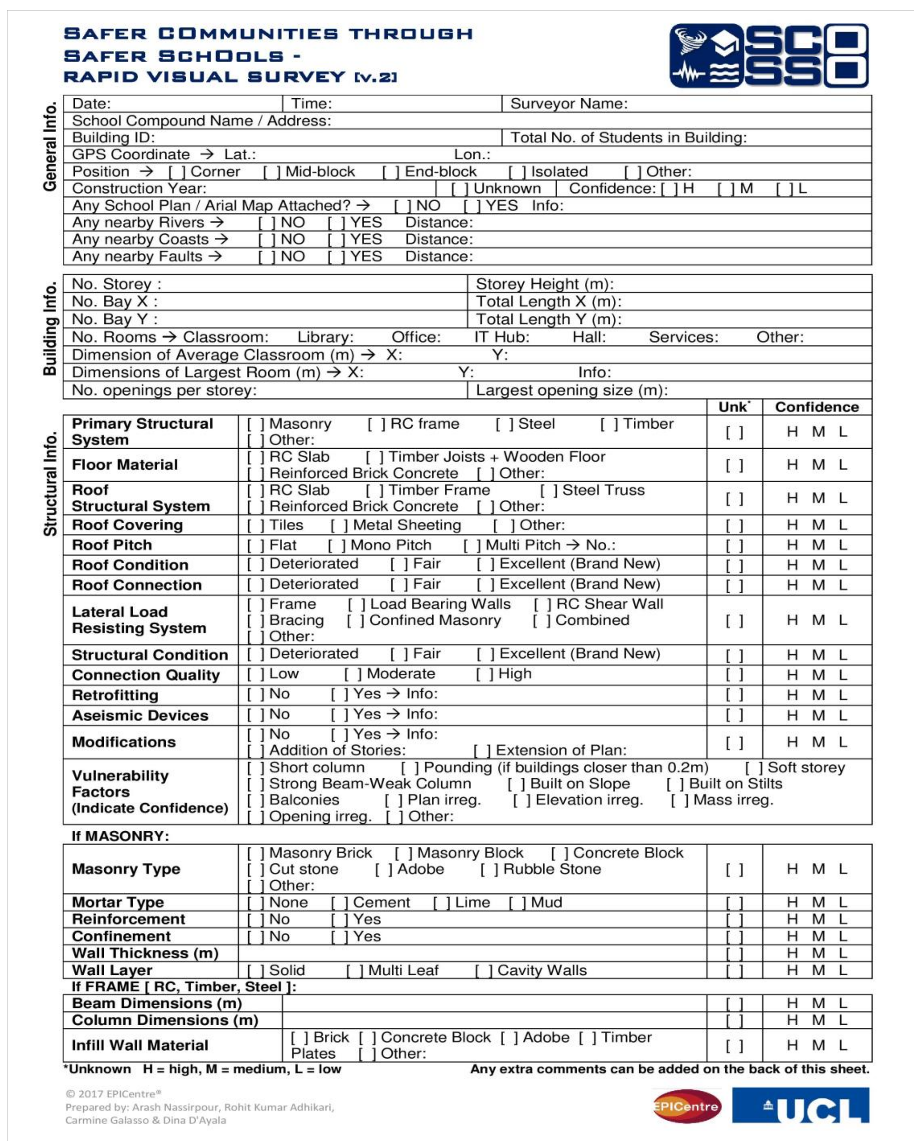


Figure 2 - Data Collection Form, including allocated spaces for documenting the general information on the building's geolocation, general information, structural characteristics and deficiencies

4. Vulnerability Index

To swiftly determine the safety level of the surveyed buildings, the collected data from rapid visual survey were related to vulnerability indices in terms of percentage, where higher values indicate the more vulnerable cases.

Structural Condition	VR
Brand New / Excellent	25
Fair / Good	50
Deteriorated / Poor	75
Unknown	50

Lateral Load Resisting System	VR
Bracing	25
RC Shear Wall	50
Frame	50
Load Bearing Walls	75
Confined Masonry	100
Others	50

Primary Structural System	VR
Steel	25
Reinforced Concrete	50
Timber	75
Masonry	100
Others	50

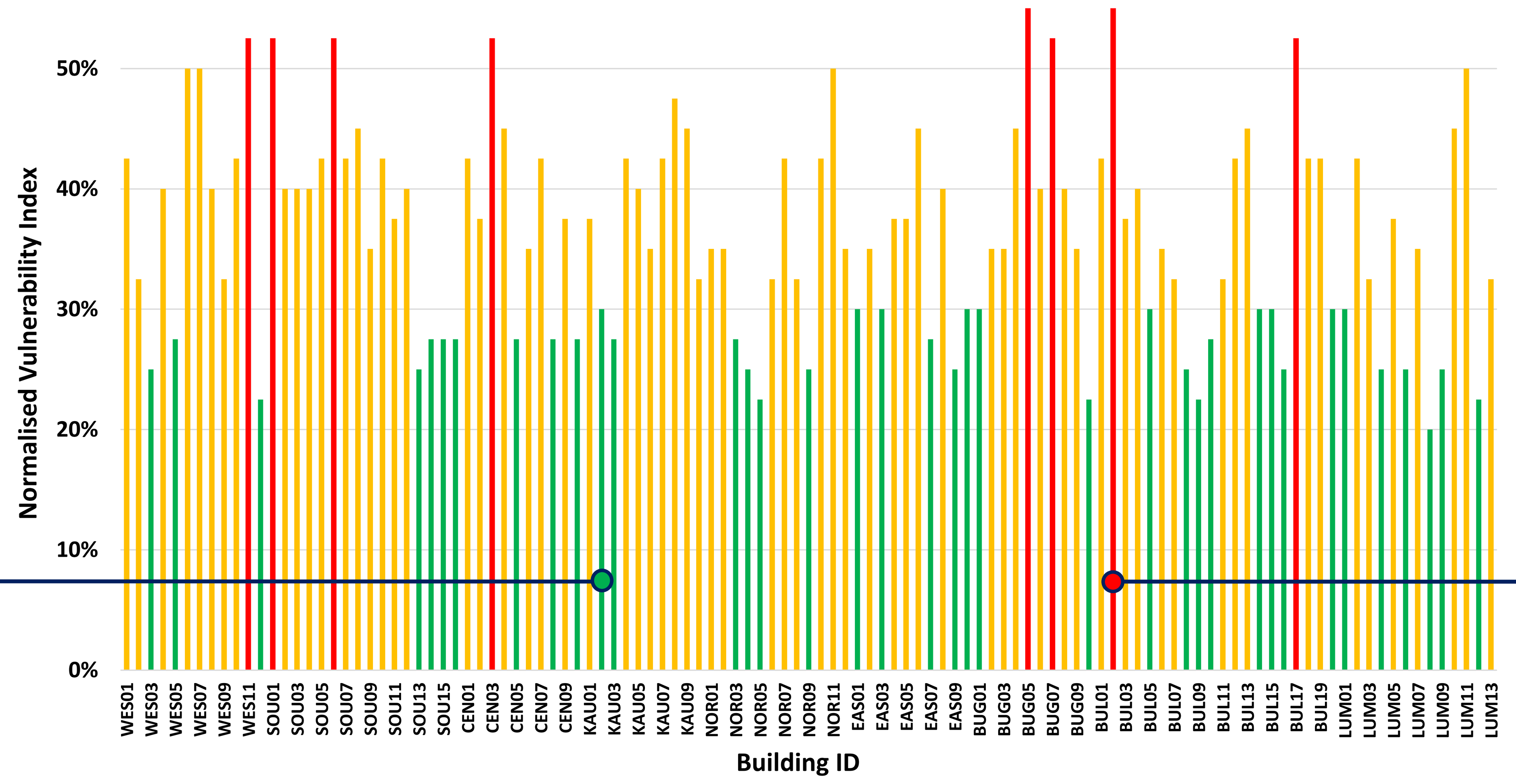
Vulnerable Factor	Susceptible	Insensitive
Short Column	100	0
Pounding	100	0
Soft Storey	100	0
Strong Beam - Weak Column	100	0

Construction Year	VR
After 2000	25
Between 1990 and 2000 (Previous Code)	50
Between 1970 and 1990 (Pre-Seismic Code)	75
Before 1970 (No Code)	100
Unknown	50

Table 1 – Examples of the Vulnerability Rating (VR) allocated to a number of surveyed factors considering multi-hazards such as earthquake, flood and cyclone

- Each of the 94 surveyed items included in the data collection form have been categories in four sets based on their importance and contribution to the vulnerability of the structure, namely High Effect, Moderate Effect, Minor Effect and No Effect.
- The vulnerability index comprises of summing the allocated vulnerability rating values allocated to each of the considered element and their sub-categories. Table 1, illustrated a number of elements with high effect and the allocated vulnerability rating (VR) for each of their options.
- The results obtained for each of the 115 surveyed buildings are presented in Figure 3, along with examples for the least and most vulnerable cases.

Kau Central – Grade II (ID: KAU02) VI: 30%
Lat.: 8.397827 Lon.: 124.597502
what3Words: *snuggle.secretly.trainer*
Construction year: 2015
Primary Structural System: Steel Frame
Reinforced Concrete Slabs + Metal Decking
Structural Condition: Brand New



Bulua Central – Grade IV (ID: BUL02) VI: 55%
Lat.: 8.503602 Lon.: 124.616493
What3Words: *urged.renew.stank*
Construction year: 1980
Primary Structural System: Masonry [Concrete Blocks]
Structural Condition: Poor connection between roof and walls, Heavy deterioration

Figure 3 - Vulnerability Index (VI) of 115 Surveyed Elementary Schools in Cagayan de Oro – Philippines. A number of cases are illustrated along with some geolocation and structural details.

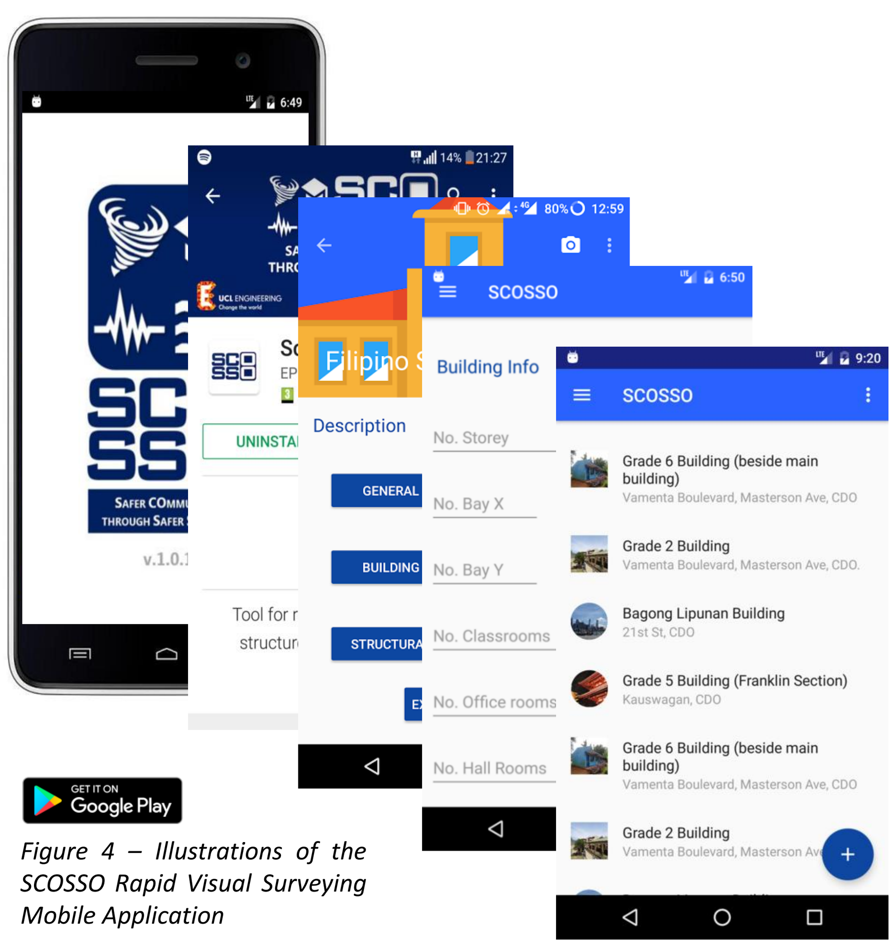


Figure 4 – Illustrations of the SCOSSO Rapid Visual Surveying Mobile Application

5. Mobile Application

In addition to the rapid visual surveying form, a mobile application has been developed to assist the surveyors for assessing the school building in a more efficient way (Figure 4). Some of the app features includes:

- Instance vulnerability estimation,
- Confidence indicator for input data,
- Cloud data storage,
- Support for different output formats (*.csv*),
- High precision location indicator, what3words
- Easy instant data sharing,
- Photographic manual and guidelines,
- User friendly interface & easy to use

6. Conclusions

- The proposed method represents a first step toward a detailed multi-hazard vulnerability assessment of school infrastructure. This can allow decision-makers to quickly identify the most vulnerable structures among the surveyed stock, guide more detailed data collection and structural assessment procedures, and ultimately plan further retrofitting measures or if necessary replacement.
- As part of the SCOSSO project, highly detailed 3D models of the buildings are developed by utilising the collected data and the construction drawings of the structures. By simulating different hazards such as real earthquake records or flood and wind forces the response of the schools are measured to estimate their vulnerability and suggest retrofitting measures.
- A similar survey is also conducted on human vulnerability and non-structural elements of the classrooms using advanced techniques such as omnidirectional photography. Furthermore, a number of workshops and training session were conducted for the local engineers and decision makers.

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