Rapid Visual Screening and Seismic Vulnerability Assessment of Several Buildings at the University of the Assumption Using FEMA P-154 Forms and SCOSSO Mobile Application

Dirk Tracy Chua[1], Carlos Elmer Guevarra[1], Christian Fhillip Nabong[1], Sarah Danielle Batu[1], Kris Roan Simbulan[2], Jenilyn Aquino[2]
[1]Student, College of Engineering and Architecture, University of the Assumption, City of San Fernando, Philippines
[2]Faculty, College of Engineering and Architecture, University of the Assumption, City of San Fernando, Philippines
Corresponding Author: dirktracychua@gmail.com

***Abstract*: Selected buildings at the University of the Assumption in the City of San Fernando, Pampanga, were assessed using the Rapid Visual Screening (RVS) approach to determine their seismic vulnerability. The researchers utilized FEMA P-154 and the SCOSSO mobile application in evaluating the buildings based on their age, occupancy, construction materials used, number of storeys, and building design layout. Through field inspections, the RVS scores and vulnerability indices of the selected buildings were established by utilizing FEMA P-154 Level 1 Forms and the SCOSSO Mobile Application in data gathering.**

The findings showed that FEMA P-154 and the SCOSSO Mobile Application classified the selected buildings differently. Varying risk levels were identified by FEMA P-154 Forms, while the SCOSSO Mobile Application indicated moderate risk for all selected buildings. The need for further evaluation is emphasized from such findings. A preparedness mapping plan was generated using QGIS software, providing visual representation of the risk levels and prioritization for retrofitting of the selected buildings. Among the assessed buildings, the Puno and Ryan Buildings were found as high priority from this evaluation.

This research found that combining FEMA P-154 with SCOSSO Mobile Application is a reliable basis for seismic risk identification and helps in strengthening the institution's disaster preparedness.

***Keywords*: Rapid Visual Screening; FEMA P-154; SCOSSO Mobile Application; Seismic Vulnerability Assessment; Preparedness Mapping Plan; QGIS; Earthquake Risk.**

1. Introduction

Earthquakes, as defined by Acosta et al. (2018), are the Earth's surface's abrupt shaking caused by the accumulation and subsequent release of stress within the Earth's faults.

Various studies have shown that the Philippines, situated on the Pacific Ring of Fire, has high vulnerability to seismic hazards. As stated by Peñarubia et al. (2020), the Philippine archipelago is classified as "tectonically complex and seismically hazardous" because of active faults causing frequent earthquakes throughout the country. Such seismic activities, like the 1990 Luzon earthquake and the 2025 magnitude 7.4 Mindanao earthquake, resulted in fatalities and damage to infrastructure (United States Geological Survey, 2025; Philippine Institute of Volcanology and Seismology, 2025).

Seismic safety has become a major concern in the country following the 1990 Luzon earthquake, 2013 Bohol earthquake, and 2019 Zambales earthquake, wherein Central Luzon and Central & Eastern Visayas experienced significant damages. The National Structural Code of the Philippines (NSCP) has provided requirements regarding earthquakes for better structural design; however, most buildings have existed before such requirements.

The University of the Assumption, located in the City of San Fernando, Pampanga, has several academic and administrative buildings that are occupied by thousands of individuals. Because of being in an area considered seismically active, it becomes necessary to study the seismic resiliency of these buildings to guarantee the safety of the residents and to maintain the continuity of learning processes amidst earthquakes. According to the Philippine Institute of Volcanology and Seismology's (PHIVOLCS) Hazard Mapping and Assessment for Effective Community-Based Disaster Risk

Management (READY) Project, the Ground Shaking Hazard Map of the City of San Fernando, Pampanga, shows the city's vulnerability that is classified under PEIS Intensity VIII and above, with 18 earthquake sources recorded.

Harirchian et al. (2020) stated that Rapid Visual Screening (RVS), following FEMA P-154 guidelines, is an accepted, reliable, and low-cost technique that utilizes visual inspection of structural and non-structural features that allows rapid identification of potentially vulnerable buildings without the need for detailed engineering analysis. This is a tool for

prioritization that enables engineers and decision-makers to effectively allocate resources for retrofitting or further evaluation.

SCOSSO complements the RVS methodology through automation of the collection and analysis of data. This approach is consistent with contemporary civil engineering methods that involve the adoption of technology for effective disaster risk management. Studies conducted in the Philippines have established the feasibility of using FEMA P-154 on educational facilities. This underscores the utility of FEMA P-154 in finding the initial susceptibility of structures in response to earthquakes (Clemente & Concha, 2020). Furthermore, findings from foreign countries suggest that the RVS methodology is a reliable determinant of building performance in seismic conditions (Haselton et al., 2016).

The utilization of Geographic Information System (GIS) technology in disaster risk reduction and preparedness has accelerated the collection, organization, analyzation, and visualization of data associated with seismic hazards. GIS technology combines earthquake exposure data and the geographical locations of buildings to generate a risk and vulnerability map to enable strategic decision-making (De Los Santos & Principe, 2021). Studies have also been conducted to ascertain the significance of GIS technology in earthquake exposure and risk/vulnerability mapping by delineating the characteristics of buildings and integrating such characteristics into a database to identify areas that require priority intervention (De Los Santos & Principe, 2021). Another study indicates that by incorporating multicriteria decision analysis into GIS technology, researchers can identify highly vulnerable areas and urban planning/disaster preparation initiatives by flagging areas that require priority intervention (Al-Shamsi et al., 2025). In addition, GIS-oriented tools have been developed to facilitate automated visualization and organization of rapid visual screening results to enable researchers to synthesize field survey results and generate interactive maps to identify areas that are most vulnerable to earthquake hazards (Mahmoud et al., 2020). The use of GIS technology improves stakeholders' ability to visualize earthquake risk patterns and support effective disaster mitigation planning. (Mahmoud et al., 2020; De Los Santos & Principe, 2021).

A. *Objectives of the Study*

Using the Rapid Visual Screening approach, the researchers will determine the seismic vulnerability of chosen buildings at the University of the Assumption. The following objectives are the focus of the study:

- To assess the effect of the building's age, number of occupants, construction materials used, and design layout on its seismic vulnerability level.
- To apply the effectiveness of FEMA P-154 method combined with the SCOSSO mobile application in identifying seismic vulnerabilities in university buildings.
- To utilize the results obtained from the Rapid Visual Screening assessment to develop a Preparedness Mapping Plan aimed at enhancing the university's earthquake risk management and disaster preparedness strategies.

B. *Statement of the Problem*

In this paper, the evaluation of the seismic vulnerability of chosen buildings at the University of the Assumption is intended by the researchers, with the Rapid Visual Screening approach as their tool. This work aims to answer the following questions:

- How does the building's age, number of occupants, construction materials used, and design layout affect its seismic vulnerability?
- How can the Rapid Visual Screening method based on FEMA P-154, combined with the SCOSSO mobile application, be utilized in identifying seismic vulnerabilities in university buildings?
- How can the results from the Rapid Visual Screening method be utilized in creating a Preparedness Mapping Plan that can be used for the University?

C. *Scope and Delimitations*

This research concentrates on analyzing the seismic vulnerability of selected buildings located within the University of the Assumption in the City of San Fernando, Pampanga. Rapid Visual Screening (RVS) method, based on the guidelines set by FEMA P-154, will be used. The SCOSSO Mobile Application will also be incorporated for the data gathering and interpretation. On this matter, structural and non-structural factors that can affect the stability and resilience of buildings were observed, such as building year built (age, occupancy level, building materials used, number of floors, and the overall building layout. This study is limited to assessing only accessible buildings inside the university.

This study will employ only Level 1 Rapid Visual Screening, which relies solely on visual inspection and excludes detailed structural analysis, material testing, or laboratory investigation. Geotechnical aspects of the site are not covered by this study. No detailed engineering design is involved.

It should be noted that the Preparedness Mapping Plan only addresses the issue of the mapping of the building vulnerability and cannot be considered a management plan covering all aspects of the university operations. Thus, the findings in this study can be used only for initial prioritization and should be validated through further analysis before implementation.

2. Methodology

A. Research Method

The researchers will utilize a quantitative method of collecting numerical data in assessing the seismic vulnerability of selected buildings at the University of the Assumption. The quantitative data are obtained from the numerical scoring of documents transmitted from the FEMA P-154 Rapid Visual Screening. Using this approach will focus on evaluating the performance of buildings on their capacity and vulnerability levels of each building based on standardized criteria.

Applying quantitative methods will ensure the validity of the outcome by analysis, systematic and rigorous processing that ensures accuracy of the data findings (Kotronoulas et al, 2023). This method ensures efficient collection of data and consistent interpretation of results for the assessment of the seismic performance of the selected buildings of the University of the Assumption.

B. Research Design

The study will apply a quantitative research design in evaluating the current seismic condition of the chosen buildings at the University of the Assumption in the City of San Fernando, Pampanga. According to Manjunatha (2019), the use of descriptive design will describe the aspects of the study by determining and identifying the phenomena and employing numerical variables for the current state of the problem. This research design will evaluate the seismic vulnerabilities of buildings by analyzing the structural features and visible defects without manipulating the data or experimental testing.

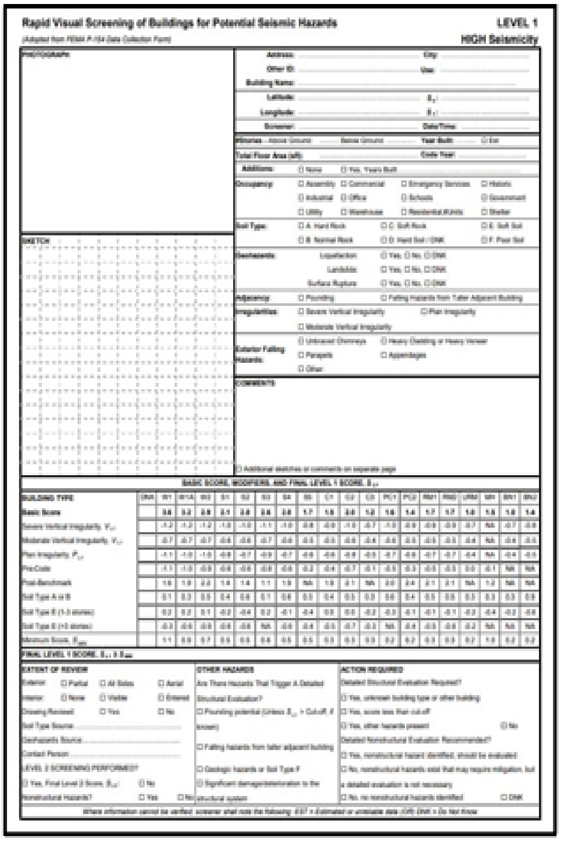
The adopted design will assist with categorizing the collected data from FEMA P-154 and the SCOSSO Mobile Application for a systematized display of results by providing graphical and tabular representations of the results of the selected buildings on their seismic preparedness and vulnerability level.

C. Research Instrument

This study will utilize FEMA P-154 Rapid Visual Screening (RVS) Form to evaluate selected buildings for potential seismic hazards. This evaluation will be based on building structure, construction materials, and observed irregularities present in the present condition of each structure. The SCOSSO mobile application will be a supplementary tool where data from RVS will be encoded, including automatic computation of seismic vulnerability scores and assessment of risk levels of each building. The assessment will result in data accuracy from their vulnerability against earthquakes. This will enable vulnerability estimation to help in making a school preparedness mapping in case of seismic activities.

1) FEMA P-154 Data Collection Form

The rapid visual screening (RVS) tool was utilized to methodically gather and assess building-specific structural characteristics, compromising age, occupancy, construction type, soil classification, and the occurrence of seismic irregularities, which are crucial for evaluating seismic vulnerability.



Rapid Visual Screening of Buildings for Potential Seismic Hazards

LEVEL 1

HIGH Seismicity

Fig.1. FEMA P-154 Data Collection Form - Level 1 High Seismicity

2) SCOSSO Mobile Application

This mobile-driven Rapid Visual Screening (RVS) tool was utilized to assess seismic vulnerabilities in university buildings. It allows the encoding of data in real-time, photographic documentation, geolocation tagging based on GPS, and automated calculation of a vulnerability index to help efficient and systematic assessment.

Fig.2. SCOSSO Mobile Application - Illustration

SAFER COMMUNITIES
THROUGH SAFER SCHOOLS
RAPID VISUAL SURVEY (v.3)

General Info.

Date: | Time: | Surveyor Name:
School Compound Name / Address:
Building ID: | Total No. of Students in Building:
GPS Coordinate → Lat.: Lon.:
Position → [ ] Corner [ ] Mid-block [ ] End-block [ ] Isolated [ ] Other:
Construction Year: [ ] Unknown | Confidence: [ ] H [ ] M [ ] L
Availability of Structural Drawing → [ ] NO [ ] YES **Sketch a Simple Building Plan on the back of this Sheet**
Any nearby Rivers → [ ] NO [ ] YES Distance:
Any nearby Coasts → [ ] NO [ ] YES Distance:
Any nearby Faults → [ ] NO [ ] YES Distance:

Building Info.

No. Storey : | Storey Height (m):
No. Bay X : | Total Length X (m):
No. Bay Y : | Total Length Y (m):
No. Rooms → Classroom: Library: Office: IT Hub: Hall: Services: Other:
Dimension of Average Classroom (m) → X: Y:
Dimensions of Largest Room (m) → X: Y: Info:
No. openings per storey: | Largest opening size (m):

Structural Info.

		Unk*	Confidence
Material of Load-Resisting System	[ ] Masonry [ ] Reinforced Concrete [ ] Steel [ ] Timber [ ] Other:	[ ]	H M L
Floor Material	[ ] RC Slab [ ] Timber Joists + Wooden Floor [ ] Reinforced Brick Concrete [ ] Other:	[ ]	H M L
Roof Structural System	[ ] RC Slab [ ] Timber Truss [ ] Steel Truss [ ] Reinforced Brick Concrete [ ] Other:	[ ]	H M L
Roof Covering	[ ] Tiles [ ] Metal Sheeting [ ] Other:	[ ]	H M L
Roof Pitch	[ ] Flat [ ] Mono Pitch [ ] Multi Pitch → No.:	[ ]	H M L
Roof Condition	[ ] Poor Deteriorated [ ] Good/Fair [ ] Excellent/Brand New	[ ]	H M L
Roof Connection	[ ] Poor Deteriorated [ ] Good/Fair [ ] Excellent/Brand New	[ ]	H M L
Lateral Load Resisting System	[ ] Frame [ ] Load Bearing Walls [ ] RC Shear Wall [ ] Bracing [ ] Confined Masonry [ ] Reinforced Masonry [ ] Combined [ ] Other:	[ ]	H M L
Structural Condition	[ ] Poor Deteriorated [ ] Good/Fair [ ] Excellent/Brand New	[ ]	H M L
Connection Quality	[ ] Poor Deteriorated [ ] Good/Fair [ ] Excellent/Brand New	[ ]	H M L
Retrofitting	[ ] No [ ] Yes → Info:	[ ]	H M L
Modifications	[ ] No [ ] Yes → Info: [ ] Addition of Stories: [ ] Extension of Plan:	[ ]	H M L
Foundation Type	[ ] RC [ ] Brick [ ] Stone [ ] Other	[ ]	H M L
Vulnerability Factors (Indicate Confidence)	[ ] Short column [ ] Pounding (if buildings closer than 0.2m) [ ] Soft storey [ ] Strong Beam-Weak Column [ ] Built on Slope [ ] Built on Stilts [ ] Balconies [ ] Plan irreg. [ ] Elevation irreg. [ ] Mass irreg. [ ] Opening irreg. [ ] Parapet [ ] Gable [ ] Other:		

If MASONRY:

Masonry Type	[ ] Masonry Brick [ ] Masonry Block [ ] Concrete Block [ ] Cut stone [ ] Adobe [ ] Rubble Stone [ ] Other	[ ]	H M L
Mortar Type	[ ] None [ ] Cement [ ] Lime [ ] Mud	[ ]	H M L
Reinforcement	[ ] No [ ] Yes	[ ]	H M L
Confinement	[ ] No [ ] Yes	[ ]	H M L
Wall Thickness (m)		[ ]	H M L
Wall Layer	[ ] Solid [ ] Multi Leaf [ ] Cavity Walls	[ ]	H M L

If FRAME [RC, Timber, Steel]:

Beam Dimensions (m)		[ ]	H M L
Column Dimensions (m)		[ ]	H M L
Infill Wall Material	[ ] Brick [ ] Concrete Block [ ] Timber Plates [ ] Adobe [ ] Other: Thickness (m):	[ ]	H M L

*Unknown: H = high, M = medium, L = low
Any extra comments can be added on the back of this sheet.

Fig.3. SCOSSO Form

3) *Quantum Geographic Information System (QGIS)*

This software was utilized in generating a seismic preparedness map by incorporating the results from the FEMA P-154 and the SCOSSO Mobile Application with spatial data like actual building locations and road networks, aimed at enhancing disaster response planning.

Fig.4. QGIS Software

4) *Locale of the Study*

This study will be conducted at the University of the Assumption, located in Unisite Subdivision, Del Pilar, City of San Fernando, Pampanga. The researchers will be conducting the seismic evaluation of the following selected buildings:

- Cruz Building
- Puno Building
- Ryan Building
- Galang Building
- Aniceto Building
- Benedictine Building
- Serrano Building

Fig.5. University of the Assumption Buildings Under Assessment

The researchers' selection of the buildings is based on a criterion of scoping educational facilities that are being occupied daily by the students, faculty, and staff. Buildings will be specified by their accommodation purposes and measurements for the researchers to investigate the structures' vulnerabilities and their visual screenings.

5) *Process Flow Chart*

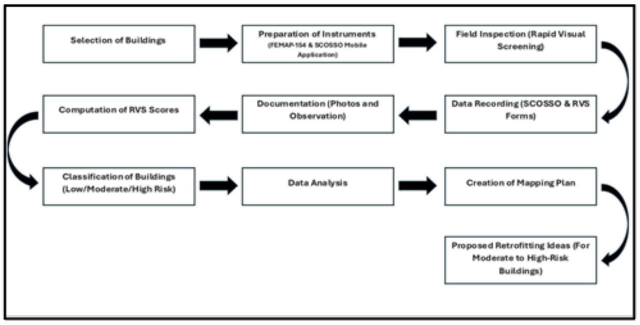


Fig.6. Process Flow Chart

D. *Data Gathering Procedure*

The following are the steps for the data collection process of each building:

1) *Pre-assessment Preparation*

Permission from the administration of the University of the Assumption was obtained before conducting the field inspection. The accessibility and connection of the buildings in relation to the study were determined. The required instruments for data collection, such as the FEMA P-154 Rapid Visual Screening (RVS) forms and the SCOSSO mobile application, were prepared. A registered civil engineer with knowledge regarding rapid visual screening was also consulted to guide the researchers during the assessment.

2) Field Inspection of buildings using FEMA P-154 forms and SCOSSO Mobile Application

The field inspection of each chosen building was conducted by utilizing the Rapid Visual Screening (RVS) method. During the field inspection, the building's structural and non-structural aspects, i.e., the design layout, number of stories, building condition, building materials, and the presence of any structural irregularities, were identified. No detailed structural analysis is required during the field inspection, which complies with the RVS methodology.

3) Data Recording and Encoding

All the gathered data were recorded by utilizing the FEMA P-154 Rapid Visual Screening (RVS) forms and simultaneously entering the data into the SCOSSO mobile application during the inspection process. The use of such a method helped in ensuring the accuracy of the data and also made it easier to organize and process the data.

4) Documentation and Additional Notes

Photographic documentation of each building was also conducted to support visual assessment and reference later on during data analysis. To capture other relevant information that is not included on the screening form, additional field notes were recorded. This ensures the completeness of information to be able to support the precise and accurate interpretation of the collected data.

5) Data Verification

All the data collected from every entry from multiple devices and forms was reviewed and cross-checked to make sure the accuracy, consistency, and completeness of the data. The field notes and photographic records were used to cross-check the discrepancies and missing information to guarantee the completeness, accuracy, and precision of the data.

6) Data Interpretation

The data collected using the Rapid Visual Screening (RVS) method was analyzed and interpreted using the standard scoring system as per the FEMA P-154 guidelines, and the computed results were obtained using the SCOSSO mobile application. The interpretation of the results is based on the seismic performance scores and vulnerability indices obtained for the buildings.

The RVS scores obtained for a particular structure represent the anticipated efficiency of the building in a seismic event. Higher RVS scores represent better building performance and lower seismic vulnerabilities, while lower RVS scores represent higher seismic vulnerability. The RVS scores are utilized to classify the buildings in terms of their respective seismic risk levels, and are used to assess the selected buildings' safety and condition. The interpretation of RVS scores in this study is adapted from the framework of FEMA P-154, which primarily uses a screening threshold of approximately 2.0 to identify buildings that need and require further evaluation. Additional categories were introduced by the researchers to facilitate comparative analysis and prioritization, and do not represent official FEMA classifications.

Table 1
RVS Scores Interpretation for FEMA P-154 Forms

RVS SCORE (S)	**Seismic Risk Level**	**Color**
$S > 2.0$	Low	Green
$1.0 \leq S \leq 2.0$	Moderate	Yellow
$S < 1.0$	High	Red

In addition, the SCOSSO mobile application provided a Vulnerability Index (VI) expressed in percentage values. This index is utilized to further categorize and interpret the building into the three risk levels, which are low, moderate, and high vulnerability. Buildings with higher vulnerability indicate those that were identified as more open to damage during an earthquake event and were prioritized for further evaluation and intervention.

Table 2
Vulnerability Index Interpretation for SCOSSO Mobile Application

Risk Categories	**Vulnerability Index (VI)**	**Description**
Red	$50\% \leq VI$	High-Risk Category
Yellow	$30\% \leq VI < 50\%$	Moderate-Risk Category
Green	$VI < 30\%$	Low-Risk Category

Based on the above analysis of RVS scores and Vulnerability Index, buildings have been classified into three different categories:

- **Low Risk (Green) -** Buildings that have shown satisfactory RVS scores and have low vulnerability indices, implying that these buildings are at little risk of damage.
- **Needs Further Evaluation (Yellow)** - Buildings that have shown moderate scores on the RVS scale or have shown varying results in the two tests, requiring closer monitoring or additional assessment.
- **High Risk (Red)** - High risk of damage during seismic events and requires the highest priority of monitoring for buildings that obtained low RVS scores and high vulnerability indices.

The classification provided in this study was used in determining the level of priority of the buildings and served as a guide in the creation of the Preparedness Mapping Plan.

It is emphasized that the Rapid Visual Screening (RVS) method is only a preliminary assessment aimed to identify potentially vulnerable buildings that may need prioritization for further assessment and retrofitting. The results are used as a guide for allocating resources and decision-making of the assessed buildings. Moreover, the obtained results shall not be interpreted as a definitive final measure and status of the safety of the building.

3. Results and Discussion

This chapter presents the seismic vulnerability findings for the selected buildings at the University of the Assumption conducted using the Rapid Visual Screening (RVS) method and the SCOSSO mobile application. The condition of the buildings and their level of seismic vulnerability risk were determined by gathering data thoroughly, analyzed, and interpreted rigorously. To ensure accuracy and compliance, the completion of forms and final scoring was guided and reviewed by Engr. Ian Kenneth Yalung, a registered Civil Engineer in the Philippines.

This section discusses the assessment findings calculated from the utilized Rapid Visual Screening (RVS) for final scoring, Seismic Vulnerability Index, and the risk level classification of each building. For clear visualization, the results of the level of vulnerability of buildings are presented in tabular, graphical, and preparedness maps. Therefore, these assessments serve as a foundation to identify what building necessitates priority development and address an appropriate area as a safe spot during seismic activities.

A. Seismic Vulnerability Assessment of Selected Buildings

1) Number of Storeys

The height of a building plays an important role for a building's seismic vulnerability. According to Kumar el al. (2024), the height of a building alters a structures behavior since it induces swaying, especially high-rise buildings which are more prone to seismic damage. Vulnerability assessment is required for these buildings since their height, mass, strength, and ductility modifies a buildings fragility curve.

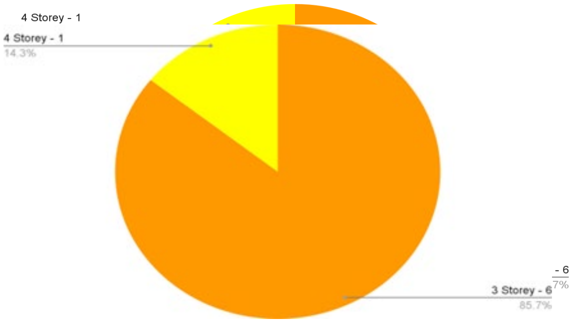


Fig.7. Number of Storeys of Selected Buildings

Based on Figure 7, out of seven assessed buildings, most of the buildings are three-storey structures. It was observed that 85.7% of six out of seven selected buildings, Aniceto, Benedictine, Cruz, Galang, Puno, and Ryan Building, consist of three levels. The remaining structure is 14.3%, the Serrano Building, which is the sole building with four levels.

2) Occupancy

As emphasized from various studies, the exposure of building occupants strongly influences the seismic risk of a building, as higher population densities significantly increase potential casualties and losses during earthquake events (Fernandez-Romero & Aparicio Roque, 2025; Fischer et al., 2022).

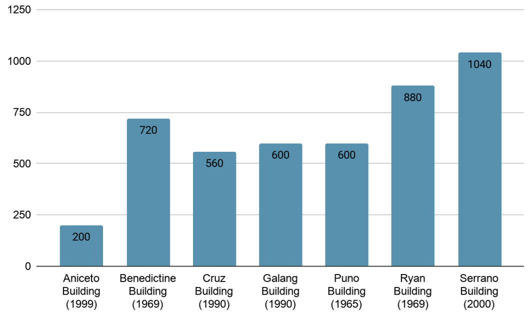


Fig.8. Occupancy of Selected Buildings

Based on Figure 4.2, the Serrano Building, with an occupancy of 1,040 people, has the highest occupancy, and the graph suggests that this building has the highest exposure in the event of seismic activity. The Ryan Building, with an occupancy of 880, and the Benedictine Building, with an occupancy of 720, the graph suggests that these buildings are required to prioritize seismic risk mitigation measures due to the large number of occupants.

On the other hand, Puno Building and Galang Building, both with an occupancy of 600, and Cruz Building, with an occupancy of 560, all fall within the mid-range of the occupancy category. And the Aniceto Building, with an occupancy of 200, has the lowest risk and exposure during instances of seismic activity.

3) Year Built

The year of construction is an important factor in determining seismic vulnerability since old buildings are more likely to be damaged because of material deterioration and failure to meet current earthquake design regulations compared to newly constructed buildings that perform better due to improvements in engineering standards (Rosti et al., 2020; Silva et al., 2020).

Table 3
Year Built of Selected Buildings

Building	**Year Built**
Aniceto Building	1999
Benedictine Building	1969
Cruz Building	1990
Galang Building	1990
Puno Building	1965
Ryan Building	1969
Serrano Building	2000

Table 3 outlines the construction year of the seven assessed buildings. The data reveals that five out of seven buildings, Benedictine, Cruz, Galang, Puno, and Ryan buildings, were constructed between the years of 1965 and 1990. These buildings were designed before the updated building code of 1992, which indicates higher seismic vulnerability from using outdated building standards and design. The two buildings, Aniceto and Serrano, were built in the year of 1999 and 2000, respectively, using the updated building design and standards of the post-benchmark year of 1992. This indicates a lower seismic vulnerability compared to buildings that used a code predating the 1992 building code, showing better seismic performance and RVS scores.

B. Construction Materials Used

Seismic performance of buildings alter from the selection of construction materials, as ductile materials such as reinforced concrete have better energy dissipation. In contrast, buildings that used brittle materials are more likely to fracture and suddenly collapse, increasing the structural seismic hazards (Rosti et al., 2020; Silva et al., 2019).

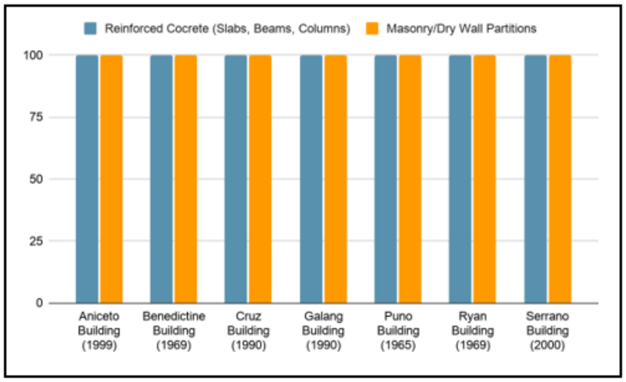


Fig.9. Construction Material Used on the Selected Buildings

Based on Figure 9, buildings that were assessed exhibit identical material used for their construction. The structural framework used reinforced concrete and steel for slabs, beams, and columns for strong resistance against tension and compression within a moment-resisting frame. Furthermore, the building walls consist of masonry and drywall partitions for the interior partitions and enclosures of the buildings.

C. Structural Frame and Building Shape

The structural frame and building shape play a crucial role in building structures. According to Farhan and Bommisetty (2019), buildings of regular shapes and clear frames exhibit stability in response to seismic forces, but buildings of irregular shapes and frames exhibit a high level of vulnerability.

Table 4
Structural Frame and Design Layout of the Selected Buildings

Building	**Structural Frame**	**Design Layout**
Aniceto Building	Reinforced Concrete Frame	Rectangular
Benedictine Building	Reinforced Concrete Frame	Rectangular
Cruz Building	Reinforced Concrete Frame	Rectangular
Galang Building	Reinforced Concrete Frame	Rectangular
Puno Building	Reinforced Concrete Frame	L - Shape
Ryan Building	Reinforced Concrete Frame	L - Shape

Serrano Building	Reinforced Concrete Frame	Rectangular

Based on Table 4, the structural frame composition of all buildings utilized a reinforced concrete frame for the resistance system and support of buildings. In design layout, five out of seven buildings, Aniceto, Benedictine, Cruz, Galang, and Serrano, characterized a rectangular layout for the structure. This exhibits a more stable distribution of seismic forces, reducing the risk during seismic activities. While two buildings, Puno and Ryan, feature an L-shape layout that introduces plan irregularity into the structures. Ghosh and Debbarma (2017) stated that L-shaped buildings are more vulnerable to seismic activities, causing structural instability and resulting in building damage.

Table 5

Structural Frame and Design Layout of the Selected Buildings

Building	**Factor**	**Observation n**	**Effect on Vulnerability ty**
Aniceto Building	Building Condition	No Observable Structural Damage / Deterioration n	Lower Vulnerability y
Benedictine Building	Age; Building Condition	Old Building; Some Deterioration n Observed	Higher Vulnerability
Cruz Building	Design Layout	Uniform Height of Storey	Lower Vulnerability
Galang Building	Building Condition	No Observable Structural Damage / Deterioration	Lower Vulnerability
Puno Building	Age; Design Layout	Old Building; L-shape Layout	Higher Vulnerability
Ryan Building	Age; Design Layout	Old Building; L-shape Layout	Higher Vulnerability
Serrano Building	Age ; Height	4-storey, Relatively New	Lower Vulnerability

As an example, no evidence of structural damage is presented in the Aniceto and Galang building, indicating that the building is completely operational and is suitable for resisting loads. This results in minimal structural failure since its components have maintained structural integrity. This supports the established theory that well-structured buildings demonstrate better performance against seismic events, as their members effectively distribute loads without failure for overall integrity.

As an example, no evidence of structural damage is presented in the Aniceto and Galang building, indicating that the building is completely operational and is suitable for resisting loads. This results in minimal structural failure since its components have maintained structural integrity. This supports the established theory that well-structured buildings demonstrate better performance against seismic events, as their members effectively distribute loads without failure for overall integrity.

Furthermore, the Cruz building exhibits a regular design layout, characterized by distribution of equal height of each storey and symmetry. In the field of structural engineering, regular layout helps in reducing the impact of torsion generated by ground movement, ensuring that seismic loads are distributed evenly throughout the structure (Zhang & Li, 2024). On the other hand, the Benedictine, Puno, and Ryan Buildings possess characteristics that increase their vulnerability to earthquakes. A primary factor is the age of the buildings, older buildings were constructed from outdated building codes that were considered a predated standard that may not have considered the modern requirement for earthquake loadings. Furthermore, buildings deteriorate due to their age that can be noticed from concrete spalling and steel corrosion. These factors affect a building by exposing it to damage and reducing its strength Puno and Ryan Buildings, having an L-shaped design layout, pose problems due to their irregular layout. Irregular shape layout produces torsional effect during seismic events that causes the building to move in differential movement. This movement increases the stress levels within the structure and creates weak points that contribute to isolated or progressive failure (Silva et al., 2019). These observations align with the existing seismic design theory that emphasize the design layouts importance in determining a building's structural vulnerability.

On the other hand, the Serrano Building, the structure in the study that is the highest building, demonstrates less vulnerability to seismic forces. Since the building is newly constructed, the building was designed according to the new building code that incorporated seismic requirements. Thus, modern engineering approaches contribute to effectively reducing the risks posed by a structure's height.

Overall, it can be concluded that seismic vulnerability revolves around a combination of several factors, like the structural design layout, the age of the building, and its maintenance status. Buildings with standard configuration, designed and built in compliance with new building codes, and well-maintained, will be less susceptible to seismic forces. In contrast, structures characterized by nonstandard configuration, old age, and poor condition are more prone to seismic hazards.

D. Utilization of Rapid Visual Screening Using FEMA P-154 Forms and SCOSSO Mobile Application

The utilization of the RVS procedure by using the FEMA P-154 forms and the mobile application of SCOSSO are discussed in terms of the identification of the chosen buildings' seismic susceptibility. The outputs from the two procedures are compared based on how accurate, reliable, and applicable they are in finding out which buildings are susceptible to earthquake risks. Moreover, this part shows how the use of mobile technology helps increase the efficiency of seismic assessment.

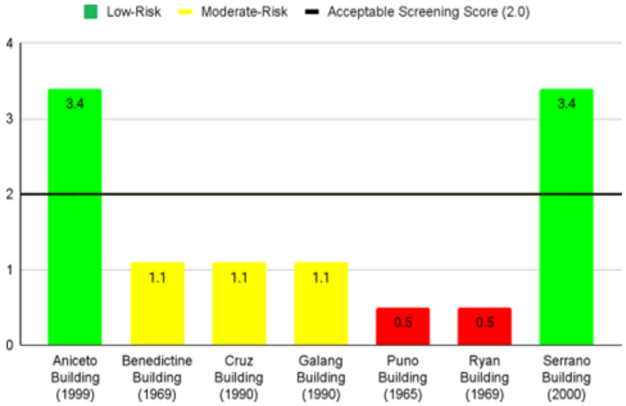


Fig.10. Interpretation of Seismic Vulnerability Based on FEMA P-154 Final Scores

Based on Figure 10, the "Final Score (SL1)" represents the probability related to a building's performance during a seismic event. If a subject building has a high score, it denotes reduced risk of building failure. Conversely, a lower score indicates a greater risk of failure during seismic events. The interpretation of RVS scores in this study is **based on the FEMA P-154 framework**, utilizing a 2.0 final score for the screening to identify buildings that need further evaluation.

Regarding the specific risk levels of each building, the Aniceto and Serrano buildings are classified in the low-risk category, earning the highest scores of 3.4. These buildings are considered to be less vulnerable and most resilient during seismic activities. While the Benedictine, Cruz, and Galang buildings are classified as moderate risk, with scores of 1.1. This interprets that these buildings are not the most vulnerable, but still possess structural deficiencies that could compromise their performance during an earthquake.

Finally, the Puno and Ryan buildings are classified in category as high-risk, their score of 0.5 reflects a low seismic resilience. These buildings are considered as highly vulnerable and are likely to experience serious damage from seismic events.

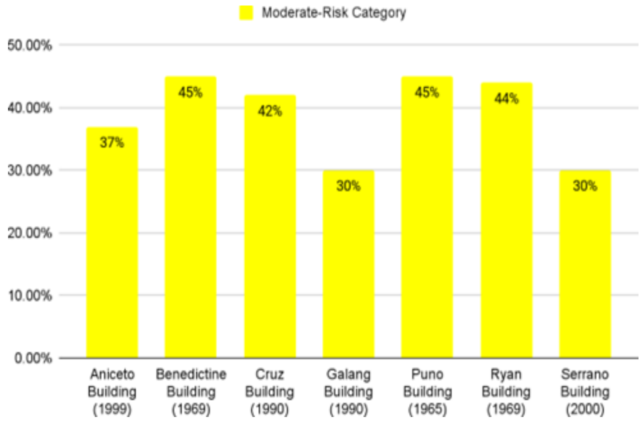


Fig.11. Interpretation of Seismic Vulnerability Based on the SCOSSO Mobile Application

Based on Figure 11, the buildings were evaluated for their seismic vulnerability using the SCOSSO mobile application. The resulting data are classified according to the Vulnerability Index (Table 2), illustrating the degrees of structural risk related to seismic activity.

The Aniceto, Benedictine, Cruz, Galang, Puno, Ryan, and Serrano Buildings have a percentage of $30\% \leq VI < 50\%$ for its vulnerability to earthquakes, which falls under the category of moderate-risk (Yellow Risk Category). Based on their vulnerability index (VI), these buildings require proactive monitoring and possible retrofitting to mitigate or prevent damage during a seismic event.

The effectiveness of the SCOSSO mobile application in this study is observed based on its operational efficiency, data accuracy, and consistency. In contrast to traditional paper-based FEMA P-154 forms, SCOSSO enables real-time data input, automated calculation of vulnerability indices, and minimizes the potential of human error from manual calculations.

However, it is important to emphasize that the study used SCOSSO for its collection of data and served as a processing tool rather than a substitute to detailed structural analysis. The integration of SCOSSO with FEMA P-154 optimizes efficiency and reliability of rapid visual screening, particularly on large-scale evaluations such as university campuses.

E. Utilization of Results for Mapping Plan

The data gathered from FEMA P-154 Rapid Visual Screening and the SCOSSO application were compiled to provide an analytical presentation for the chosen buildings' seismic vulnerability. Outcomes of the classification of buildings are discussed in this section, in which they will be applied for the development of the Preparedness Mapping Plan.

Table 6
Classification of Selected Buildings Based on the Results RVS

Building	**Description**		**Classification**
	FEMA P-154 Forms	**SCOSSO Mobile App**	
Aniceto Building	Low Risk	Moderate Risk	Needs Further Evaluation (Yellow)
Benedictine Building	Moderate Risk	Moderate Risk	Needs Further Evaluation (Yellow)
Cruz Building	Moderate Risk	Moderate Risk	Needs Further Evaluation (Yellow)
Galang Building	Moderate Risk	Moderate Risk	Needs Further Evaluation (Yellow)
Puno Building	High Risk	Moderate Risk	Needs Further Evaluation (Yellow)
Ryan Building	High Risk	Moderate Risk	Needs Further Evaluation (Yellow)
Serrano Building	Low Risk	Moderate Risk	Needs Further Evaluation (Yellow)

Table 6 presents the buildings' classification according to their results from the FEMA P-154 RVS and the SCOSSO mobile application. This comparison highlights the advantage of using both methods in assessing the vulnerability of buildings in seismic events.

Despite the differences in individual scores of the buildings, all structures were classified as **"Needs Further Evaluation (Yellow Category"**. The FEMA P-154 identified the Aniceto and Serrano building as low risk, Benedictine, Cruz, and Galang building as moderate risk, and Puno and Ryan building as high risk. On the other hand, SCOSSO identified all buildings as moderate risk.

This suggests that buildings that were categorized as low risk harbor a certain level of vulnerability when assessed through a more detailed digital assessment. The uniform classification of yellow emphasizes that none of the buildings can be considered completely as safe and all buildings require further evaluation and proactive monitoring.

The findings suggest that seismic safety must look beyond basic compliance and also consider relative vulnerabilities among structures. While all buildings have an overall classification, Puno and Ryan buildings, which exhibit lowest scores and have a structural irregularity in design layout should be prioritized for immediate response.

F. Preparedness Mapping Plan

The development of the preparedness mapping plan was made possible by using QGIS software in presenting the evaluated buildings' level of seismic vulnerability. This platform integrates information about the buildings at the University of the Assumption with their geographical location determined through RVS.

The preparedness mapping plan was established to serve as a strategic decision support tool in determining which buildings require most attention during an earthquake and provide assistance in making decisions for streamlining evacuation routes. With spatial data included in the mapping, the university can be more effective in dealing with earthquake hazards. Besides, it also functions as a risk-reduction technique that is easy to use in determining the vulnerability level.

In Figure 12, the map produced through the use of QGIS software in the Preparedness Mapping Plan illustrates clearly the distribution pattern of seismic vulnerability on the university campus. The buildings under the category "Needs Further Evaluation" are specifically marked to point out the areas of concern.

As can be seen from the mapping process, while all the buildings are of the same category, their varying structural features and different RVS scores suggest that there are priority areas among them.

Figure 12: Preparedness Mapping Plan of the University of the Assumption

The Puno and Ryan buildings have structural irregularity and low RVS scores, and hence, they are crucial areas in the map. This is because such buildings suffer from high stress due to the torsion effect caused by their L-shaped structure.

On the other hand, buildings like Aniceto and Serrano, which rank high on the RVS rating system and are also well configured, are found in areas with low-risk intensity. Nevertheless, the ranking of these buildings in the moderate vulnerability class makes it important that they be kept under observation and preparedness measures.

The functional utility of the Preparedness Mapping Plan is enhanced by incorporating evacuation routes, free space, and walkable paths into the QGIS map. This allows easy evaluation of people from each building that presents high seismic risk to areas that are considered as low risk zones.

Overall, the preparedness mapping plan demonstrates that incorporating structural assessment data with spatial analysis provides a more robust approach to earthquake preparedness, enabling the university to be informed and make improved strategies in campus safety.

Table 7
Prioritization of the Buildings Based on RVS, VI, and Occupancy

Building	**RVS Score**	**Vulnerability Index (VI)**	**Occupancy**	**Prioritization**
Puno Building	0.5	45%	600	High Priority
Ryan Building	0.5	44%	880	High Priority
Benedictine Building	1.1	45%	720	Moderate Priority
Cruz Building	1.1	42%	560	Moderate Priority
Galang Building	1.1	30%	600	Moderate Priority
Aniceto Building	3.4	37%	200	Lower Priority
Serrano Building	3.4	30%	1040	Lower Priority

Figure 13: Visual Representation of Table 7

Table 7 and Figure 13 illustrates the prioritization level for the selected buildings based on their analysis of RVS scores, Vulnerability Index, and occupancy levels. This prioritization provides university stakeholders to identify buildings that should be prioritized for further evaluation and have potential retrofitting.

Buildings that scored lower in RVS, have structural irregularities, and have higher occupancy are labeled as high-priority since they have a higher risk during seismic events. On the other hand, buildings that scored higher on RVS and have a regular design layout are considered as lower priority. However, these buildings still require consistent monitoring and preparedness. This prioritization ensures the effective allocation of resources of the university for buildings that poses great risk to campus safety.

4. Summary, Conclusions, and Recommendations

A. Summary

Throughout the study, the researchers assessed the Puno, Ryan, Benedictine, Cruz, Galang, Aniceto, and Seranno Buildings, at the University of the Assumption. This evaluation used a combined assessment method of Rapid Visual Screening (RVS) based on FEMA P-154 and the SCOSSO mobile application. The evaluation aimed to identify the risk levels and preparedness of buildings by determining their seismic vulnerability on seismic activities. In assessing each building, the structures are examined by taking measurements and observing visible structural components such as columns, beams, structural irregularities, and potential hazardous cracks that could indicate vulnerability to the buildings. These inspections enabled the researchers to gather data on the structural state of the buildings, which were encoded on the FEMA P-154 Forms and SCOSSO application. Figure 7 shows that most structures are three-storey reinforced concrete buildings, while the Serrano building alone is four-storey. These characteristics impact the buildings' seismic behavior because higher buildings sway more. Furthermore, the data gathered in Figure 8 for the occupancy of buildings indicates that the Serrano, Ryan, and Benedictine buildings accommodate the largest number of students, with 1040, 880, and 720 students, respectively. While the Puno, Galang, and Cruz buildings range from 560-600 building users, the lowest accommodating building is Aniceto, with 200 students. This emphasizes that a larger number of people exposed to seismic risks requires buildings to enhance their seismic risk preparedness and mitigation measures to avoid casualties.

Table 3 illustrates those five structures, Benedictine, Cruz, Galang, Puno, and Ryan, were built between 1965 and 1990, which were built on an outdated building code for design and standards, making them more vulnerable. While Aniceto and Serrano were constructed in 1999 and 2000, respectively, using post-benchmark 1992 standards, resulting in lower seismic vulnerability. Figure 9 outlines the construction material used on buildings, showing that all assessed buildings utilized a structural framework of reinforced concrete and steel for slabs, beams, and columns. The walls are composed of masonry and dry-wall partitions for their enclosure. In Table 4, all assessed buildings consist of reinforced concrete frames as the primary resisting system of the building. While the structural features, Aniceto, Benedictine, Cruz, Galang, and Serrano used a rectangular layout that facilitates a more stable distribution of seismic forces, and an L-shaped layout for the Puno and Ryan building that configures an irregular shape, which is more vulnerable to seismic activity because of being more prone to torsion and instability.

Table 5 demonstrates the influence of observed structural characteristics, which are determined by the combined effects of design layout, age, and physical condition. Structures that are well-maintained and have regular design layouts, such as Aniceto and Benedictine buildings demonstrated lower vulnerability because of their compliance to the modern seismic building code and structural integrity. While older structures, Benedictine, Puno, and Ryan, are more exposed to damage due to their deterioration and design layout irregularity of L-shaped that is prone to torsion during ground movement.

The results in Figure 10 show the interpretation of seismic vulnerability on the basis of FEMA P-154, which utilized the Final Score (SL1) to determine their seismic performance, revealing that all seven buildings exceeded the minimum safety score of 0.3. The Aniceto and Serrano buildings achieved the highest scores of 3.4, classifying them as low-risk structures and low vulnerability to seismic events. In contrast, Benedictine, Cruz, and Galang buildings were categorized as moderate risk, with scores of 1.1. Puno and Ryan buildings are the most vulnerable, with a score of 0.5, indicating a higher risk and damage in seismic events.

Figure 11 shows the interpretation of seismic vulnerability based on the SCOSSO mobile application, where all buildings fall under the moderate-risk category with vulnerability percentages between 30%-50%. From their vulnerability to the yellow risk category, the buildings require proactive monitoring and potential retrofitting to ensure safety and less damage. Table 6 presents the classification of chosen buildings, where all are classified in the "Needs Further Evaluation (Yellow Category)". The findings highlight that structures that are high-risk or low-risk require consistent monitoring due to their RVS scores. Puno and Ryan buildings that have irregular design layouts are in high priority due to their RVS scores. Table 7 details the prioritization of selected buildings based on RVS scores, vulnerability index, and number of occupancy to ensure a strategic decision making as the university authorities allocate resources for evaluation and possible retrofitting of high risk level buildings. The Benedictine, Cruz, and Galang buildings are classified as moderate priority, and Puno and Ryan buildings are classified as high priority based on the assessment scores. Figure 13 shows the preparedness mapping plan of the University of the Assumption, which utilized QGIS software to map the distribution of seismic vulnerability of the selected buildings. Buildings are marked as "Needs Further Evaluation," but their difference in RVS scores shows priority buildings among them. Puno and Ryan buildings are high-priority areas due to their L-shaped irregularities and low RVS scores. Aniceto and Serrano buildings are positioned in lower-risk zones from their RVS scores, yet they remain under observation for continued preparedness. The mapping plan provides a functional guide for safely moving occupants from high-risk structures to secure locations.

B. Conclusions

By utilizing the Rapid Visual Screening approach, this study concentrated on determining the chosen buildings' seismic vulnerability at the University of the Assumption.

For the first objective, the researchers determined that structural vulnerability is significantly influenced by the building's age, construction materials, design layout, and physical condition. The FEMA P-154 assessment determined that buildings built before the 1992 post-benchmark of building code, namely, Benedictine, Cruz, Galang, Puno, and Ryan, exhibit higher vulnerability from the unupdated standards and design used. While Aniceto and Serrano show a lower vulnerability since the design and building code used is from the post-benchmark year of 1992. It is also concluded that the Puno and Ryan buildings, being L-shaped in design layout, which introduces plan irregularities that are hazardous in torsion, have higher vulnerability compared to other buildings that have a rectangular design layout, which is more stable and seismic resilient.

For the second objective, the researchers concluded that there is a significant advantage in combining the FEMA P-154 method with the SCOSSO mobile application. In using the FEMA P-154 for rapid visual screening, the buildings chosen in this study showed varying levels of seismic risk. The SCOSSO application provided a detailed evaluation, classifying all buildings under the moderate risk or yellow category, which implies "Needs Further Evaluation". This integration demonstrates that by combining both methodologies, a more detailed assessment and safer approach is provided for each building's risk level. Researchers are using the FEMA P-154 approach as their basis screening, and the digital SCOSSO mobile application as an auxiliary, a clearer classification of seismic vulnerability.

For the third objective, the assessment data is used by the researchers to create a Preparedness Mapping Plan by utilizing the QGIS software. The study concludes that the vulnerability planning efficiently and adequately demonstrates the allocation of the buildings' risk levels, identifying the Puno building and Ryan building as high-priority zones for seismic activities and retrofitting. A functional preparedness mapping plan shall be issued by the study, assuring the efficient and effective observation and preparedness readiness for campus safety.

C. Recommendations

In regard to the performance of selected structures at the University of the Assumption when assessing their vulnerability to seismic events using the FEMA P-154 RVS approach and SCOSSO mobile application, the researchers recommend the following to strengthen the structural safety and the institutional preparedness for earthquakes.

First, future researchers should consider advancing the study to a more detailed assessment through Level 2 screening, use of detailed structural software, or analytical evaluation. This would enable a more comprehensive investigation on the responses on seismic forces of a building, considering the factors of detailed material used, loads imposed, and potential failure mechanisms. A significant advantage from this approach is the ability to move the study by developing effective retrofitting strategies designed for the needs of each building being studied.

Second, the university administrators and other stakeholders can use the findings of this study as their valuable basis in improving their preparedness mapping plan and making decisions on highlighting priority buildings for retrofitting. From the findings, they can better identify the buildings that need immediate priority and improve their decisions on lessening the risk of structural damage during seismic activities to ensure the safety of the university.

Third, to assure the buildings' sturdiness and stability and to avoid potential decaying that would pose risks during an earthquake event, the researchers recommend frequent inspections and maintenance of the buildings. Frequent inspections can help locate problems such as wear and tear, cracks, and other deficiencies in the building before the situation gets worse. Appropriate maintenance would positively affect the efficient operations of the buildings.

Fourth, further and additional research study could expand the extent of the study by adding new buildings or various varieties of buildings to produce a more accurate and precise picture of the seismic hazards of the region. This would also support a more reasoned and logical decision-making in campus-wide or community-level disaster risk reduction planning.

Lastly, future studies are encouraged to further explore the integration of digital assessment tools, such as mobile-based applications, in seismic evaluation. Digital technology has great potential for improving the accuracy and efficiency of structural assessment when developed further. Comparison of digital and manual techniques of assessing seismicity can lead to useful information regarding their effectiveness and feasibility.

References

[1] Acosta, M., Passelègue, F. X., Schubnel, A., & Violay, M. (2018). Dynamic weakening during earthquakes controlled by fluid thermodynamics. Nature Communications, 9, Article 3074. https://www.nature.com/articles/s41467-018-05603-9

[2] Peñarubia, H. C., Johnson, K. L., Styron, R. H., Bacolcol, T. C., Sevilla,

[3] W. I. G., Perez, J. S., Bonita, J. D., Narag, I. C., Solidum, R. U., Pagani, M., & Allen, T. I. (2020). Probabilistic seismic hazard analysis model for the Philippines. Earthquake Spectra, 36(1_suppl), 58–84. https://journals.sagepub.com/doi/10.1177/8755293019900521

[4] Calvi, G. M., Pinho, R., Magenes, G., Bommer, J. J., Restrepo-Vélez, L. F., & Crowley, H. (2015). Development of seismic vulnerability assessment methodologies over the past 30 years. ISET Journal of Earthquake Technology,52(3–4), 129–160.

[5] Silva, V., Amo-Oduro, D., Calderon, A., Dabbeek, J., Despotaki, V., Martins, L., Crowley, H. (2019). Development of a global seismic risk model.Earthquake Spectra, 35(4), 1717–1741.

[6] Jeswani, K., Guo, J., & Christopoulos, C. (2022). Seismic risk assessment and mitigation analysis of large public school building portfolios in Metro Manila. Earthquake Spectra, 38(3).

[7] Federal Emergency Management Agency. (2015). Rapid visual screening of buildings for potential seismic hazards: A handbook (3rd ed., FEMAP-154).

[8] Rosti, A., Del Gaudio, C., Ricci, P., & Verderame, G. M. (2020). Empirical fragility curves for reinforced concrete buildings. Bulletin of Earthquake Engineering, 18,1–25. https://link.springer.com/article/10.1007/s10518-020-00971-4

[9] Harirchian, E., Lahmer, T., & Rasulzade, S. (2020). Improved rapid visual screening methods for seismic vulnerability assessment. Applied Sciences, 10(3), 890. https://www.mdpi.com/2076-3417/10/7/2375

[10] Ningthoujam, M. C., et al. (2018). Rapid visual screening procedure of existing buildings based on statistical analysis. International Journal of Disaster Risk Reduction, 28,720–730. https://doi.org/10.1016/j.ijdrr.2018.01.033

[11] Perrone, D., Aiello, M. A., & Pecce, M. (2015). Seismic assessment of hospital buildings using rapid visual screening. Earthquakes and Structures, 9(1), 1–20.

[12] Haryanto, Y., Sulistyorini, D., & Nugroho, A. (2020). Seismic vulnerability assessment of educational buildings using rapid visual screening. IOP Conference Series: Materials Science and Engineering, 930, 012–018.

[13] Kassem, M., Succar, B., & Dawood, N. (2021). Digital transformation in construction: The role of BIM and mobile technologies. Automation in Construction, 122, 103–115.

[14] Rodrigues, H., Furtado, A., Arêde, A., & Costa, A. (2022). Mobile-based tools for seismic vulnerability assessment of buildings. Engineering Structures, 252, 113–125. https://www.mdpi.com/2075-5309/15/14/2541

[15] Wahyuni, E., et al. (2018). Smartphone-based rapid visual screening for building assessment. Procedia Engineering, 212, 108–115. https://ijaseit.insightsociety.org/index.php/ijaseit/article/view/4336

[16] Cutter, S. L., Burton, C. G., & Emrich, C. T. (2015). Disaster resilience indicators for benchmarking baseline conditions. Journal of Homeland Security and Emergency Management, 12(2), 1–22.

[17] Martins, L., Silva, V., & Crowley, H. (2020). Development of seismic risk maps for urban planning. Natural Hazards, 104, 1–20.

[18] Lagmay, A. M. F., et al. (2018). Hazard assessment and mapping in the Philippines. Philippine Journal of Science, 147(3), 329–343. https://doi.org/10.5194/nhess-16-875-2016

[19] Clemente, S. J. C., & Concha, N. C. (2020). Assessment of seismic vulnerability of public schools in Metro Manila within 5 km from the West Valley Fault Line using rapid visual survey (RVS). https://ieeexplore.ieee.org/document/9400131

[20] Clemente, S. J. C., Arreza, J. S. B., Cortez, M. A. M., Imperial, J. R. C., & Malabanan, M. J. F. (2020). Risk assessment of seismic vulnerability of all hospitals in Manila using rapid visual screening (RVS). IOP Conference Series: Earth and Environmental Science, 479, 012002. https://iopscience.iop.org/article/10.1088/1755-1315/479/1/012002

[21] Lacorte, G.B. et al. (2025). Seismic resilience of public elementary school buildings in Bacolor, Pampanga using FEMA P-154 and SCOSSO mobile application [PDF]. International Journal of Scientific Research and Engineering Development, 8(3). https://www.ijsred.com/volume8/issue3/IJSRED-V8I3P488.pdf

[22] Philippine Institute of Volcanology and Seismology. (2025). Seismic activity report for the Philippines. https://www.phivolcs.dost.gov.ph/

[23] De Lautour, O., & Omenzetter, P. (2016). Seismic risk prioritization frameworks for infrastructure systems. Structure and Infrastructure Engineering, 12(9), 1131–1143.

[24] United States Geological Survey. (2025). Earthquake hazards program. https://www.usgs.gov/programs/earthquake-hazards Manjunatha, (2019). Descriptive research.

[25] Kotronoulas, G., et al. (2023). An overview of the fundamentals of data management, analysis, and interpretation in quantitative research. https://www.sciencedirect.com/science/article/pii/S0749208123000293

[26] Haselton, C., et al. (2016). Validation of rapid visual screening procedures using earthquake damage data. Earthquake Spectra, 32(3), 1545–1567.

[27] De Los Santos, M. J. D., & Principe, J. A. (2021). GIS-based rapid earthquake exposure and vulnerability mapping using LiDAR DEM and machine learning algorithms: Case of Porac, Pampanga. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences,XLVI-4/W6, 125–132. https://doi.org/10.5194/isprs-archives-XLVI-4-W6-2021-125-2021

[28] Al-Shamsi, G., AlHamaydeh, M., Aly, N., & Ali, T. (2025). Integrated GIS-AHP based assessment of earthquake vulnerability and risk for urban residential buildings in Muscat, Sultanate of Oman. Scientific Reports. https://www.nature.com/articles/s41598-025-17618-6

[29] Mahmoud, H. H., & colleagues. (2020). Visualization of seismic vulnerability of buildings with the use of a mobile data transmission and an automated GIS-based tool. Structures, 24, 50-58. https://doi.org/10.1016/j.istruc.2020.01.004

[30] Kumar, A., Ghosh, G., & Jain, N. (2024). The Effects of Height on the Seismic Vulnerability of RC Frame Buildings. Lecture Notes in Civil Engineering, 303–311.

[31] Fernandez-Romero, E., & Aparicio Roque, F. G. (2025). Seismic vulnerability of buildings: A review of current approaches and challenges (2000–2025). International Journal of Educational Practices and Engineering, 2(4), 77–100.

[32] Fischer, E., Biondo, A. E., Greco, A., Martinico, F., Pluchino, A., & Rapisarda, A. (2022). Objective and perceived risk in seismic vulnerability assessment at urban scale. arXiv. https://doi.org/10.48550/arXiv.2208.06367

[33] Ghosh, S., & Debbarma, R. (2017). Effect of plan irregularity on seismic response of buildings: A review. International Journal of Civil Engineering and Technology,8(4), 1–10. https://link.springer.com/article/10.1007/s40091-017-0151-3

[34] Farhan, M. A. A., & Bommisetty, J. (2019). Seismic analysis of multistoried RCC buildings regular and irregular in plan. International Journal of Engineering Research & Technology, 8(11).

[35] Harirchian, E., & Lahmer, T. (2022). Conventional RVS methods for seismic risk assessment for estimating the current situation of existing buildings: A state-of-the-art review. Sustainability, 14(5), 2583.

[36] Arellano et al. (2019). Seismic vulnerability assessment of buildings among BPSU campuses in Bataan using RVS method [Presentation]. Scribd.

[37] Zhang, Y., & Li, H. (2024). Seismic performance of torsionally irregular reinforced concrete buildings. Buildings, 10(11), 296. https://doi.org/10.3390/buildings10110296