Risk Assessment of Seismic Vulnerability of All Hospitals in Manila Using Rapid Visual Screening (RVS)

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Abstract. Philippine is one of the countries near in the Pacific Ring of Fire. In recent years, several moderate to high seismic activities happened that leads to casualties, deaths and damages in different structures. Manila is the capital of the Philippines with a population of almost 1.8 million. Many structures have been considered as old and unsafe and with an impending earthquake, it is essential to rehabilitate these structures. The imminent danger of the West Valley Fault when it moves is known throughout the metro manila and other neighbouring regions. The damage and casualties that will sustain from the possible 7.2 magnitude earthquake is fatal. Conducting mitigation programs is critical for it will greatly benefit the government and the people. Rapid Visual Screening (RVS) is an effective and efficient way of assessing the building’s structural integrity. This methodology is used to assess the structure’s seismic risk by visual observation of the exterior and interior of the buildings and a data collection form. RVS was applied in 26 hospital building’s located in Manila and the outcome of the assessment has shown that only 6 hospital buildings proved to be seismically adequate when using the level 1 data collection form. RVS is an effective tool in providing initial insight in the building’s vulnerability to seismic event.

1. Introduction

Earthquakes are not new in the Philippines, considering every decade this country experiences powerful earthquakes that leads to casualties due to collapse infrastructures. As the danger brought by the upcoming movement of the West Valley Fault System is now widely known. Assessing the building’s structural integrity especially those that are crucial after a calamity occurs is a key factor for it would greatly decrease the impact of this disaster.

Some of the structures erected here in Manila are old considering this city is one of the oldest. Meaning, some of the buildings here might be prone to damage or collapse when earthquake strikes. The city of Manila has numerous hospitals some are even historical which would be easily means that it is built decades ago. Using the Rapid Visual Screening (RVS) as a medium in assessing the seismic risk of critical facilities like hospitals. The RVS approach uses a methodology based on a “sidewalk survey” of an existing building [1]. It will be completed based on the visual observation of the building from the exterior or if possible, the interior without performing complicated calculations. From this, final scores will be obtained and shall determine the hospitals seismic risk. As a result, it will provide awareness throughout the community and make necessary actions to mitigate risk [1].

The main focus of this study is to assess the hospitals in Manila whether they are seismically vulnerable or not. The gathered RVS score of each building can estimate the risk of Manila in terms of its response during an event such as earthquake [2]. The result of this RVS survey is essential for decision makers like government officials to prioritize structure with higher risk due to the impending earthquake [3][4].
This research determined the RVS score from the level 1 survey form of each hospital in Manila, Philippines. The results would be analysed on what causes these hospital buildings to pass or fail based on the structural features, age, and structural system type which has an equivalent score on the data collection form. A visual representation was generated to show the seismic risk of hospitals in Manila. A hazard map was also created to determine what particular area(s) or district in Manila has greater risk in terms of RVS score of each hospital [5] [6].

Irregularity of the building is one of the major factors that lowers the RVS score of the building. According to the study of Jeong and Lee [7], when the irregularity of a building increases, the chances to such damages also increases and it was proven before during severe earthquake that due to the torsional movement of a building, the damages increases.

2. Methods
Figure 1. Describe the whole framework of this research. The first part was carrying-out the plans of the research, this includes communicating with the parties involved, identifying the possible problems, the training of staffs needed in the performance of the RVS and the preparation of documents and initial calculations needed. The second part is the implementation of the survey, in which the members were divided to 2 groups and performed the survey. The last part is the evaluation of the data gathered, using the checklist of FEMA 154, the researchers calculate the vulnerability score of each building, also a comprehensive report was included on each form. The hazard map was also created after the scores of each building was checked.

![Figure 1. Framework [1]](image)

The study determined the seismic vulnerability of hospitals in Manila by using FEMA P-154 2015 Rapid Visual Screening (RVS) See Figure 2. This methodology is designed to be implemented without performing any structural calculations. It is easy and relatively inexpensive; it only needs a visual inspection to perform the method. It is used by the researchers to determine the potential seismic risk of the building by using a data collection form.
The level 1 data collection form contains space for documentation of the building’s identification including its type of occupancy and size, a photo of the building, outline, and documentation of relative data related to seismic rendition. The score is based on the information collected during the survey; a score is computed that will provide a lead of the anticipated seismic performance of the structure. This method is used to distinguish the high risk and low risk hospitals situated in Manila. The final score has an expected damage level as function of RVS score and it will be defined by the grade of damageability which corresponds to type of damage that the building would sustain. Table 1 and Table 2 were used as basis for the risk of a building to damages.

After the final score was obtained, it was used as a data together with coordinates of each hospitals location which was gathered with the use of Google Maps to generate a contour map. This contour map has indicated the high and low risk hospitals in Manila.

Figure 2. FEMA P-154 2015 Rapid Visual Screening (RVS) [1]
Table 1. Grade of Damageability [8]

| Grade | Description                  |
|-------|------------------------------|
| Grade 1 | Negligible to slight damage  |
| Grade 2 | Moderate damage              |
| Grade 3 | Substantial to heavy damage  |
| Grade 4 | Very heavy damage            |
| Grade 5 | Destruction                  |

Table 2. Expected damage level as function of RVS Score [8]

| RVS Score | Potential Damage                                           |
|-----------|------------------------------------------------------------|
| S<0.30    | High probability of Grade 5 damage, very high probability of Grade 4 damage |
| 0.30<S<0.70 | High probability of Grade 4 damage, very high probability of Grade 3 damage |
| 0.70<2.0 | High probability of grade 3 damage, very high probability of Grade 2 damage |
| 2.0<S<3.0 | High probability of Grade 2 damage, very high probability of Grade 1 damage |
| S>3.0     | Probability of grade 1 damage                              |

3. Results and Discussion

The actual survey was conducted by the researchers with the use of level 1 data collection form and analysed the results on what causes these hospitals to be vulnerable based on structural design. Table 3 shows the type of form used (moderate or high) for assessment and the type of lateral resisting frame for each building. There were nine hospitals that were assessed using the high seismicity level. Among twenty-six hospitals in Manila, only one of them was constructed using steel as the main lateral resisting frame (S1) and the remaining were constructed using reinforced concrete (C1). This is typical way of constructing a building in the Philippines.

The seismicity level was determined using the spectral acceleration of Manila and the structure period “T”. The basis for this is the spectral acceleration of areas in seismic zone 4 which 0.4g and the structure period “T”. The structure period “T” can be computed by using the National Structural Code of the Philippines’s structure period formula. The formula depends on the type of lateral resisting frame used in the building and the value of the height per floor level is based on the RVS manual which is 3.5m per floor level.

In Figures 3-5, it shows different parameters of all 26 hospitals in Manila City. Figure 3 shows the benchmark (year of built), the researchers used the year 1992 as the cut-off for post-benchmark for this is the year seismic codes were significantly improved. For the pre-code, the year 1972 was used as the basis for this the year where the first NSCP was issued. Meaning, buildings that are built before 1972 are under pre-code. This score modifier has also affected the final score of each hospital buildings. There were 17 out of 26 hospitals in Manila that are built prior to 1972 (Pre-code). This is a testament that it is necessary for Manila to conduct thorough assessment of its hospitals and start to mitigate through retrofitting if necessary. Figure 4 shows the seismicity level used for each hospital, 65% were in moderate seismicity while the remaining 35% were considered in high seismicity. Figure 5 shows that 95% or 25 out of 26 hospitals were built using reinforced concrete and sole hospital was built using steel frame.
In figure 6, it is shown here the number of irregularities that is present in the 26-hospital building’s that was screened by the researchers. It shows here that mostly of hospitals has plan irregularity. The vertical irregularity is divided into two categories, severe and moderate. In the graph, it shows that 54% has severe vertical irregularity while 19% has moderate irregularity. Only 8% of the hospital has shown none of any irregularities. These score modifiers have affected the final score of each hospital buildings.
Figure 6. Irregularity in the Building

Figure 7 shows the RVS score of each hospital, 20 out of 26 hospitals have scores less than 2 which means they are susceptible to at least substantial to heavy damage when a major earthquake strike Manila. There are also 12 hospitals which get a score less than 0.30 which means they are highly probable to a destruction. Among 26 hospitals 6 of them have scores greater than 2 which means they can endure slight damages. The building can be classified now into two categories, priority and lower risk. This will enable the government to prioritize buildings that have higher risk of damages during an earthquake [9] [10].

Figure 8 shows the hazard map created using the RVS score. There were two areas in Manila that stands out because of a very high score in RVS which means the risk is very low. The upper left corner of the map which is a district called Tondo is very vulnerable not only due to the fact that their hospitals show high risk but also it is the most populated area in the city of Manila. In the time of calamity like earthquake, hospitals are the most vital infrastructure because it will accommodate all the casualties. The second most populated district which is Sampaloc is also vulnerable because the surrounding hospitals is at risk. The safest area in terms of vulnerability of hospitals is the Intramuros.
area, also in this area, many government facilities are located and adjacent to this area is the business district of Manila which is called Ermita.

![Hazard Map According to RVS Score of Hospitals](image)

**Figure 8.** Hazard Map According to RVS Score of Hospitals

4. **Conclusion**

The Rapid Visual Screening methodology has enabled the researchers to identify level of seismic risk of each hospital building’s in Manila. The grade of damageability of the hospital building’s that didn’t make the cut-off score ranges from substantial heavy damage to very heavy damage or destruction. While hospital building’s that showed adequate seismic performance could sustain moderate damage or negligible to slight damage.

Hospital building predominantly built using reinforced concrete which is the common practice in the Philippines. The main factor that increases the risk of a hospital building in Manila is the age were 17 out of 26 hospitals are built before the code exist. Also, the risk increases because of the severe vertical irregularity in 54% of hospitals and 77% of which have plan irregularity. Only 6 hospitals were assumed to pass the threshold level from FEMA in terms of RVS score, this is an evidence to which the city of Manila needs to do further analysis and rehabilitation.

The areas of Paco and Intramuros are assumed to have lower risk because hospitals near this district have lower risk of damages according to their RVS scores. Tondo and Sampaloc area which also have the most populated area in the city of Manila are assumed to have the highest risk.

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