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Utilizing Google Street View for Rapid Seismic Vulnerability Assessment: Case Study in the City of Manila, Philippines

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Abstract. Earthquake Impact Reduction Study for Metro Manila (MMEIRS) estimated that around 40% of the total number of residential buildings within Metro Manila will either collapse or be affected by the M7.2 generated by the West Valley Fault. Need arises to evaluate the seismic vulnerability of structures in the area to enhance the city's resilience to seismic hazards. Rapid seismic vulnerability assessments are typically conducted by means of sidewalk surveys. However, advances in digital technologies such as Google Street View (GSV) provide the potential to do remote assessments, particularly amid mobility restrictions brought about by the COVID-19 pandemic. This paper aims to demonstrate the usefulness of GSV in collecting data needed for rapid seismic vulnerability assessments through the case of buildings in the City of Manila. Six 300 m x 300 m blocks were evaluated using GSV for identifying seismic-related building parameters. Results show the ease of use of GSV in data collection on areas encompassing commercial and residential zones within the city and poses difficulty for blocks dominated by informal settlements. Among the challenges observed in formal zones include blockages in views due to fences, trees, and/or vehicles parked in front. For informal settlements, much of the buildings are not visible in GSV for evaluation thereby necessitating supplemental data collection. Overall, GSV demonstrates usefulness, and has the potential to speed up seismic vulnerability assessments in urban areas in conjunction with existing in situ assessments currently conducted.

1. Introduction

According to the Earthquake Impact Reduction Study for Metro Manila (MMEIRS), around 40% of residential buildings within Metro Manila will be damaged by M7.2 generated by the West Valley Fault [1]. Hence, seismic vulnerability assessments are crucial for the development of the rapidly urbanizing metropolitan. Evaluating the seismic vulnerability of the structures, especially non-engineered ones, will provide the governing body an opportunity to implement mitigation measures before an earthquake occurs. Once implemented, the risk of everyone to earthquakes is reduced, and the overall resilience of the cities is increased.

Rapid seismic vulnerability assessments are typically conducted by means of field survey or on-site investigation. FEMA P-154 [2], one of the most used rapid visual methods for evaluating the seismic vulnerability of structures, rates buildings based on information obtained through sidewalk surveys. Buildings are typically assessed based on their physical attributes which includes vertical and plan irregularities, height, structural material, and the lateral force-resisting system. On the other hand, the %NBS Rating System in New Zealand evaluates the performance of a building compared with a similar new one in terms of protecting life in the occurrence of an earthquake [3]. In the Philippines, the

Philippine Institute of Volcanology and Seismology (PHIVOLCS) created a self-check questionnaire for the evaluation of one to two-story concrete hollow block (CHB) houses in the Philippines [4]. The aforementioned tools assess the seismic vulnerability of a building through site inspection.

In the field of remote sensing, satellite imagery was used for visual-based seismic vulnerability assessments. A high-resolution optical satellite imagery in Germany allowed the extraction of building shape, position, and height to some extent [5]. In Yancheng, China, a mid-resolution satellite imagery in the study areas provided seismic vulnerability estimation while field investigation calibrated the assessment [6]. Given the limitations of these methods, further inquiry in the potential of remote sensing can provide a convenient, but not ultimate, assessment of seismic vulnerability of buildings.

In situ assessments have recently been challenging to implement due to mobility restrictions brought about by the COVID-19 pandemic. In particular, the City of Manila imposed hard lockdowns and curfews to curb the spread of the virus [7]. Thus, alternative means to collect building parameters necessary for the seismic vulnerability assessment of structures need to be explored.

Google Street View (GSV), launched in 2007, is a technology embedded in Google Maps and Google Earth which allows the view of buildings from a street perspective. It seeks to provide captured and processed street-level imagery that can provide an immersive experience to the users [8]. Initially, GSV only covered a handful of cities, but the platform has immensely expanded to include urban and rural areas globally. Such a rich dataset has the potential to be tapped for visual-based assessments. In a similar study, GSV was used for the automatic identification of soft-story buildings at a city scale using deep learning [9]. In the field of health science, it was highlighted that using GSV was feasible for auditing neighborhood environments albeit limited by temporal elements [10]. As for urban planning, GSV was deemed suited for assessing urban street greenery in cities [11]. The aforementioned studies highlighted the advantage of GSV in simplifying the data collection procedure.

This paper investigated the utility of GSV in conducting virtual structural surveys for potential usage to rapid seismic vulnerability assessments in an urban area in a developing country. Specifically, we test the usefulness of GSV in the data collection needed for vulnerability assessments through the case of buildings in selected districts in the City of Manila, Philippines. This was established by extracting the houses accessible through GSV and identifying two key parameters for seismic vulnerability — the building type and the number of floors. Different areas in the city were evaluated based on these criteria. Furthermore, this study was limited to data acquisition for seismic vulnerability assessment through remote means in the absence of physical site inspection.

2. Research Method

Case studies are utilized for both quantitative and qualitative research, and a single-case design is used for testing a particular theory [12]. As a methodology, it drives the validation of findings through analyzing context-dependent structures [13].

Testing the applicability of GSV for seismic vulnerability assessments was conducted by looking at the case of buildings in the City of Manila — the capital of the Philippines. Having 409,987 occupied housing units [14], it is the center of commerce, socio-political activities, and industrial development in the country. However, the city faces urbanization problems such as informal settlements thriving in the city — owing to the accessibility of employment [15]. Testing GSV through a case study in the City of Manila yields insights on its application in urban areas. Moreover, it would permit further inquiry on the limitation of this method at the city level.

2.1. Identifying the Sample Blocks

To investigate the utility of GSV for data collection needed for the conduct of seismic vulnerability assessment in the City of Manila, sample blocks were derived from the predominant land-use zones in the city. These were identified to be high density residential/mixed-use zones (R-3/MXD), medium intensity commercial/mixed-use zones (C-2/MXD), and high intensity commercial/mixed-use zones (C-3/MXD) based on the Official Zoning Maps 2005 - 2020 [16]. The three major zones encompass the majority of residential settlements in the city. Afterwards, a stratified sampling was conducted.

Using ArcGIS Pro, the "Create Fishnet" function under "Geoprocessing" was used to define cells of 300 meters by 300 meters grid, and the City of Manila Boundary was used for the "Template Extent" in the program. The created grid was superimposed to the Official Zoning Map and two blocks per zone type were randomly identified. Figure 1 shows the sample blocks within the City of Manila in Google Earth layout, with the following areas: Baseco (R-3/MXD), Sampaloc (R-3/MXD); Tondo (C-2/MXD), Paco (C-2/MXD); Binondo (C-3/MXD), and Sampaloc (C-3/MXD).

Figure 1. Sample blocks (300m x 300m) in the City of Manila for virtual structural survey in GSV.

2.2. *Virtual Structural Survey through GSV*

Seismic vulnerability assessments require data on the building characteristics. Using GSV, these were extracted remotely in the City of Manila sample blocks by identifying the building type and number of floors of each building. The key building types in Metro Manila that were established by the University of the Philippines Diliman - Institute of Civil Engineering (UPD-ICE) [17] were used as reference for this study. If both information were identified using GSV, the structure was then labeled as "Classified." For buildings with limited view using GSV for which the building type and/or number of floors cannot be determined, these were labeled as "Unclassified."

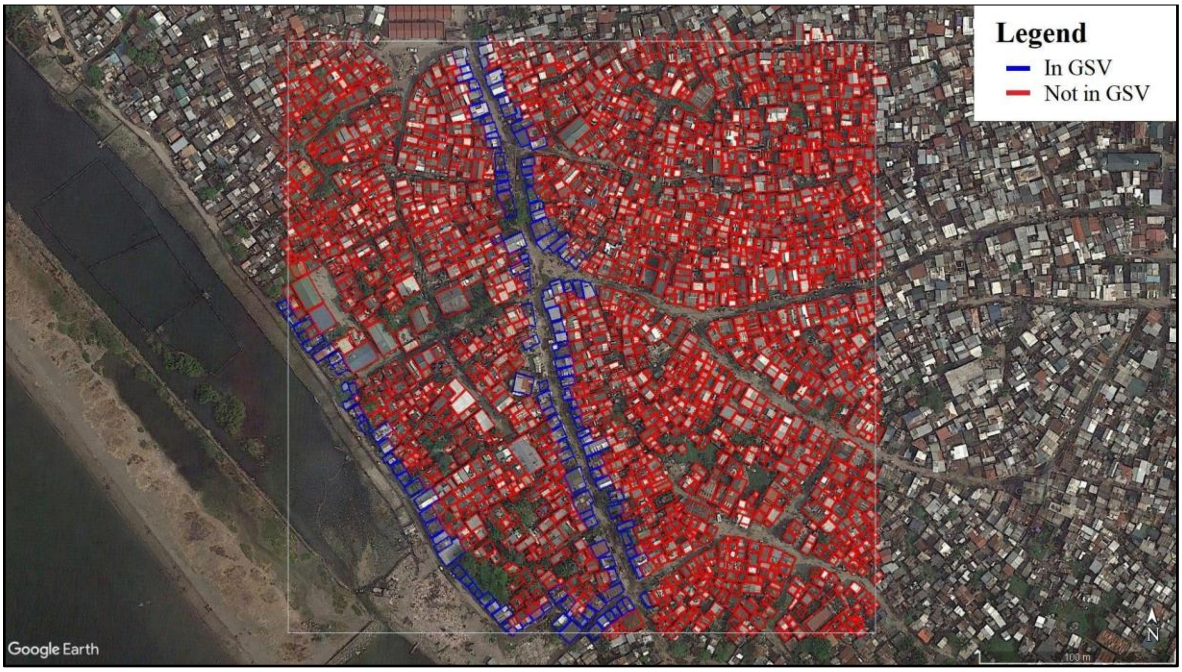
To supplement the data gathering and account for the buildings that are not accessible in GSV, the Google Earth Satellite View was utilized. The building footprints within each block were identified by manually tracing the roof of a building, and if visible, the walls that were projected from the view. As a rule, buildings partially situated within a sample block were included in the count.

3. Results and Discussion

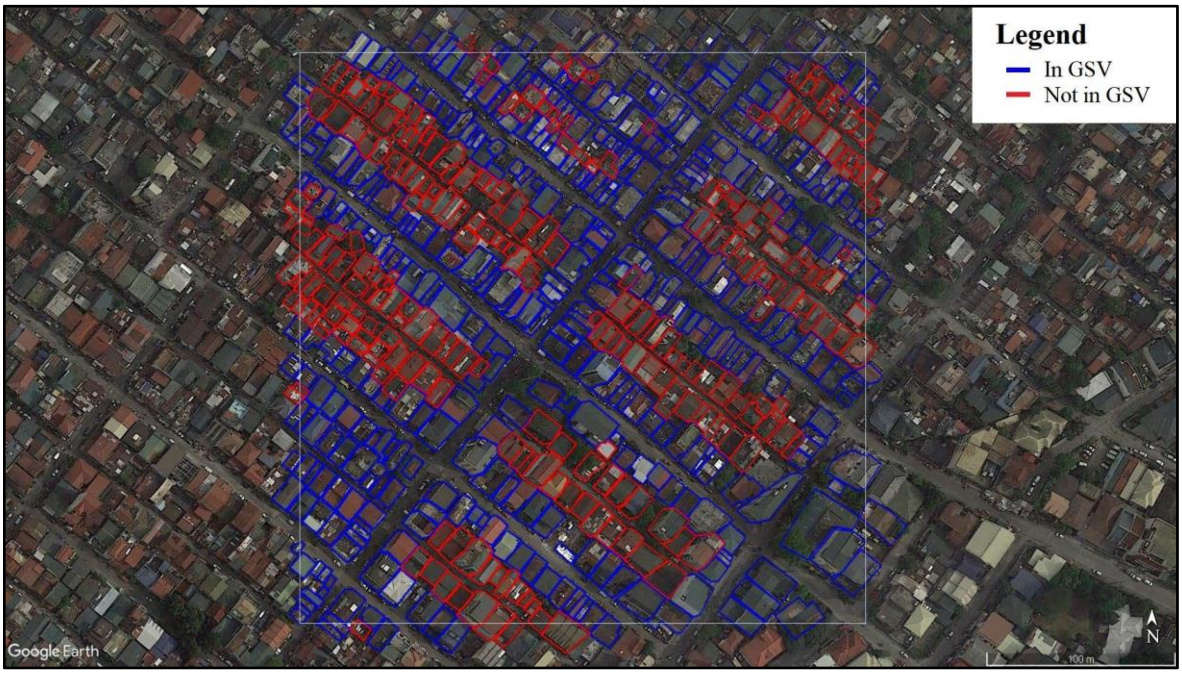
Virtual structural survey in the City of Manila through GSV allowed the extraction of building parameters essential for seismic vulnerability assessments. The investigation was conducted in each sample block as shown in figures 2, 3, and 4. The building footprints were marked blue, pertaining to the buildings visible in GSV and the red marks, otherwise. The white border indicates the boundary of the sample block.

From figure 2(a), there is only one main road in Baseco accessible using GSV as observed from the blue outlines in the area. Majority of the houses in the block are inaccessible. Notably, most of the buildings have makeshift building types, making identification from both GSV and satellite view difficult.

On the other hand, figure 2(b) shows the extent of the GSV in the Sampaloc area. It was observed that most building footprints are in blue as most buildings are accessible using GSV. Despite the grid configuration, there are still some roads in the area accessible to motorized vehicles yet have no available GSV data. This explains the red marks in between the blue marks that are apparent in the figure.



(a)

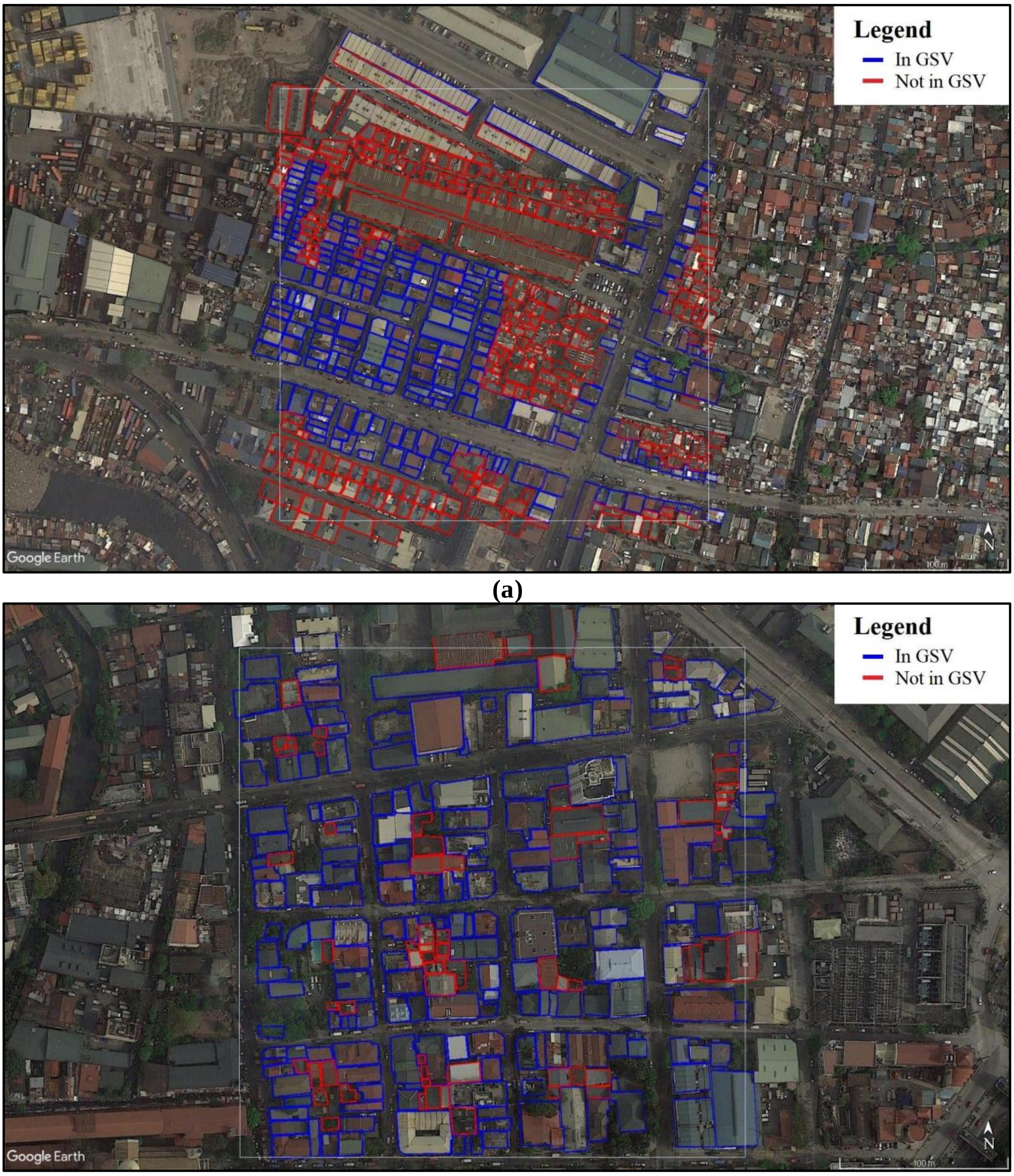


(b)

Figure 2. Satellite view of study block in R-3/MXD zones in **(a)** Baseco and **(b)** Sampaloc.

The block in figure 3(a) is an area in Tondo. It can be observed that there are evident clumps of red-marked buildings on the east as a consequence of having informal settlements in the area. There are also some roads with no access to GSV, which are apparent on the southwestern and northern areas of the block. The blue-marked buildings are those that are adjacent to the roads.

For the block shown in figure 3(b), there are some houses in Paco that are inaccessible in GSV. Commonly, these areas have a small opening or "esquinita" which serves as access points for the residents. As motorized traffic is not allowed, there is limited GSV in such areas.



(a)

(b)

Figure 3. Satellite view of study block in C-2/MXD zones in **(a)** Tondo and **(b)** Paco.

The highly commercial areas of Binondo and Sampaloc in figure 4 show that the majority of the areas are visible in GSV. Hence, there is an ease in assessing the buildings. Though the east part of Sampaloc has an area which lapsed GSV, most of its roadways have visibility in the virtual structural survey. Notably, the buildings in Binondo have relatively larger footprints, with condominiums and malls evident in the satellite view. However, there are evident obstructions that block the view to low-rise buildings, such as tents of street vendors.

(a)

(b)

Figure 4. Satellite view of study block in C-3/MXD zones in **(a)** Binondo and **(b)** Sampaloc.

Figure 5 shows the distribution of buildings within each block in terms of its accessibility in GSV. Notably, R-3/MXD areas have high percentages of inaccessibility, partly due to the high population density of the area, as well as the proliferation of informal settlements. Tondo also has more than half of the total surveyed with inaccessible buildings, particularly due to the limited GSV in the block. On the other hand, areas in C-3/MXD have high accessibility rates, marking the wide extent of GSV in these areas.

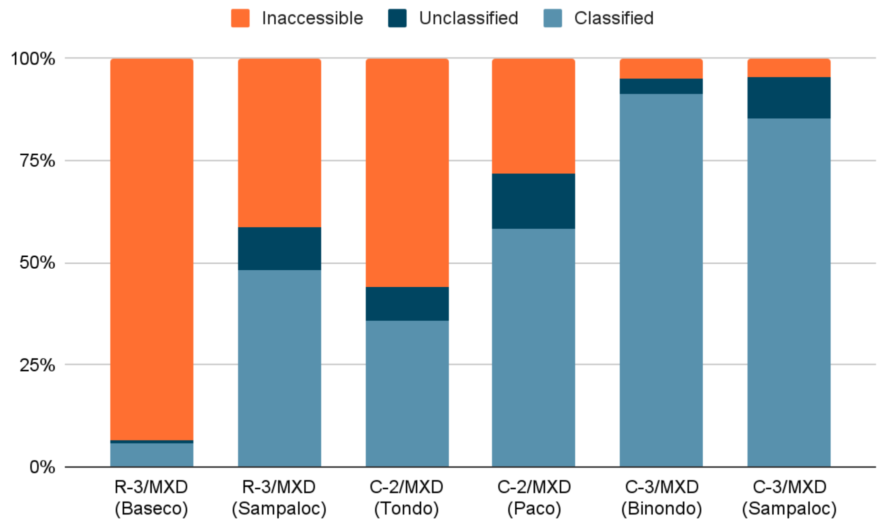


Figure 5. Building distribution in terms of accessibility based on conducted virtual structural surveys through GSV in selected areas in the City of Manila.

Several challenges were identified during the virtual structural survey. One of these is the limited perspective that is available in GSV. In particular, the building characteristics were easier to identify for buildings located at corner streets as there were multiple views available. It was also observed from the virtual structural survey that there were cases wherein roads can accommodate vehicular traffic, yet do not have access to GSV.

Another challenge encountered was obstructions such as tents, vendors, trees, and fences, that block the view to the buildings. Such obstructions constitute for the majority of the low-rise buildings labelled as "Unclassified". Tents, especially if the GSV is located underneath it, completely block the view to a building. There are areas, particularly for the case of buildings in Binondo, that were difficult to assess as these were located within small alleyways or "esquinita." Therefore, the limited angles in GSV hinder the identification of building parameters.

In assessing commercial areas, there was a need for multiple views to identify the building type properly, especially for buildings that have larger building footprints such as malls and condominiums. Projection was also an issue especially in high-density commercial areas. Condominium towers and apartments generally have a projected view in Google Earth satellite view. As such, adjacent low-rise buildings were seldomly partitioned and, in some cases, invisible from the satellite view. Hence, GSV was needed to supplement the identification of the building footprint.

Informal settlements in high density residential areas also exhibited low accessibility to GSV. Hence, incomprehensive data collection through GSV merits the need for further investigation on the site.

Data derived from GSV may be supplemented by data gathered through stakeholder interviews and through previously published reports.

4. Conclusion and Recommendation

Site limitation hinders physical investigation for seismic vulnerability assessment, making remote assessments a crucial endeavor in the time of COVID-19 pandemic. This paper investigated the utility of GSV for the conduct of data collection for seismic vulnerability assessments. The building characteristics, namely building type and number of floors were identified for buildings in the selected areas in the City of Manila using GSV. Results showed that high intensity commercial zones, and areas with regular spatial patterns exhibited high accessibility in GSV. Therefore, GSV has the potential to simplify the data collection in seismic vulnerability assessments.

However, remote assessments like the conducted virtual structural survey using GSV have its own limitations. In this study, obstructions, such as fences and trees, and limited angles provided by GSV hinder the identification of the building characteristics. Moreover, informal settlements and areas with organic spatial configurations lack accessibility to GSV, making the process of data collection inconsistent. As such, secondary sources of data may be utilized to accommodate this limitation. It is highly recommended to conduct onsite validation of the data acquired through remote means for a comprehensive seismic vulnerability assessment.

Further advancements in GSV and satellite imagery may improve the coherence of the data collection process. For future research, automatic tracing of the building footprint, especially for high-density residential areas, may simplify the virtual structural survey process. Automated detection of building attributes may also be facilitated by deep learning techniques.

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