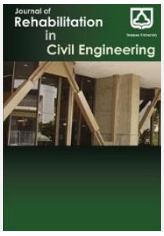
Journal of Rehabilitation in Civil Engineering 12-3 (2024) 1-16



Journal of Rehabilitation in Civil Engineering

Journal homepage: https://civiljournal.semnan.ac.ir/

Rapid Visual Screening for Seismic Assessment of Hospital Buildings: A Case Study of Kabul City

Abdul Ali Raoufy[1*]; Ali Kheyroddin[2]; Hosein Naderpour[2]

1. Ph.D. Candidate, Department of Civil Engineering, Semnan University, Semnan, Iran
2. Professor, Faculty of Civil Engineering, Semnan University, Semnan, Iran

Corresponding author: *a.a.raoufy@semnan.ac.ir*

ARTICLE INFO

Article history:
Received: 08 May 2023
Revised: 31 August 2023
Accepted: 14 September 2023

Keywords:
Rapid visual screening (RVS);
Vulnerability assessment;
Seismic vulnerability;
Crisis prevention;
Risk reduction;
Existing hospital buildings.

ABSTRACT

Considering the unexpected occurance of natural and man-made disasters over the world including Afghanistan, the importance of hospitals preparedness, as the first reference points for people to get healthcare services, becomes clear. Hospitals as critical infrastructures play an essential role in reducing casualties after an earthquake. The present research was conducted to evaluate the seismic vulnerability of the existing hospital buildings in Kabul City, with the aim of evaluating the current state of hospitals in terms of structural resistance. In the current applied research, the seismic vulnerability of 26 hospitals that had 79 existing buildings were assessed with the Rapid Visual Screening (RVS) technique of FEMA P-154 method in two levels for the first time, and their location was determined by Geographic Information System (GIS). The existing hospital buildings evaluated at level 1 and level 2 were estimated to be seismically vulnerable in the event of a possible destructive earthquake; the seismic vulnerability of these buildings was obtained to be different. Based on the obtained Final Scores, the probability of collapse for these hospitals at level 1 ranged from 3.16% to 59.2%, and at level 2 it ranged from 3.16% to 64%. Based on the results, in the event of destructive phenomena such as earthquakes, there is a probability of damage that would prevent hospitals to provide uninterrupted Immediate Occupancy services. So; these buildings should be prioritized, and subjected to a detailed seismic vulnerability assessment, then solutions to rehabilitation or retrofitting of buildings against earthquakes should be investigated.

E-ISSN: 2345-4423

How to cite this article:
Raoufy, A. A., Kheyroddin, A., & Naderpour, H. (2024). Rapid Visual Screening for Seismic Assessment of Hospital Buildings: A Case Study of Kabul City. Journal of Rehabilitation in Civil Engineering, 12(3), 1-16.
https://doi.org/10.22075/jrce.2023.30600.1848

1. Introduction

Kabul City is located at 34°31' N, 69°12' E with a total urban area of 48,493 hectares [1], and sits at an altitude of 1800 m and is situated in a valley surrounded by high mountains and a network of active faults [2]. Kabul and its neighborhood are surrounded by some great fault systems [3, 4]. Based on detailed studies, the Chaman, Paghman, Herat, Sarobi, Gardez faults close to the Kabul City has been identified as the main source of seismic hazard [5]. The seismic behavior of old existing buildings is affected by their main structure. Also, the destruction of materials through the aging and the changes have been made over the years of operation, such as the creation of new openings and new sections that cause asymmetry in the plan, height, etc., affects the old buildings [6].

Hospitals play an important role of the healthcare system [7]. Hospitals and medical centers must be in an immediate occupancy after the earthquake in order to protect the lives of patients and healthcare workers. Also, provide emergency care and medical treatment for the increasing number of patients who are transferred to medical centers in the first hours after significant earthquakes [8]. Hospitals' performance before and after an earthquake to provide relief services depends on either structural or non-structural elements as well as medical equipment; the recent earthquakes clearly showed the importance of this issue [9, 10]. In times of disaster, preparedness is required for hospitals to be able to continue the provision of health care [11]. The role of hospitals during a disaster is even more important; therefore, it is vital to provide timely and high-quality treatment to injured patients in order to minimize casualties [12]. Hospitals must continue to provide health care during disasters, and this requires preparation [11]. The experience of the last earthquakes showed that the failure of medical equipment in a hospital during the post-earthquake relief operation can prevent the full service of the hospital [13]. Hospitals are known as safe havens after any type of disaster; however, in severe seismic events, hospitals themselves are also susceptible to damage [14]. To keep the hospital active in such incidents, the only possible solution is to identify the deficiencies in the building and reduce it [15]. However, records show that health centers and workers are among the major victims of emergencies, disasters and other crises [16]. From the human and economic point of view, the collapse of a building due to an earthquake causes huge damages [17]. Resilience of an urban area, housing, school, hospital, infrastructure, etc. after a disaster is essential [18, 19].

Determining the vulnerability of hospitals against possible earthquakes is critical in preventive seismic crisis management programs [20]. Due to its complexity and high cost, the assessment of seismic vulnerability can be made in a limited number of buildings from a technical perspective. Therefore, rapid assessment of the vulnerability characteristics of different types of buildings using simpler methods is important, and more complex methods could be limited to assess the buildings with vital importance [21]. Basic tools of seismic hazard assessment are employed to screen existing buildings in order to determine the potential damage may occur during an earthquake, and buildings with poor performance will be listed as a priority for detailed assessment and defining their status [22]. Assessing the seismic vulnerability of hospitals is crucial in order to mitigate the impact of earthquakes on people's lives and prepare healthcare centers to effectively cope with future earthquake disasters [23].

The seismic performance of hospitals plays an essential role in dealing with emergency situations such as earthquakes. Hospitals are usually very vulnerable due to the age of construction, type of equipment, occupancy rate, services provided, etc. [24].

In an earthquake, the key parts of a hospital, which include the hospital building, staff, technical systems and equipment, are affected [25]. In the 8.1 magnitude earthquake in Mexico City, in 1985, five hospitals were collapsed, and 22 others were severely damaged. Almost eleven hospitals were evacuated. The direct failure was estimated at about 640 million $ [14]. In a natural disaster in Caribbean and Latin America in period of 1981 to 1996, over than 630 hospitals and health centers were collapsed or substantially damaged, and evacuated [14]. The National Society for Earthquake Technology (NSET) carried out two evaluations in 2001 and 2003, "Structural Assessment of Hospitals and Health Institutions of Kathmandu Valley" and "Non-Structural Vulnerability Assessing of Hospitals in Nepal." The outcomes show approximately 80% of the evaluated hospital buildings did not have an acceptable level of performance and needed to be rebuilt, and 20% of the hospitals are at life safety and have a performance of collapse prevention [26]. In 2003, during the Bam earthquake, almost all health facilities were destroyed and nearly 50% of local health workers were killed or missing [27]. In India's Gujarat earthquake, all of the medical systems in the region failed [28]. In the February 27, 2010 earthquake in Chile, four hospitals were closed and 12 hospitals lost approximately 75% of their functionality due to the failure of non-structural components, including fire extinguishing systems [29].

RVS method for 26 hospital buildings located in Manila, Philippines, according to Level 1 Survey Form; FEMA P-154 was applied, and the evaluation results showed that only six hospitals were seismically sufficient [30]. RVS methods are commonly used without any calculations to assess buildings; this method also uses a rapid assessment to estimate the damage to a building that may occur due to an imminent earthquake [31]. Assessing the seismic vulnerability of a vast number of structures and buildings can be very difficult due to the required time and resources. The RVS method reduces this problem by classifying buildings into different vulnerability classes and prioritizing them, thus limits the technical and other resources for detailed analysis to only a few selected vulnerability classes [32-34].

The main focus of this research is to conduct a rapid seismic vulnerability assessment of the structural components of hospital buildings in Kabul City. However, hospital buildings are composed not only of structural components but also of non-structural and functional components, which have a direct or indirect impact on the building's performance and management. Evaluating non-structural and functional components are also important, but the focus of this research is only on structural components and their seismic assessment.

2. Research background

The RVS method is a fast and efficient process for identifying and ranking buildings [35]. This method is based on crucial factors such as seismicity of the area, soil condition, building type, structural irregularities, and non-structural hazards, also based on the buildings importance, usage and occupation that affects the vulnerability consequence [36]. The rapid visual seismic vulnerability assessment techniques of buildings were reviewed in (Scawthorn, 1986), and soon after, the FEMA154 methodology was published as the handbook of rapid visual screening of buildings for potential seismic hazards (FEMA, 1988a) [37]. Initially, in the late 1980s, the RVS method; was developed for seismic hazards of buildings by the Applied Technology Council (ATC). Additionally, in 2002, owing to the impact of earthquake disasters in 1990s, this method was revised in order to incorporate the most recent technological advances [38]. The third edition of FEMA 154 Method, called FEMA P-154, was published in 2015, which included not only information of building type definitions and key features, but also a completed screening form and management of the RVS program [37]. Many countries follow the RVS method similar to FEMA with some modifications to suit the conditions of their region or country [39]. RVS focuses on on-site inspections of each home [33]. In the RVS method, visual screening of buildings is usually done by street inspections and with no entrance of screener to the buildings, and it may long a quarter to half hour for any building [39].

Rapid Visual Screening provides information about the basic features of the building, such as; type of building, the number of stories, soft and weak story, short columns, vertical and plan irregularities, the age of the building, the soil type , seismicity of the site, external quality of construction and other valuable features. A structural score is obtained using the collected data, and with no structural calculations to determine the damage expected to the building after an earthquake. This score determines need of the building for next level of evolution. The RVS method can save time and prevent the resource consumption and it has the ability to be utilized to determine the structures requiring detailed evaluation [33].

The RVS method has a number of limitations that need to be understood when developing and implementing a screening program, and when using the results. Some of these limitations include, Limited review, Lack of accurate identification of systems resistant to seismic force in some buildings, Inability to assess interior hazards, Lack of detailed calculations, and Occurrence of errors (due to variations in expertise of screeners). These limitations arise from the method's inherent characteristics, which also contribute to its main advantage [37]. This method is based on the decisions of simple expert and non-expert screeners and provides an initial insight about the vulnerable buildings to seismic risks in a city; therefore, it is not a complete method. Based on the RVS method information, government officials can utilize quantitative tools to recognize the amount of the corrective work needed for a particular area [40]. The RVS method results can be relatively different according to the screener's experience. This method does not have a definitive opinion about the level of vulnerability and defers these structures to detailed evaluation. Therefore, it cannot be said that it has a high level of reliablity. In other words, the reliablity of estimations in this approach is lower compared to detailed vulnerability assessment methods. This paper focuses on the most common method used by the Federal Emergency Management Agency (FEMA) introduced in the following section.

2.1. FEMA P-154 method

The latest version of FEMA154, the third edition, is known as FEMAP-154; reviewed and identified several areas for improvement and published in 2015. The third edition focuses on the evolution of computer tools to implement the method more effectively. The main improvements in this edition include as follow [37].

1- The form of data collection (Level 1) is reorganized to increase usability.

2- For more information and more accurate evaluation, an optional form of level 2 data collection has been attached without a significant increase in effort or time. This assessment is however a rapid visual screening method, yet it depends on more data that an experienced engineer or architect should collect.

3- To increase the precision of the screening in areas with higher seismicity, the number of seismic regions has been increased from three to five, and the seismic areas are based on MCE_R ground movements.

4- The Score Modifiers and Basic Scores were all updated.

5- A reference guide for assessors to identify vertical and plan irregularities is provided in this edition to guide screeners in determining the presence of irregularities, decreasing obscurity, and limiting the requirement for arbitration. Supplementary figures have been attached to assist the show of different irregularities in this edition, and modified values are now different based on the irregularity intensity.

6- Large multi-unit buildings, wood-framed residential units with multi-story, as well as prefabricated buildings were added.

7- For non-structural hazards, the rapid visual screening method has been improved.

8-User classes have been updated for compatibility with HAZUS-MH MR4 (FEMA, 2009a) and (ICC, 2012).

9- In this edition, the pounding of adjacent buildings is considered.

10- A better guide with additions is provided to evaluate the buildings.

11- In the Optional Data Form, Level 2 includes attention to existing retrofitting.

12- The Minimum Score is listed to handle the negative scores in the data collection form.

13- Software (FEMA, 2014b, ROVER) is discussed, and an optional electronic scoring method is presented.

14- How to execute an effective program of additional RVS information, including essential and optional tasks, needs, and relevant resources provided.

15- An additional consideration of how to utilize RVS outcomes for support has been added.

The FEMA P-154 method has presented forms for different seismicity regions. The person using the RVS method selects a relevant data collection form based on the seismic classification. In the first section of the data collection form, public information including building address, building location, building usage, construction date, and buildings images and sketches are included. The second section provides scores for several parameters according to the type of the building in the following, all the parameters and how to calculate the Final Scores of the building are described. By selecting a suitable Basic Score for each building, this method begins, which changes with the use of Score Modifiers, so that the smaller score, indicates the higher buildings' vulnerability [37].

- Minimum Score, S_{MIN}: The data collection form in FEMA P-154 provides the Minimum Score that a building can achieves, and this score is minimum because, in some conditions, the Final Score received for a building can reach zero or less; this means that the building's eventuality of collapse is more certain than 100%. To avoid this problem, a Minimum Score has been created to be considered the Final Score.
- Basic Score: The type of buildings are classified by FEMA P-154, and a Basic Score is provided for the building as per the classification.
- Vertical Irregularities: There are seven vertical irregularities based on FEMA P-154. This method categorize the vertical irregularities into two categories, severe vertical irregularity, and moderate vertical irregularity. In the irregularity section of the form, in case of one or multiple severe vertical irregularity detection; the Score Modifier will circle the severe vertical irregularity score, and in case of one or more moderate vertical irregularities or no severe vertical irregularity detection, the Score Modifier should circle the moderate vertical irregularity score.

- Plan Irregularities: based on FEMA P - 154, there are five kinds of plan irregularities, and if one or more of these irregularities are observed in the plan, so this plan irregularity score modifier should be circled.
- Pre-Code: The screeners must use the pre-code Score Modifier when the building is designed and constructed before implementation of initial approved and applicable seismic codes. Due to the method that calculates the Basic Score, this Score Modifier cannot be applied to buildings located in an area with region of low seismicity.
- Post-Benchmark: This Score Modifier applies if the local jurisdiction has significantly improved the seismic codes and the FEMA building type were adopted and enforced be made after. Year of first time seismic code execution, and the year that the area's seismic code (standard year) has been improved must be known in advance for pre-code and post-benchmark modifiers.
- Soil type: Score Modifiers for soil types A, B, and E are presented. In the soil type section of the form, if type A or soil type B is specified, the screener circles the specified soil type Score Modifiers. In case of type E recognition and the building with three floors or less; the modifier evaluator scores the soil type E score (1-3 floors), or if the soil type E was specified and the building had four or more floors; the screener circles the soil type E Score Modifier (more than three floors). No Score Modifiers are applied to type C and type D soils because Basic Scores are calculated assuming CD type soil, the average of soil types of C and D. The Score Modifier for type F soils is not considered because the RVS method is not able to effectively screen the buildings constructed on type F soils. The Geological hazards of type F soil are presented in the section of the other hazards included in the form, which makes an accurate structural assessment of the building constructed on Type F soil.

2.1.1. The final score determination of Level 1

The Final Score of level 1, S_{L1}, for an under-screened building, is determined by adding the circled Scores Modifier of that building with the building's Basic Score. The total of the Basic Score and the Score Modifiers summation should be compared with S_{MIN} by the screener, and if it is smaller than the S_{MIN}, the S_{MIN} should be used [37].

2.1.2. Optional Level 2 data collection form

The screening of Level 2 is more detailed and has higher eligibility compared to the Level 1; Level 2 form is designed for more accurate and conservative scoring. Level 2 screening allows the screener to utilize more specific Score Modifiers related to vertical irregularity and plan irregularity. Other Level 2 modifiers, such as pounding, retrofit, and Level 2 screening statements for specific type of building are identified from a similar combining the Level 1 Score Modifier and engineering judgment.

The screener name and the score of level 1, S_{L1}, are registered by the screener on the top of the optional level 2 data collection form. Level 1 score contains Level 1 Score Modifier for vertical irregularities and plan irregularities (V_{L1} and P_{L1}); to be able to use the modified level 2 irregularities (V_{L2} and P_{L2}) instead of (V_{L1} and P_{L1}), the (V_{L1} and P_{L1}) Score Modifiers are subtracted from S_{L1} to obtain an adjusted Basic Score of S'. This score is the Basic Score for level 2. The screener records the summation for the Level 2 vertical irregularity (V_{L2}) and the plan irregularity (P_{L2}) Score Modifiers, as well as the subset of the other level 2 (M), Score Modifiers [41].

2.1.3. The final score determination of Level 2

The Final Score of level 2, S_{L2} can be determined by the sum of the level 2 V_{L2}, P_{L2}, and M Score Modifiers, the Minimum Score determined for the level 1, and the Basic Score, S'. Whereas in the assessment of level 2, the characteristics of the building are examined in more detail. Score Modifiers may have low conservatism. The Final Score more accurately represents the expected performance of the building with less built-in conservatism. Level 2 assessment has a higher score than Level 1 assessment in many of considerations; the Final Score of level 2 includes the S_{MIN}, which is the score of level 1 [41]. The probabilities of collapse calculated at the Maximum Considered Earthquake (MCE) corresponding to Final Scores between 4.0 and 0.0 are shown in Table 1 [42].

Table 1. Calculated probabilities of collapse versus Final Score, S (Wang and K. A. Goettel) [42].

Final Score, S	Probability of Collapse
4.0	0.01%
3.5	0.03%
3.0	0.10%
2.5	0.32%
2.0	1.00%
1.5	3.16%
1.0	10%
0.5	32%
0.0	100%

The Final Score is the summation of the Basic Score and Score Modifiers. The Basic Score is determined by the type of structural system and the Score Modifiers are obtained from the selection of parameters (Several Vertical irregularity, Moderate Vertical irregularity, Plan Irregularity, year of construction, soil type, Redndancy, and Pounding). Therefore, ignoring or misdiagnosing any of these parameters can affect the accuracy of the results.

2.1.4. Combining Level 1 and Level 2 screening

In the RVS program, level 1 screening is performed for each considered buildings. Optional level 2 screening collects information on additional structural features that affect risk and provides refined Score Modifiers. Performing the Level 2 screening adds cost because it adds additional time, and the screener must be a structural engineer or other qualified professional. If the level 2 screening is performed at the same time as the level 1 screening, the added time per building is typically around 5-15 minutes. If a level 2 screening is follow-up to an earlier level 1 screening, the added time per building is much greater [37].

Various permutations of Level 1 and Level 2 screenings are described below.

1. Level 1 only. In this approach, more buildings will be screened with the minimum cost of screening, and it may increase the review time of the supervising engineer to validate the results.
2. Level 1 with Level 2 on higher priority buildings. This approach provides valuable level 2 information on previously selected high priority buildings for a minimal additional cost.
3. Level 1 with Level 2 as part of the second round on a subset of buildings. In this approach, level 2 screening is done for a subset of buildings based on the Final Score determined by level 1 screening or building type. In this case, the number of detailed evaluations required may be reduced and benefit the overall project.
4. Level 1 and Level 2 for all buildings. This approach is likely to yield the most accurate results, but is also likely to be the most expensive.

Some programs may want to make screening programs as simple as possible; this simplified approach is not recommended and RVS is not expected to provide meaningful or accurate data on the seismic hazard of their building stock.

Considering the special importance and centrality that hospital buildings have in saving people's lives and providing health services, it was decided to perform rapid visual screening level 1 and level 2 at the same time for all hospital buildings in Kabul City. This decision has been used as a logical and scientific approach due to the following:

1. Optimum decision-making according to limited resources: simultaneous screening of level 1 and level 2 for all hospital buildings allows us to make more precise decisions about buildings that require a detailed vulnerability assessment using the lowest cost of time and financial resources.
2. More effective identification of risks and vulnerabilities: simultaneous screening of level 1 and level 2 allows us to identify possible risks and weak points of hospital structures in a more comprehensive way and take appropriate measures in order to manage and reduce them.
3. Determining priorities in decision-making: simultaneous screening of level 1 and level 2 for all buildings helps us to make better decisions by setting priorities and identifying risks in a more comprehensive way.

More accurate diagnosis: simultaneous screening of level 1 and level 2 ensures us to provide a more accurate diagnosis of the vulnerabilities and risks of hospital buildings.

According to the above justifications, simultaneous assessment of level 1 and level 2 for all hospital buildings in Kabul city in order to quickly and reliable assess the vulnerability of the structural components of these crucial buildings was chosen as a logical approach in this research.

The FEMA P-154 method is quite robust in assessing structural vulnerability. But in the screening of non-structural components, it only recognizes whether the hazards of non-structural components exist or not and emphasizes the hazards of non-structural components falling. If there is a hazard of non-structural components falling; it recommends detailed assessment and no assessment is necessary if there is no hazard of external falls. So; it performs very poorly in the evaluation of non-structural components and scoring.

3. Research significance

One of the most dangerous events in human life is natural disasters that require emergency solutions due to their sudden occurrence [43]. Earthquakes can be the most destructive natural disasters that cause severe economic, social, and environmental problems. Damage to the buildings due to earthquakes is the main cause of deaths during earthquakes, and consequently severe financial losses. The behavior of various types of buildings during an earthquake and their vulnerability generally depend on vertical load-bearing elements, which is confirmed by published articles [44]. Buildings analysis under earthquake action requires better engineering strategies and tools in order to the economic design of buildings because earthquakes have a random and unpredictable nature [45]. Human casualties and economic losses caused by natural disasters have increased dramatically in the last few decades all over the world [46]. Earthquake is a severe threat to the people and institutions of Afghanistan. Afghanistan is a country that is seismically located in a region where the possibility of earthquakes with human and financial losses is inevitable. Earthquakes have killed more than 7,000 Afghanistanian in recent years; The Nahrin earthquake killed at least 4,000 people in May 1998; the history of devastating earthquakes goes back more than four thousand years in Afghanistan. We expect future large earthquakes, driven by ongoing geological processes in the region near to population centers and lifelines, resulting in a greater risk of loss and damage. The consideration of seismic hazards is essential for the siting location, construction, and reconstruction of communities and facility installation in Afghanistan. Among Afghanistan's major cities, the capital Kabul is by far the most seismically hazardous ciry due to its proximity to active Chaman fault [47]. On June, 2022, a 6.1 magnitude earthquake hit the southeastern region of Afghanistan, centered in Paktika province, which also affected Khost province. This earthquake killed at least 1,000 people, injured over 3,600 people and caused damages to 70% of the houses in the earthquake zone [48, 49]. The role of public facilities such as health care clinics and hospitals is very important and vital in disaster management after a crisis. In order to have a real preparedness, strategies of response-action and effective management of earthquake hazards, it is necessary to assess their seismic vulnerability. In areas with high seismic risk, increased losses for weak buildings have been reported [20].

Most hospitals in Kabul City are old. The buildings that have been built in the last two decades could be found defecs due to failure to meet acceptance criteria, faults, and possible inaccuracies that occur during the construction period of hospital structures. Eventually, these defects can lead to a weaker structure compared to what was initially designed; and cannot provide the level performance of immediate occupancy, and due to the fact that several faults threaten Kabul City from an earthquake increases this concern. In this regard, rapid seismic vulnerability assessment of hospital buildings in Kabul City makes it possible to predict the initial information on the extent and severity of potential vulnerabilities without spending money and time for a detailed assessment. Thus, hospital buildings that do not require detailed vulnerability assessment are identified and removed from detailed evaluation priority. On the other hand, structures identified as prone to vulnerability in rapid seismic assessment should be carefully examined, and the capacity of these structures in different magnitudes of earthquakes should be evaluated. This study will lead to the presentation of a rehabilitation or reconstruction plan.

Another aspect of this research importance is crisis management during earthquakes, which can be considered as the first step in promoting this vital issue in Kabul City. Assessing the seismic vulnerability of the hospital building will be the first and most crucial step of crisis management measures of a medical complex. Hospital preparedness for natural disasters stems from several complex factors that organize the natural disaster response program; managing such a program should be one of the essential priorities of the hospital board. Hospitals that have planned in the face of natural disasters such as earthquakes and implement it continuously will suffer less damage.

4. Method

Figure 1 describes the general flowchart of this investigation. The first section of this research involves on communication with the sides involved, determining the probable problem, and personnel training that are required for the RVS implementation, the required documents and preliminary calculations. In the second section of this research, the screeners go to the building to conduct interviews and surveys by completing the pre-prepared data collection form. In the last section, by using the data collected in the level 1 and level 2 FEMA P-154 data collection form, the researchers estimate the probable vulnerability of buildings through the calculation of their Final Scores.

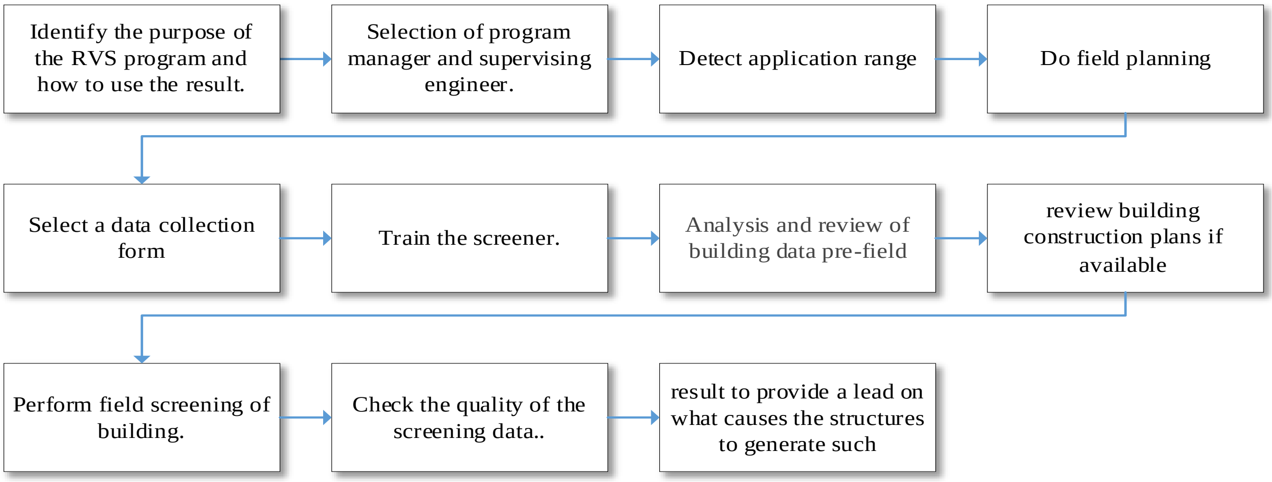


Fig. 1. The Flowchart of Research Method.

This research assesses the seismic vulnerability of hospital buildings in Kabul City using FEMA P-154, 2015 data collection form of high seismicity. Owing to the high importance of hospital buildings, two levels of level 1 and optional level 2 data collection forms for high seismicity were used. This method is easy and relatively cheap to walk around the building and, if possible, inside the building without doing any calculations. It just requires a visual survey to assess the potential seismic hazard threatens the building. The Level 1 data collection form encompasses a place at the top of the page for the screener's name and the building address. There is a space for documenting building characteristics such as its type, age, size, the number of stories, images of the building, and general plan placed in the middle of the forms' page. Finally, the assessing result and required next action are recorded at the bottom of the page.

The Final Score as a function of the RVS score, represents the expectable level of damage and is defines the degree of vulnerability related to the type of the damage the building suffers [26].

5. Results and discussion

Rapid visual screening of hospital buildings in Kabul City was performed according to Level 1 and Level 2 data collection forms for regions of high seismicity; FEMA P-154, 2015 and the Final Score of these buildings were determined.

Among the 26 hospitals in Kabul City with 79 buildings, 18 buildings were unreinforced masonry bearing –wall buildings (URM), one was made of steel moment-resisting frame (S1), and the other 60 were made of concrete moment-resisting frame (C1) as the primary lateral reinforcement. Figure 2 shows the percentage distribution of these hospital buildings.

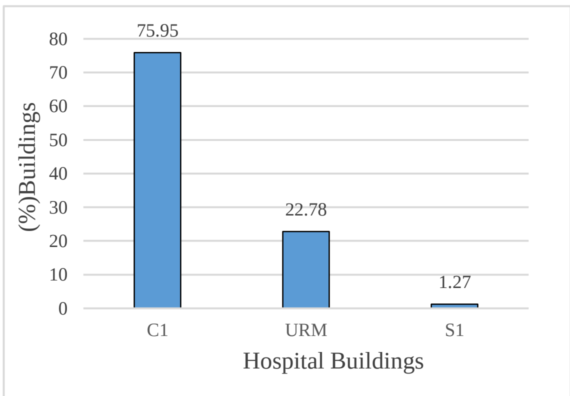


Fig. 2. Types of hospital buildings in Kabul City from the materials perspective.

Figure 3 shows some picture as examples of hospital buildings.

Fig. 3. Pictures of some hospital buildings in Kabul City.

Figure 4 shows the number of irregularities in 79 hospital buildings in Kabul City.

Here it shows that 28 hospital buildings have irregularities in the plan. Vertical irregularities are divided into two categories: severe and moderate; six buildings had severe vertical irregularities, while four buildings had moderate irregularities, and the most significant number of buildings (i.e., 41buildings) were without any irregularities.

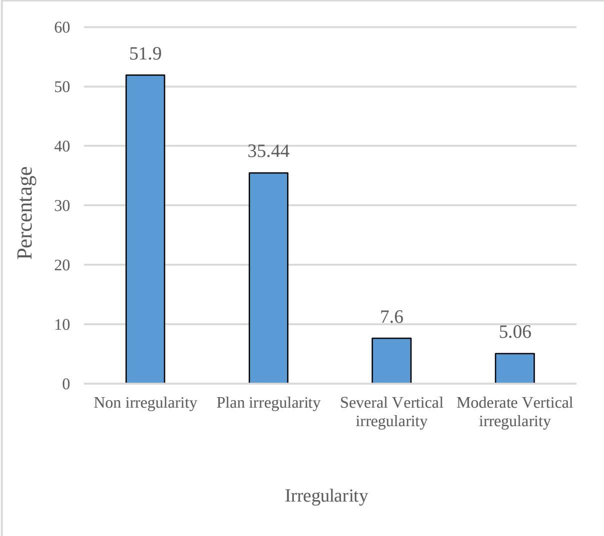


Fig. 4. Irregularities in hospital buildings in Kabul City

Figure 5 shows the locations of the evaluated hospital buildings in Kabul City.

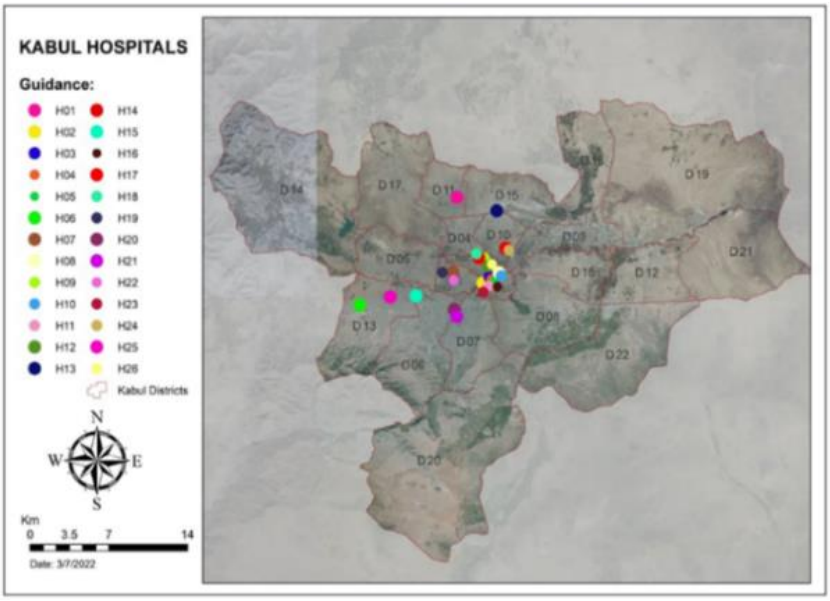


Fig. 5. Location of hospital buildings in Kabul City.

The Final Scores of hospital buildings evaluated according to level 1 of the FEMA P-154 (2015) method are shown in Figure 6.

As can be seen, the RVS scores of all hospital buildings in Kabul City are less than 2.

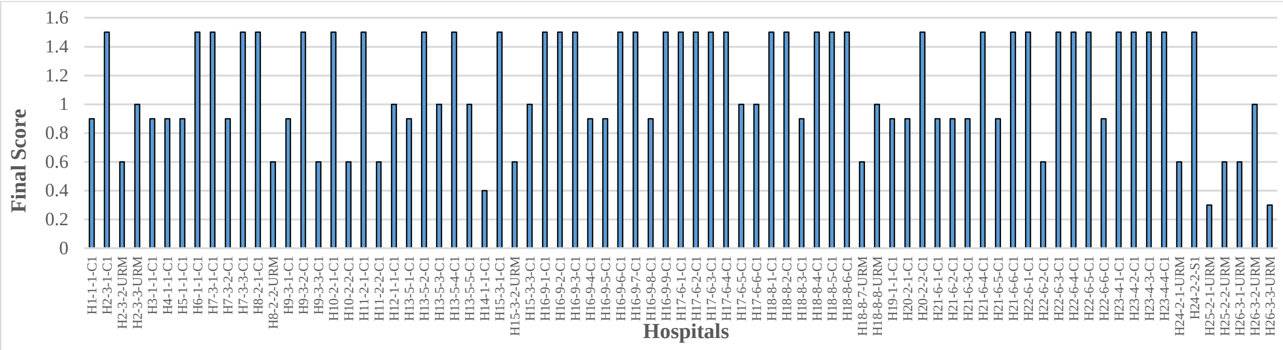


Fig. 6. Final Scores according to level 1 of the FEMA P-154 (2015) method.

The Final Scores of hospital buildings evaluated according to level 2 of the FEMA P-154 (2015) method are shown in Figure 7. As can be seen, the RVS scores of all hospital buildings in Kabul City are less than 2.

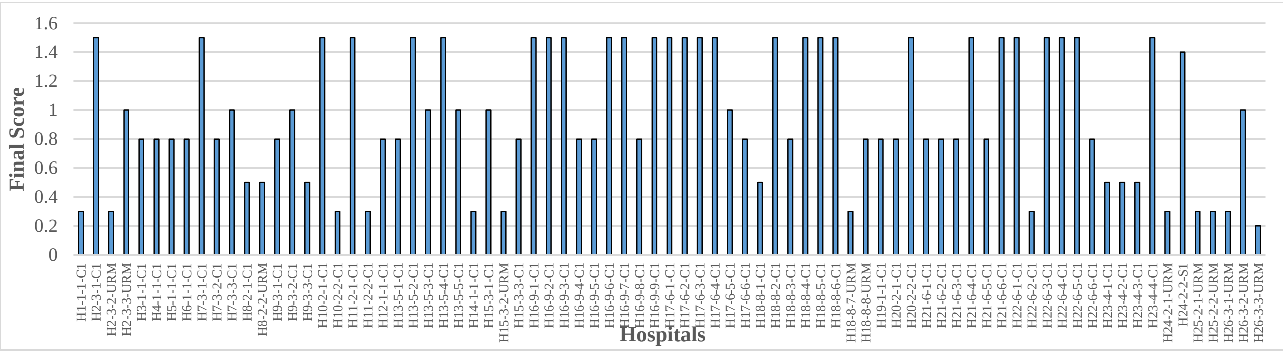


Fig. 7. Final Scores according to level 2 of the FEMA P-154 (2015) method.

The RVS Final Scores for each hospital buildings in Kabul City, calculated using the Level 1 and Level 2 data collection forms of FEMA P-154 (2015), are presented in Figure 8. As depicted in the figure, the Final Scores of hospital buildings evaluated at level 1 are greater than or equal to those evaluated at level 2, which indicates more conservatism of level 2.

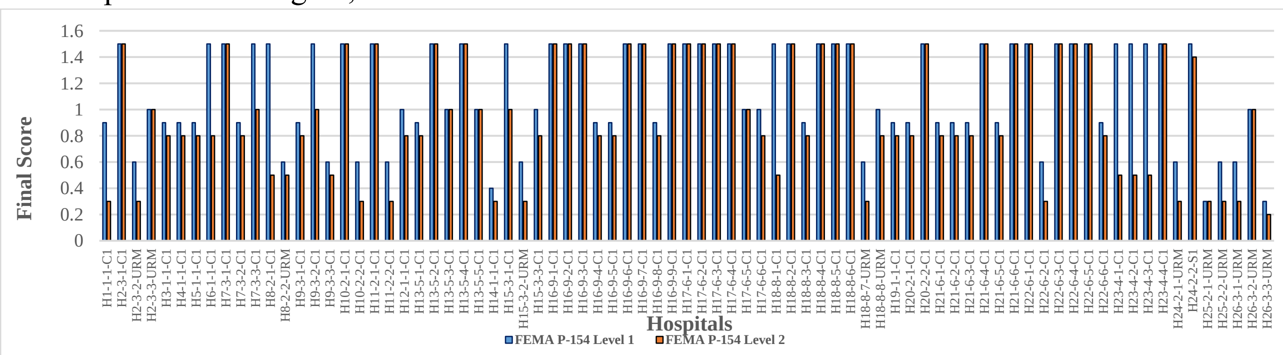


Fig. 8. Final Scores according to Level 1 and Level 2 of FEMA P-154 (2015) method.

The Final Scores of hospital buildings based on the level 1 were classified into six categories.

Two buildings had a Final Score of 0.3, one building had a Final Score of 0.4, 11 buildings had a Final Score of 0.6, 18 buildings had a Final Score of 0.9, 9 buildings had a Final Score of 1.0, and 38 buildings had a Final Score of 1.5, as shown in Figure 9.

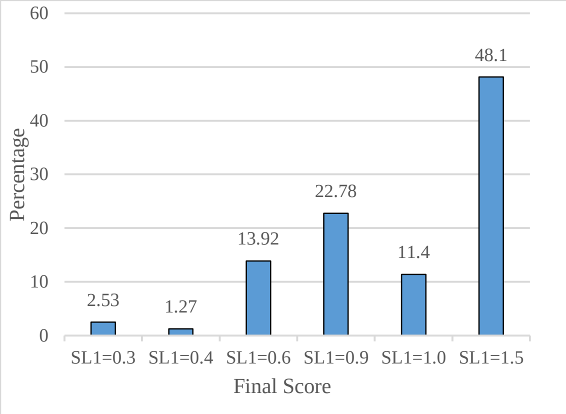


Fig. 9. Percentage of Final Scores according to FEMA P-154, 2015 Level 1 in 6 categories.

The Final Scores of hospital buildings based on the level 2 were classified into seven categories. Among 79 hospital buildings, one building scored 0.2, 12 buildings scored 0.3, 7 buildings scored 0.5, 22 buildings scored 0.8, 8 buildings scored 1.0, 1 building scored 1.4, and 28 buildings had a score of 1.5, as shown in Figure 10.

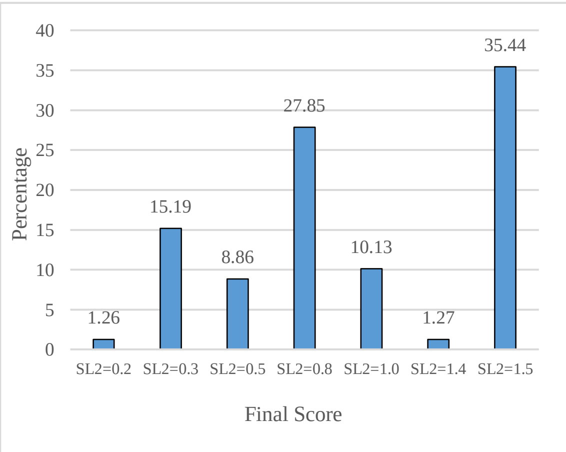


Fig.10. Percentage of Final Scores according to FEMA P-154, 2015 Level 2 in 7 categories.

According to the Final Score of each category that is shown in Figure 9, it is possible to estimate the probability of collapse for each category based on their Final Score from level 1. These probability of collapse is shown in Figure (11).

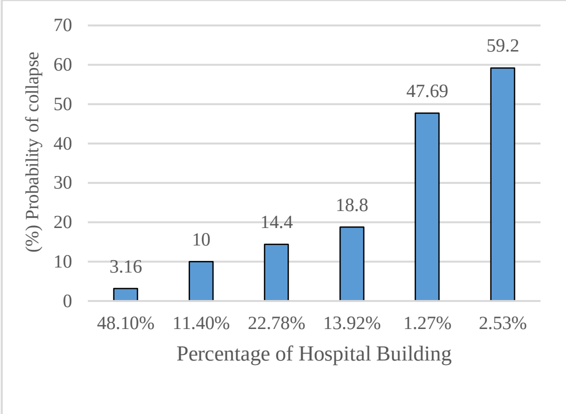


Fig.11. The probability of collapse of hospital buildings according to the Final Score at level 1.

According to the Final Score of each category that is shown in figure (10), the probability of collapse of each category can be estimated according to their Final Score from level 2, which is shown in figure (12).

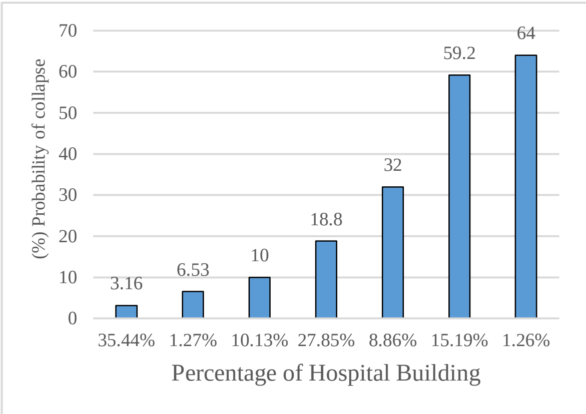


Fig.12. The probability of collapse of hospital buildings according to the Final Score at level 2.

6. Conclusions

Hospital buildings must be able to achieve immediate occupancy after the occurrence of natural disasters such as earthquakes. Therefore, estimating the level of vulnerability of existing hospital structures in the city due to the probability of earthquakes in the future is one of the most essential engineering measures. In this research, a comprehensive study was conducted to investigate and rapidly assess the level of seismic vulnerability of existing hospital buildings in Kabul City. Therefore, necessary information and features were collected in two levels according to FEMA P-154 criteria.

After collecting information and checking the structural characteristics of hospitals, FEMA P-154 data collection forms were completed at two levels, and then the Final Score was calculated. None of the hospital buildings received a Cut-Off Score (2).

The results of this research indicate that the assessed existing hospital buildings have probable seismic vulnerability during an earthquake, with varying degrees of probability ranging from low to high vulnerability. The probability of collapse for reinforced concrete hospital buildings in level 1 ranged from 3.16% to 47.6%, and in level 2, it ranged from 3.16% to 59.2%. The probability of collapse for unreinforced masonry hospital buildings in level 1 ranged from 3.16% to 59.2%, and in level 2, it ranged from 10% to 64%. Only the steel bending frame hospital building had a collapse probability of 3.16% in level 1 and 4.53% in level 2. The average Final Score in level 1 was 1.497, and in level 2, it was 1.272, indicating that the level 2 of FEMA P-154 is more conservative.

Based on the research findings, hospital buildings are prioritized according to the probability of collapse. That buildings with the highest probability of collapse must undergo detailed vulnerability assessment, and their retrofitting and rehabilitation requirements should be provided. Coordination between hospital authorities and relevant entities should be established for the implementation of earthquake preparedness measures. Financial resources should be provided for the retrofitting and rehabilitation of structures, as well as for the execution of preparedness programs. Buildings should also be evaluated from the point of view of non-structural and functional components. Hospitals that have not been assessed for seismic vulnerability assessment (such as defense, security, and private entities), especially private hospitals that often not originally designed for medical purposes, require seismic vulnerability evaluation. By carrying out these practical measures, hospitals will ensure the improvement of their preparedness in facing earthquakes and will provide better services in times of crisis.

Otherwise, if a destructive earthquake (such as the historic Paghman earthquake, which has a significant probability of occurring) were to strike and the hospitals are not able to provide immediate occupancy service, a human tragedy will ensue.

References

[1] P. Collier, P. Manwaring, and M. Blake, "Policy options for Kabul’s informal settlements," IGC Growth brief, International Growth Centre, London, 2018.

[2] R. L. Wheeler and K. S. Rukstales, Seismotectonic map of Afghanistan and adjacent areas: US Geological Survey, 2007.

[3] P. Tapponnier, M. Mattauer, F. Proust, and C. Cassaigneau, "Mesozoic ophiolites, sutures, and arge-scale tectonic movements in Afghanistan," Earth and Planetary Science Letters, vol. 52, pp. 355-371, 1981.

[4] P. J. Treloar and C. N. Izatt, "Tectonics of the Himalayan collision between the Indian plate and the Afghan block: A synthesis," Geological Society, London, Special Publications, vol. 74, pp. 69-87, 1993.

[5] U.-H. Afghanistan, "Seismic Hazard and Risk Assessment of Kabul and Mazar-i-Sharif; Risk Assessment is Piloted in 3 Gozars of Each City " January 2019.

[6] A. S. Arya, T. Boen, and Y. Ishiyama, Guidelines for earthquake resistant non-engineered construction: UNESCO, 2014.

[7] A. Menekşe and H. C. Akdağ, "Seismic risk analysis of hospital buildings: A novel interval-valued spherical fuzzy ARAS," Journal of Risk Analysis and Crisis Response, vol. 12, 2022.

[8] D. Perrone, M. Aiello, M. Pecce, and F. Rossi, "Rapid visual screening for seismic evaluation of RC hospital buildings. Structures," ed: Elsevier, 2015.

[9] D. Perrone, M. A. Aiello, M. Pecce, and F. Rossi, "Rapid visual screening for seismic

evaluation of RC hospital buildings," in Structures, 2015, pp. 57-70.
[10] C. Yao and Y. Tu, "The generation of earthquake damage probability curves for building facilities in Taiwan," in Proceedings of the International Symposium on Engineering Lessons Learned from the, 2011, pp. 1-4.
[11] D. Roshani and A. Karimian, "Earthquake Preparedness in Iranian Hospitals: A Systematic Review and Meta-Analysis," Bulletin of Emergency & Trauma, vol. 9, p. 1, 2021.
[12] G. P. Cimellaro, A. M. Reinhorn, and M. Bruneau, "Seismic resilience of a hospital system," Structure and Infrastructure Engineering, vol. 6, pp. 127-144, 2010.
[13] G. Monti and C. Nuti, "A procedure for assessing the functional reliability of hospital systems," Structural Safety, vol. 18, pp. 277-292, 1996.
[14] P. A. H. O. E. Preparedness and D. R. C. Program, Principles of disaster mitigation in health facilities: Pan American Health Org, 2000.
[15] A. F. Mohammad, R. A. Khan, M. A. Siddiqui, and M. Hammad, "Case Study: Rapid Seismic Assessment of Existing Hospitals in Karachi," Engineering Proceedings, vol. 22, p. 8, 2022.
[16] W. H. Organization, Hospital safety index: Guide for evaluators: World Health Organization, 2015.
[17] M. Ahmadi, H. Naderpour, A. Kheyroddin, and A. H. Gandomi, "Seismic failure probability and vulnerability assessment of steel-concrete composite structures," Periodica Polytechnica Civil Engineering, vol. 61, pp. 939-950, 2017.
[18] S.-Q. Li and Y.-S. Chen, "Vulnerability and economic loss evaluation model of a typical group structure considering empirical field inspection data," International Journal of Disaster Risk Reduction, vol. 88, p. 103617, 2023.
[19] D. Samadian, M. Ghafory-Ashtiany, H. Naderpour, and M. Eghbali, "Seismic resilience evaluation based on vulnerability curves for existing and retrofitted typical RC school buildings," Soil Dynamics and Earthquake Engineering, vol. 127, p. 105844, 2019.
[20] S. Ghaychi Afrouz, A. Farzampour, Z. Hejazi, and M. Mojarab, "Evaluation of seismic vulnerability of hospitals in the Tehran metropolitan area," Buildings, vol. 11, p. 54, 2021.
[21] R. Sinha and A. Goyal, "A national policy for seismic vulnerability assessment of buildings and procedure for rapid visual screening of buildings for potential seismic vulnerability," Report to Disaster Management Division, Ministry of Home Affairs, Government of India, Hindistan, pp. 1-9, 2004.
[22] A. F. C. Dya and A. W. C. Oretaa, "Seismic vulnerability assessment of soft story irregular buildings using pushover analysis," Procedia Engineering, vol. 125, pp. 925-932, 2015.
[23] N. Achour, M. Miyajima, M. Kitaura, and A. Price, "Earthquake-induced structural and nonstructural damage in hospitals," Earthquake spectra, vol. 27, pp. 617-634, 2011.
[24] K. D. Pitilakis, F. Taucer, U. Hancilar, and S. Argyroudis, Systemic seismic vulnerability and loss assessment: Validation studies: Publications Office, 2013.
[25] Y. Hooda and P. K. Goyal, "Seismic assessment of a hospital building: a case study," in IOP Conference Series: Earth and Environmental Science, 2021, p. 012006.
[26] R. Guragain and A. M. Dixit, "Seismic vulnerability assessment of hospitals in Nepal," in 13th World Conference on Earthquake Engineering (13, 2004, Vancouver, Canadá). Vancouver, Canadá, 2004.
[27] UNICEF, "Crisis appeal earthquake in Bam," ed: Iran, 2004.
[28] A. Ardalan, A. Najafi, A. Sabzghabaie, V. Zonoobi, S. Ardalan, H. Khankeh, et al., "A pilot study: Development of a local model to hospital disaster risk assessment," Hospital Journal, vol. 9, 2011.
[29] E. Miranda, G. Mosqueda, R. Retamales, and G. Pekcan, "Performance of nonstructural components during the 27 February 2010 Chile earthquake," Earthquake spectra, vol. 28, pp. 453-471, 2012.
[30] S. Clemente, J. Arreza, M. Cortez, J. Imperial, and M. Malabanan, "Risk assessment of seismic vulnerability of all hospitals in Manila using rapid visual screening (RVS)," in IOP Conference Series: Earth and Environmental Science, 2020, p. 012002.

[31] N. Bektaş and O. Kegyes-Brassai, "Conventional RVS Methods for Seismic Risk Assessment for Estimating the Current Situation of Existing Buildings: A State-of-the-Art Review," Sustainability, vol. 14, p. 2583, 2022.

[32] S. Ishack, S. P. Bhattacharya, and D. Maity, "Rapid Visual Screening method for vertically irregular buildings based on Seismic Vulnerability Indicator," International Journal of Disaster Risk Reduction, vol. 54, p. 102037, 2021.

[33] S. K. Jain, K. Mitra, M. Kumar, and M. Shah, "A proposed rapid visual screening procedure for seismic evaluation of RC-frame buildings in India," Earthquake Spectra, vol. 26, pp. 709-729, 2010.

[34] A. Aldemir, E. Guvenir, and M. Sahmaran, "Rapid screening method for the determination of regional risk distribution of masonry structures," Structural Safety, vol. 85, p. 101959, 2020.

[35] A. K. Sinha, "Rapid visual screening vulnerability assessment method of buildings: a review," International Journal of Advanced Technology and Engineering Exploration, vol. 9, p. 326, 2022.

[36] R. P. Nanda, N. K. Paul, and N. M. Chanu, "Seismic loss estimation tool as rapid survey for prioritizing buildings for disaster preparedness: case study to hospital buildings," Natural Hazards, vol. 95, pp. 769-781, 2019.

[37] B. Lizundia, S. Durphy, M. Griffin, W. Holmes, A. Hortacsu, B. Kehoe, et al., "Update of FEMA P-154: Rapid visual screening for potential seismic hazards," in Improving the Seismic Performance of Existing Buildings and Other Structures 2015, ed, 2015, pp. 775-786.

[38] M. Yadollahi, A. Adnan, and R. M. Zin, "Seismic vulnerability functional method for rapid visual screening of existing buildings," Archives of Civil Engineering, pp. 363-377-363-377, 2012.

[39] P. Kapetana and S. Dritsos, "Seismic assessment of buildings by rapid visual screening procedures," Earthquake Resistant Engineering Structures VI, vol. 93, p. 409, 2007.

[40] M. M. Kassem, S. Beddu, J. H. Ooi, C. G. Tan, A. Mohamad El-Maissi, and F. Mohamed Nazri, "Assessment of seismic building vulnerability using rapid visual screening method through web-based application for Malaysia," Buildings, vol. 11, p. 485, 2021.

[41] F. E. M. Agency, Rapid visual screening of buildings for potential seismic hazards: Supporting documentation: Government Printing Office, 2015.

[42] Y. Yang and K. A. Goettel, Enhanced rapid visual screening (E-Rvs) method for prioritization of seismic retrofits in Oregon: Oregon Department of Geology and Mineral Industries Portland, OR, USA, 2007.

[43] M. Ortiz-Barrios, M. Gul, P. López-Meza, M. Yucesan, and E. Navarro-Jiménez, "Evaluation of hospital disaster preparedness by a multi-criteria decision making approach: The case of Turkish hospitals," International journal of disaster risk reduction, vol. 49, p. 101748, 2020.

[44] E. Harirchian, T. Lahmer, S. Buddhiraju, K. Mohammad, and A. Mosavi, "Earthquake safety assessment of buildings through rapid visual screening," Buildings, vol. 10, p. 51, 2020.

[45] M. M. M. Aung and M. N. Aye, "Seismic Safety Assessment of Existing Low-rise RC Buildings with Rapid Visual Screenings and Preliminary Evaluation Methods," ASEAN Journal on Science and Technology for Development, vol. 38, pp. 29–36-29–36, 2021.

[46] A. Bhalkikar and R. P. Kumar, "A comparative study of different rapid visual survey methods used for seismic assessment of existing buildings," in Structures, 2021, pp. 1847-1860.

[47] O. S. Boyd, C. S. Mueller, and K. S. Rukstales, "Preliminary earthquake hazard map of Afghanistan," US Geological Survey Open-File Report, vol. 2007, p. 1137, 2007.

[48] M. Y. Essar, A. Nemat, Z. Islam, S. Ahmad, and J. Shah, "Devastating earthquake in Afghanistan amid a humanitarian crisis: a call for action," The Lancet Global Health, vol. 10, pp. e1244-e1245, 2022.

[49] K. Ethiopia and S. S. Somalia, "Public health round-up," Bull World Health Organ, vol. 100, pp. 468-469, 2022.