Harmonizing Seismic Vulnerability Data for Effective Seismic Risk Assessment: Expert Judgment Method and Findings from a Multi-Stakeholder Study in Indonesia

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Abstract

Seismic Risk Management (SRM) is crucial for mitigating the impact of earthquakes, encompassing earthquake preparedness, response planning, building design, and emergency management systems. The 2006 Yogyakarta earthquake in Indonesia resulted in significant loss of life, infrastructure damage, and economic impact, underscoring the importance of Seismic Risk Assessment (SRA) for effective risk reduction. Seismic vulnerability functions are commonly used for SRA, but data collection can be expensive and challenging, and results may be biased due to expert judgment. In Indonesia, variability in house damage state definitions among agencies poses challenges in harmonizing data. This study used expert judgment to harmonize differences in damage state variables resulting from variable references. Data on damage states from five (5) agencies were collected and harmonized through input from earthquake engineering experts via online questionnaires. The resulting data identified five (5) types of damage and reduced variables to nine through harmonization. Twenty (20) experts with diverse backgrounds, including academics, researchers, contractors, consultants, volunteers, and government stakeholders, participated in the study through online questionnaires, and the results were processed and analyzed. The expert judgment method successfully harmonized the differences in damage state variables, ensuring a consistent, reliable, and accurate assessment of building damage, particularly housing damage. The findings of this study underscore the crucial role of expert judgment in harmonizing data for seismic risk assessment. The survey gathered input from experts with diverse backgrounds, including government stakeholders and academics, enriched the study's findings and contributed to a comprehensive understanding of earthquake disaster management. Through expert judgment, the study successfully consolidated variables from different agencies into nine (9) harmonized variables for assessing building damage. Furthermore, experts proposed an additional fourteen (14) factors that need to be considered in residential house damage inspection forms, providing critical information for estimating the extent of damage and informing decisions about repairs or demolition. These variables can be categorized into Rapid Visual Screening (RVS) and observation in more detail, aiding in effective earthquake risk management. However, further validation through comparative literature and field analysis is needed to enhance accuracy and adaptability and explore the potential of incorporating soft computational algorithms in seismic vulnerability assessments as a promising approach.

Keywords: Seismic Risk Assessment, Expert Judgment, Damage State Variable, House

I. INTRODUCTION

Seismic Risk Management (SRM) encompasses a range of strategies and measures to minimize the impact of earthquakes and mitigate their potential consequences. These measures include earthquake preparedness, response planning, adherence to building design and construction standards, and implementing emergency management systems. Seismic risk management strategies are developed based on SRA results and aim to reduce the risk of loss of life, damage to infrastructure, and economic impact. In addition, seismic hazard depends on seismic zone area, and seismic vulnerability depends upon model building type and damage state affected by the hazard.

In SRA, two (2) commonly used methods are deterministic and probabilistic approaches. While deterministic models offer high precision, their complexity limits their application to only high-importance situations. Probabilistic models estimate seismic hazards and vulnerability based on historical and site-specific data, but they might not account for all uncertainties in SRM. In addition, assessing empirical vulnerability functions based on analytic studies can be expensive. It typically involves collecting a large amount of data on past earthquakes and the resulting damage and conducting statistical analysis to develop the vulnerability function. This can require significant resources and expertise and may be challenging in areas with limited infrastructure or resources.

The use of expert judgment to assess empirical vulnerability functions is often deemed cost-effective. However, it may lead to biased results due to personal biases, limited information, or a lack of understanding of statistical relationships. This issue is further complicated in Indonesia, where the choice of house damage state varies among five (5) agencies, making it challenging to harmonize the data. To address this issue, we utilized an expert judgment method to harmonize the differences in damage state variables resulting from variable references. This harmonization can be used as input for the government to assess building damage, especially for houses, quickly. In order to harmonize the numbers of differences due to various references in Indonesia, expert judgment, twenty (20) experts are involved in this study with the background of academics, researchers, contractors, consultants, volunteers and government stakeholders. First, these experts will assess using online questionnaire tools then the results are processed and analyzed. The technical guidelines of the Ministry of Public Works are frequently used in Indonesia for rapid inspection of building damage and refer to multiple sources such as the 2006 Ministry of Public Works guidelines, the Quick Inspection Manual for Damaged Concrete Buildings due to Earthquakes, NILIM 2002, and FEMA 154 [1], [2].

II. BACKGROUND OF THE STUDY

A. *The earthquake had an impact on house damaged*

Earthquakes affect human lives severely as thousands of people die. It can destroy buildings, factories, roads, and bridges and cause many people to become homeless. It will cause a loss of jobs and the country's income and make the economy unstable. Every year, around sixty-thousand (60,000) people die worldwide in natural disasters. Most deaths are caused by building collapses in earthquakes, and most occur in the developing world. Most of the deaths are even though engineering solutions exist that can almost eliminate the risk of such deaths [3]. For example, based on [4], in New Zealand year 1840-2017, Earthquake-related deaths were caused by building damage (431 deaths, 88%), ground damage (34 deaths, 7%), or other causes (24 deaths, 5%). Damage to at least ninety-five (95) unreinforced masonry (URM) buildings resulted in two hundred seventy-two (272) deaths, and damage to five reinforced concrete (RC) buildings resulted in one hundred forty- five (145) deaths. In the last 20 years, one of the earthquakes in Indonesia that claimed many lives was the 2006 Yogyakarta earthquake. The 6.3 magnitude Yogyakarta earthquake, which had its epicentre twenty (20) kilometres southeast of Yogyakarta city at 7.96200 S and 110.45800 E, caused massive damage. Over five thousand seventy hundred (5,700) people died, thirty-seven thousand nine hundred twenty-seven (37,927) were injured, and two hundred forty thousand three hundred ninety-six (240,396) houses were destroyed, leading to severe disruption of infrastructure, local, and economic activities [5].

B. *Seismic Risk Assessment*

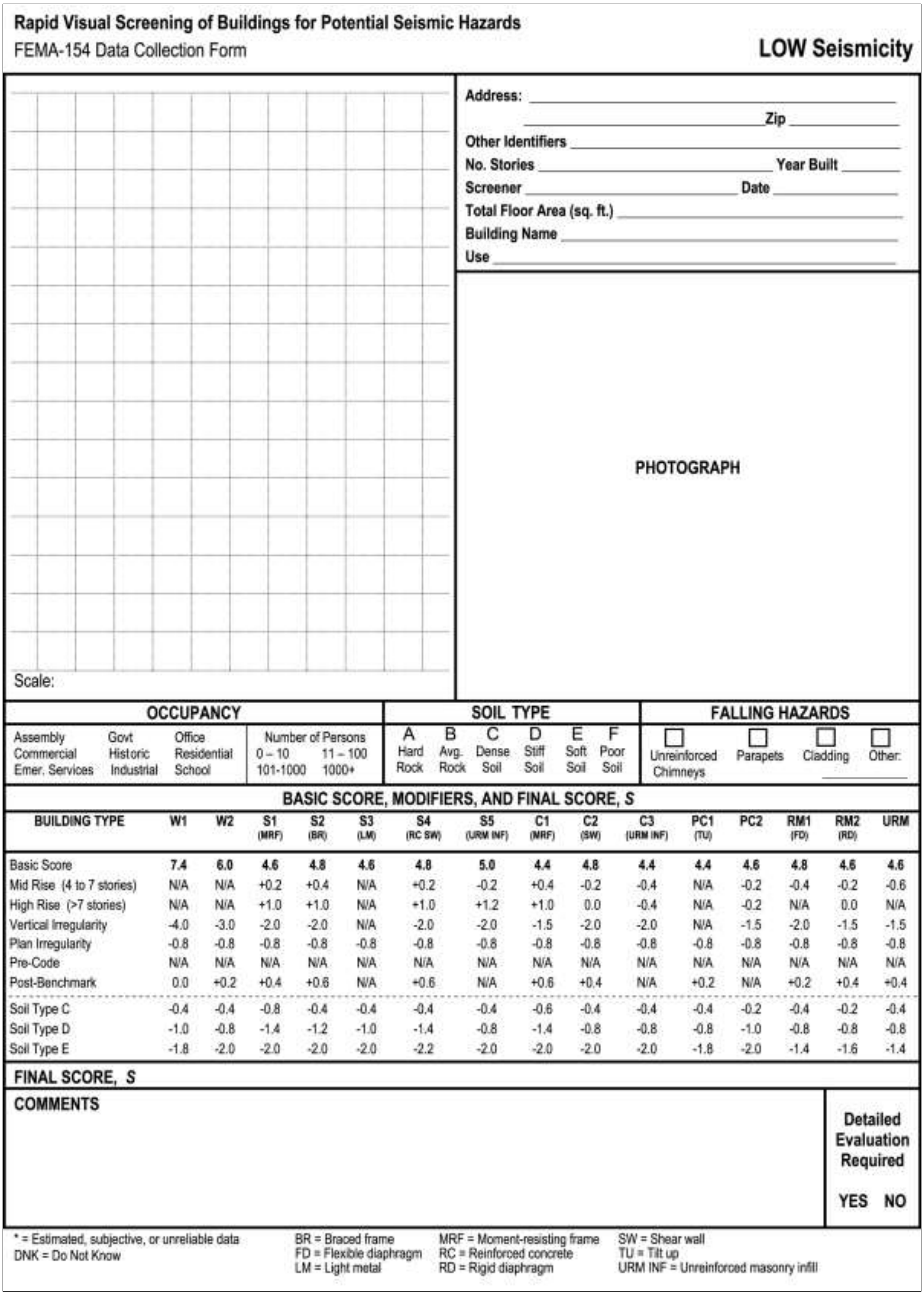
Seismic Risk Assessment (SRA) is crucial for effectively mitigating the risks of loss of life, infrastructure damage, and economic impact caused by seismic activity. However, seismic hazard intensity varies depending on the location's seismic zone. In contrast, a building's vulnerability is determined by its model type and the damage status caused by the seismic event. Therefore, a comprehensive set of criteria for distinct damage states can be utilized to speed the evaluation process to harmonize the assessment process for building damage, particularly housing damage. Using this method, SRA can quickly determine the proper response and mitigation actions needed to mitigate the impact of a seismic event.

C. *Indonesian House Damage State*

Five (5) different agencies determined Indonesia's data validity and choice of house damage state. There are 1) Direktorat Jenderal Cipta Karya - Departemen Pekerjaan Umum, 2) Badan Koordinasi Nasional (BAKORNAS), 3) Pusat Penelitian dan Pengembangan (Puslitbang) Permukiman Kementerian Pekerjaan Umum, 4) Badan Nasional Penanggulangan Bencana (BNPB), and 5) Kementeriaan Pendidikan dan Kebudayaan Direktorat Jenderal Pendidikan Anak Usia Dini (DIRJEN PAUD) dan Pendidikan Masyarakat (PERMAS) [6]–[9]. Therefore, the difference in the number of damaged houses and their categories, i.e., slight, moderate, extensive and complete damage, have different criteria. Hence, it needs to harmonize to get one (1) regulation.

D. *Building Structure Inspection Methods Building Against Earthquake Hazards*

Of the five (5) agencies, the one most frequently used for rapid inspection of building damage is the technical guidelines of the Ministry of Public Works. In 2022, the Ministry of Public Works issued Technical Guidance for Building Materials and Structures. This document explained that during quick inspections, the guidelines used were based on the 2006 Ministry of Public Works guidelines and the Quick Inspection Manual for Damaged Concrete Buildings due to Earthquakes, which NILIM published in 2002. The inspection guide also refers to FEMA 154, a Rapid Visual Screening guideline for developing ATC 21. The variables screened in the RVS are Seismic Design Code, Building Identity, Land Type, Building Function, Number of Building Levels, and Building Plans. Whereas in NILIM 2022, the variables screened in the RVS focus on structural elements (column and beam), as shown in Figure 1 [1], [2], [10]



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA-154 Data Collection Form

LOW Seismicity

Scale:

Address: ______________________________
______________________________ Zip ________
Other Identifiers ______________________________
No. Stories ______________________ Year Built ________
Screener ______________________ Date ________
Total Floor Area (sq. ft.) ______________________
Building Name ______________________
Use ______________________

PHOTOGRAPH

OCCUPANCY				SOIL TYPE	FALLING HAZARDS
Assembly Commercial Emer. Services	Govt Historic Industrial	Office Residential School	Number of Persons 0 – 10 11 – 100 101-1000 1000+	A Hard Rock, B Avg. Rock, C Dense Soil, D Stiff Soil, E Soft Soil, F Poor Soil	☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	7.4	6.0	4.6	4.8	4.6	4.8	5.0	4.4	4.8	4.4	4.4	4.6	4.8	4.6	4.6
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.2	-0.2	+0.4	-0.2	-0.4	N/A	-0.2	-0.4	-0.2	-0.6
High Rise (>7 stories)	N/A	N/A	+1.0	+1.0	N/A	+1.0	+1.2	+1.0	0.0	-0.4	N/A	-0.2	N/A	0.0	N/A
Vertical Irregularity	-4.0	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-1.5	-2.0	-2.0	N/A	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
Pre-Code	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Post-Benchmark	0.0	+0.2	+0.4	+0.6	N/A	+0.6	N/A	+0.6	+0.4	N/A	+0.2	N/A	+0.2	+0.4	+0.4
Soil Type C	-0.4	-0.4	-0.8	-0.4	-0.4	-0.4	-0.4	-0.6	-0.4	-0.4	-0.4	-0.2	-0.4	-0.2	-0.4
Soil Type D	-1.0	-0.8	-1.4	-1.2	-1.0	-1.4	-0.8	-1.4	-0.8	-0.8	-0.8	-1.0	-0.8	-0.8	-0.8
Soil Type E	-1.8	-2.0	-2.0	-2.0	-2.0	-2.2	-2.0	-2.0	-2.0	-2.0	-1.8	-2.0	-1.4	-1.6	-1.4

FINAL SCORE, S

COMMENTS

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know
BR = Braced frame
FD = Flexible diaphragm
LM = Light metal
MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm
SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Figure 1. Variable for Quick Assessment Visual Screening caused by Earthquake - FEMA 154 [2]

Damage Rank	Column width > 40cm	Column width < 40cm	Beam - Column Joint	Beam
Rank I Slight	Visibly narrow shear cracks (Crack width < 0.2 mm)	No shear cracks	No shear cracks	Visibly narrow shear cracks (Crack width < 0.2 mm)
Rank II Light	Visibly clear shear cracks (0.2 < Crack width < 1 mm)	Visibly clear shear cracks (Crack width < 0.2 mm)	No shear cracks Spalling of column corner concrete	Visibly clear shear cracks (0.2 < crack width < 1 mm)
Rank III Medium	Wide cracks (1 < Crack width < 2 mm) Local crush of cover concrete and small-exposure of reinforcing bars may be observed	Visibly clear shear cracks (Crack width < 0.2 mm)	No shear cracks Spalling of cover concrete joint	Wide or big shear cracks (1 < crack width < 5 mm) Local crush of core concrete and small-exposure of reinforcing bars may be observed
Rank IV Heavy	Big cracks (Crack width > 0.2 mm) Massive Spalling of cover concrete and extensive exposure of reinforcing bars are observed But buckling of the reinforcing bars is not observed	Big cracks (Crack width > 2 mm) Spalling of cover concrete Exposure of reinforcing bars without buckling	Diagonal shear cracks Spalling of cover concrete joint	Big shear cracks (Crack width > 5 mm) Extensive Spalling of cover Concrete Extensive exposure of reinforcing bars
Rank V Collapse	Buckling and/or breaking of reinforcing bars Crush of core concrete Visible settlement and/or incilnation of floor	The sama as left	Buckling of reinforcing bars Crush of core concrete Visible vertical deformation of joint	Buckling and/or breaking of reinforcing bars Visible settlement and/or inclination of floor

Figure 2. Variable for Quick Assessment Visual Screening caused by Earthquake - NILIM 2022 [1]

E. Expert Judgment

In order to harmonize the numbers of differences due to various references in Indonesia, expert judgment, twenty (20) experts are involved in this study with the background of academics, researchers, contractors, consultants, volunteers and government stakeholders. First, these experts will assess the questionnaire online using SurveyMonkey tools to provide an assessment ranking of the variables published by five (5) different agencies. Then the results are processed and analyzed.

F. Survey Research

Survey research is a valuable method for collecting opinions, beliefs, and sentiments from selected demographic groups through various modes of distribution, including face-to-face, paper, telephone, and web-based surveys, with the data gathered accessible to various parties in secondary research. This approach can also be applied to experts in the field of disaster, primarily related to damage to houses due to earthquakes, providing valuable insights into best practices for mitigating and responding to such events. Careful consideration of factors such as content, wording, response design, question arrangement, and sequence can help ensure the accuracy and informativeness of the responses. Additionally, the comprehensive set of criteria for different damage states can be applied to expedite the evaluation process for building damage and determine appropriate response and mitigation measures. Using survey research is an invaluable means of improving decision-making and enhancing response strategies in disaster management. Online survey development tools, such as SurveyMonkey, a cloud-based software service company founded by Ryan Finley in 1999, have been developed to facilitate the process of conducting survey research. These online survey tools allow users to customize surveys free of charge and utilize paid back-end programs that include a range of advanced features, including data analysis, sample selection, bias elimination, and data representation tools. By leveraging such online tools, survey research can be conducted with greater accuracy and efficiency, significantly bolstering its efficacy in disaster management. The survey research process and SurveyMonkey's services can aid in decision-making and improving response strategies in disaster [11], [12].

III. METHODOLOGY

A. Collect Damage States Data

In order to accurately assess the potential damage and inventory of elements at risk, it is crucial to collect and harmonize information on damage states from the five (5) agencies involved. By doing so, the resulting data will be more reliable and enable a more systematic inventory of the elements at risk and their relative value and vulnerability. Obtaining local seismic risk assessment criteria is possible by harmonizing and improving data on damage states. This information is crucial for developing effective measures to mitigate the risks posed by seismic events. With accurate risk assessment criteria, communities can take necessary precautions and plan for potential disasters, reducing the impact of earthquakes on people's lives and infrastructure.

B. Collect Earthquake Engineering Expert

Experts in earthquake disaster management must complete research questionnaires about their experience with rehabilitation, reconstruction, research, inspection, and housing damage. By providing insights and information through the questionnaires, these experts can help improve housing damage data. A total of twenty (20) experts, including academics, researchers, contractors, consultants, volunteers, and government stakeholders with extensive experience in earthquake disaster management, including the 2004 Aceh Earthquake, the 2006 Yogyakarta Earthquake, the 2009 Padang Earthquake in West Sumatra, the 2018 Palu Earthquake, the 2020 Pangandaran Earthquake, the 2018 Lombok Earthquake, and the 2018 Banjarnegara Earthquake, were involved in this research.

C. Survey Design

Online methods were employed to distribute questionnaires related to residential home damage criteria in Indonesia. To facilitate this, SurveyMonkey was used to administer the questionnaires online. Despite the challenges posed by the pandemic, the data needed to inform the research was successfully collected and analyzed. Interviews were conducted either web-based using SurveyMonkey or in person. Qualitative data were primarily collected using SurveyMonkey, allowing interviewees to think before responding to questions. SurveyMonkey, an online survey tool that allows for creating and conducting surveys without paper and pen, was easy to use, with a familiar user interface design and various survey templates. The reporting feature was also helpful for marketing surveys to improve marketing skills and techniques. However, the free plan has weaker security than the paid one, exposing users to the risk of stealing their survey data [13]. The survey comprised three sections: 1) Collecting expert data profiles, 2) Collecting data on experts' experience in earthquake disaster management related to residential damage, and 3) Collecting data on respondents' perceptual assessment of building damage criteria. The first (1^{st}) section aimed to establish respondents' credentials and ensure they had the qualifications and experience to provide accurate information and insights on the subject. The second (2^{nd}) section aimed to identify experts with practical experience in responding to earthquake disasters and direct knowledge of the damage that can occur to residential homes. The third (3^{rd}) section provided valuable information on how experts evaluate and prioritize earthquake damage types, identify critical factors essential to harmonize damage states, and then analyze .

IV. RESULT AND DISCUSSION

According to a survey conducted by SurveyMonkey.com, forty per cent (40%) of the experts in this study are government stakeholders with an average of twenty-five (25) years of experience in earthquake disaster management. In the meantime, thirty per cent (30%) are academics with an average of thirty-four (34) years of experience in this field. Figures 1 and 2 show the remaining participants. This diverse group of experts contributes valuable insights from various angles, enriching the study's findings and contributing to a more comprehensive understanding of earthquake disaster management.

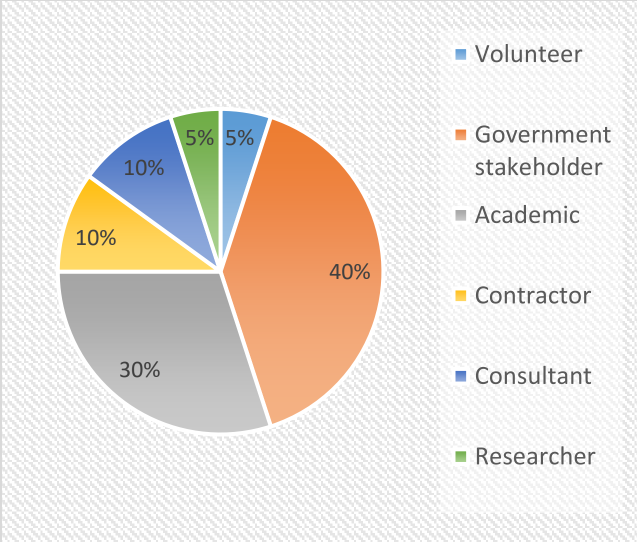


Figure 3. Data Profile of Experts

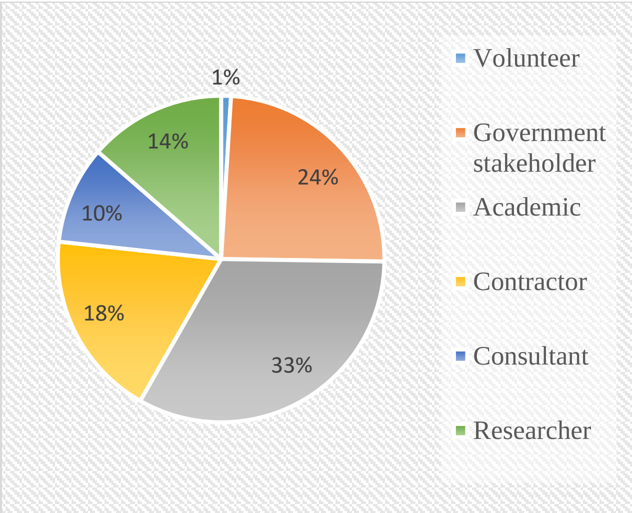


Figure 4. Data Experience in Earthquake Disaster Management Related to Residential Damage

Based on the experience of experts, seventy per cent (70%) agreed that there were five (5) types of damage, namely slight, moderate, extensive and complete. In comparison, thirty (30%) answered that they disagreed because it was completely damaged, included in the extensive category, as shown in Figure 3.

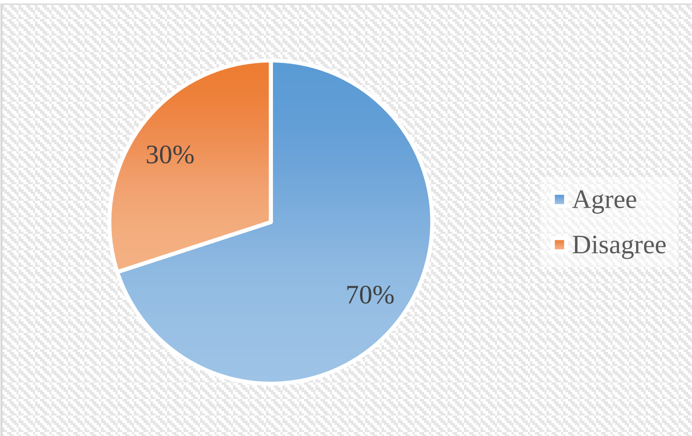


Figure 5 Comparison between experts who agree with the five (5) damage categories (slight, moderate, extensive, and complete) with those who disagree

Based on Figure 3, the experience of experts, seventy per cent (70%) answered that the variables needed to be reduced, and thirty per cent (30%) answered that the variables did not need to be reduced, as shown in Figure 4.

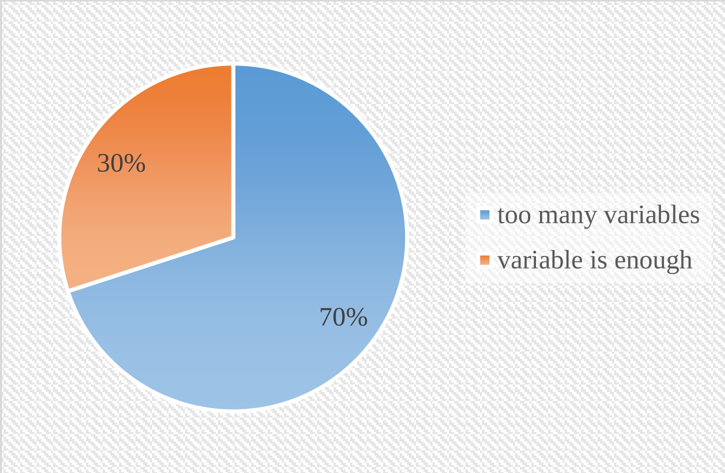


Figure 6. House Damage Variable

According to Figure 4, the reasons for too many variables were stated by seventy per cent (70%) of the experts, so it is necessary to reduce two (2) variables, namely Floodgate and Channel Irrigation so that there are only nine (9) new variables after harmonization, consisting of 1) Walls, 2) Wall Plastering, 3) Non-Structural Elements, 4) Structure, 5) Building condition, 6) Roof covering/tiles, 7) Ceiling, 8) Electrical Installation; and 9) Doors/Windows, as shown in Table I.

TABLE I. DIFFERENCES IN BUILDING DAMAGE VARIABLES ACCORDING TO PREVIOUS AND CURRENT STUDIES

Variable of Damage	**PU-Cipta Karya (2006)**	**BAKORNAS (2006)**	**BNPB (2011)**	**PU-Puslitbang Permukiman (2013)**	**DIRJEND PAUD dan PENMAS (2019)**	**PU-Puslitbang Permukiman (2019**	**Harmonize Variable from Expert**
Wall	V			V		V	V
Plastering the wall	V	V	V	V		V	V
Wide	V						
Non-structure element	V				V	V	V
Structure	V		V	V		V	V
Building condition	V	V	V			V	V
Roof/tile cover		V					V
Ceiling		V		V			V
Electrical installation		V					V
Door/ window		V					V
Floodgate			V				
Channel irrigation			V				

After being analyzed, there were fourteen (14) additional factors from the expert, namely: 1) Type of soil, 2) Floor conditions, 3) Lintel beam, 4) Structure type (wood, steel, reinforced concrete, masonry), 5) Foundation, 6) Types of roof structures (wood, mild steel, concrete, mountains, 7) Roof wind ties, 8) Wall anchor ties with structure, 9) Age of building, 10) Distance of the building from the source of the earthquake, 11) Dimensions of the largest/widest wall, 12) Slope of the building, 13) Building height, 14) Potential of surrounding buildings to damage affected buildings, as shown in Table II.

TABLE II. ADDING A NEW VARIABLE OF INDONESIA CATEGORY DAMAGES

No	Variable	A brief overview of how each variable can be used
1	Type of soil	The soil type can affect the level of shaking that the house experiences during an earthquake, which can impact the extent of the damage.
2	Floor conditions	The condition and quality of the floors can impact the building's ability to withstand shaking and can affect the extent of the damage.
3	Lintel beam	The condition of the lintel beam can impact the stability of the walls,
4	Structure/Building type (wood, steel, reinforced concrete, masonry)	The type of structure can impact the level of seismic resistance and, thus, the level of damage.
5	Foundation	The foundation can impact the building's ability to withstand shaking and can affect the extent of the damage.
6	Roof type (wood, mild steel, concrete, mountains	The type of roof structure can impact the building's ability to withstand shaking and can affect the extent of the damage.
7	Roof wind ties	The presence of roof wind ties can improve the building's stability and reduce the extent of the damage.
8	Wall anchor ties with structure	The presence of wall anchor ties can improve the building's stability and reduce the extent of the damage.
9	Age of building	Older buildings may have less earthquake-resistant designs and materials, which can increase the extent of the damage.
10	Distance of the building from the source of the earthquake	Buildings closer to the earthquake source are likely to experience more shaking and, thus, more damage.
11	Dimensions of the largest/widest wall	Larger walls may be more vulnerable to damage during an earthquake.
12	The slope of the building	Buildings on steep slopes may be more vulnerable to damage during an earthquake due to potential landslides or sliding of the building itself.
13	Building height	Taller buildings are generally more susceptible to damage from earthquakes.
14	The potential of surrounding buildings to damage affected buildings	Nearby buildings that collapse or suffer extensive damage can cause additional damage to other buildings in the area.

If evaluated with descriptive statistics, it means that there are twenty-three (23) variables proposed by experts that need to be prepared in the residential house damage inspection form, as shown in Table III.

TABLE III. HARMONIZE NEW VARIABLES OF INDONESIA, CATEGORIZE DAMAGES

No	Variable	No.	Variable
1	Type of soil	13	Building height
2	Floor conditions	14	The potential of surrounding buildings to damage affected buildings
3	Lintel beam	15	Walls
4	Structure/Building type (wood, steel, reinforced concrete, masonry)	16	Wall Plastering
5	Foundation	17	Non-Structural Elements
6	Roof type (wood, mild steel, concrete, mountains	18	Structure Elements
7	Roof wind ties	19	Condition of the building
8	Wall anchor ties with structure		
9	Age of building	20	Roof covering/tiles
10	Distance of the building from the source of the earthquake	21	Ceiling
11	Dimensions of the largest/widest wall	22	Electrical Installation
12	The slope of the building	23	Doors/windows

Taking into account the variables in Table III can provide critical information for estimating the extent of damage a house may sustain in an earthquake. It can also help inform decisions about needed repairs or potential demolition. It can be divided as follows: 1) Rapid Visual Screening and 2) Observation in more detail, as shown in Table IV.

TABLE IV. RAPID VISUAL SCREENING AND OBSERVATION IN MORE DETAIL

No.	Rapid Visual Screening	No.	Observation in more detail
1	Floor conditions	1	Type of soil
2	Lintel beam	2	Foundation
3	Structure/Building type (wood, steel, reinforced concrete, masonry)	3	Distance of the building from the source of the earthquake
4	Roof type (wood, mild steel, concrete, mountains		
5	Roof wind ties		
6	Age of building		
7	Dimensions of the largest/widest wall		
8	The slope of the building		
9	Building height		
10	The potential of surrounding buildings to damage affected buildings		
11	Walls		
12	Wall Plastering		
13	Non-Structural Elements		
14	Condition of the building		
15	Roof covering/tiles		
16	Ceiling		
17	Electrical Installation		
18	Doors/windows		
19	Structure Elements		
20	Wall anchor ties with structure		

Based on Table IV, it can be seen that the analysis of observations that require more detailed tools is the type of soil, foundation and distance to the earthquake source. This right is due to the need for additional tools to check it, in contrast to the Rapid Visual Screening (RVS) column, which can be seen immediately. This initial study needs to be reviewed because it needs more comparative literature and analysis according to field conditions, such as FEMA 154 or NILIM 2022.

The traditional RVS has inaccuracies. Several studies have been carried out to evaluate, compare, implement, develop, and improve the RVS technique [14]. According to [15], the accuracy of RVS FEMA P-154 and EMPI techniques is less than 30%. Conventional RVS techniques, which rely on expert opinion, are also difficult to improve. In recent years, a soft RVS (S-RVS) method has been developed to address these limitations. Soft computational algorithms such as machine learning, fuzzy logic, and neural networks are used in the S-RVS method. The parameters used in traditional RVS methods were identified in order to create the S-RVS method, which is based on fuzzy logic and can quickly adapt to recent progress and data from previous earthquakes. Some parameters, such as wall density, vertical irregularity, plan irregularity, wall slenderness, and wall openings, may need to be included in the S-RVS assessment. The parameters listed in Table IV must be evaluated in greater detail in this preliminary study, which has been further developed in other studies [14]–[16].

V. CONCLUSION

The results and discussions of this study highlight the importance of expert judgment in harmonizing data for seismic risk assessment. The survey among experts with diverse backgrounds, including government stakeholders and academics, enriched the study's findings and contributed to a comprehensive understanding of earthquake disaster management. The study successfully reduced variables from different agencies through expert judgment, resulting in nine (9) harmonized variables for assessing building damage. Additionally, the study identified fourteen additional factors proposed by experts that need to be considered in residential house damage inspection forms, providing critical information for estimating the extent of damage and informing decisions about repairs or demolition. The variables can be categorized into Rapid Visual Screening and observation in more detail, aiding in effective earthquake risk management. However, further validation through comparative literature and field analysis is needed. The potential of incorporating soft computational algorithms in seismic vulnerability assessments presents a promising approach for improving accuracy and adaptability.

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