

A Model to Determine the Degree of Housing Damage for Flood-Affected Area: A Preliminary Study

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Abstract Recent years, global warming and ozone depletion had impacted people's lives in many ways. In Malaysia, floods have become a common phenomenon caused by a combination of natural factors such as heavy monsoon rainfall and human factors like poor drainage system and deforestation. Heavy year-round rainfall has led to "spillover" effect bringing heavy rains and subsequent flooding. Floods can cause damage to housing and its possession as well as disruption to communication. At times, relocation is deemed necessary. In reality, flood victims are relocated or evacuated to a safe area provided by the authorities but some run to their own shelter. Therefore, the focus of the government is to accelerate the construction of permanent houses for the affected people. The question arises whether the estimated replacement needs took into account the degree of damage to the affected homes? Do they really deserve to receive the permanent house based on the condition of their house post-flood? Is the condition of the house deemed acceptable by end users? Thus, this preliminary study emphasizes on the understanding of the degree of housing damage after a flood, and the findings provide a conceptual model for the degree of housing damages in the Malaysian context.

Keywords Flood · Flood disaster · Flood housing damages · Damage assessment · Degree of housing damages

1 Introduction

The past few decades have witnessed a rapid expansion of population in Malaysia. The population was 10,881,000 in 1970, but in 2013, the statistics indicated that the population in Malaysia has risen to 29,947,600 (Malaysian Department of Statistics [1]). The increasing population has resulted in an increase in the number of property

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ownership. Therefore, a greater percentage of the country's land area, often in areas that previously were seen as being unsuitable for urban development and human settlement, are taken up to cater to the need for accommodation [2,3]. This increased number of properties, changes in water collection and flows and poor drainage system coupled with heavy monsoon rainfall, intense convection rainstorms, and other local factors have caused seasonal floods in Malaysia [3,4]. In recent years, floods have become very common. Following such disaster, there is often a tally of the preliminary damage assessment with respect to the injuries, loss of lives, cost of damage, and destroyed properties. With these disasters attracting considerable media attention, people are more aware of the damage that occurred at the affected area [5]. There have been numerous studies pertaining preliminary damage assessment to buildings after a flood. A variety of damage assessments had been carried out in different countries after the event of a natural disaster. There are several guidelines for assessing the degree of building damage prepared by government agencies, researchers, local authorities, and nongovernmental organization (NGO). In 2009, Attaullah Shah, Hamid Mumtaz Khan, and Ehsan U. Qazi outlined the evaluation of the buildings destroyed or damaged due to the flooding in Pakistan. The evaluation of damage is made on mud houses which are the most common type of building structure in Pakistan [6]. In USA, Federal Emergency Management Agency (FEMA) has developed an operations manual to standardize the procedures in preliminary damage assessment nationwide. There are several state authorities in USA, like New Jersey and Florida, which reviewed this operation manually and did some modification to suit the type of disasters that their states often experienced. Apart from that, there are also numerous literatures that emphasized on residential properties damaged from hurricanes and floods [7, 8]. In concordance with the variety of the degree of housing damage, different countries are likely to have different construction methods, materials used, and the nature of the flood. A general assessment that determines the extent of flood-hit houses seems irrelevant in other countries. Moreover, in Malaysia, there is still no standardized damage assessment used by the authorities or relevant agencies in assessing the degree of housing damages after a disaster. As a result, errors in assessing the degrees of housing damages and providing inaccurate type of assistance might occur. Furthermore, the attributes for each degree of damage are not coherent because a detailed description on the attributes for each degree of damage has not been prepared yet. Thus, the attribute model from a synthesis of existing eight degrees of housing damages will be laid out. These models might not be comprehensive in listing the attributes, in which many could be added, but these attributes are sufficed to illustrate the research aims and objectives of this research.

2 The Attribute Model of the Degrees of Housing Damages for Flood-Affected Area

2.1 European Macro-Seismic Scale 1998 (EMS-98)

The EMS-98 is the basis for the evaluation of seismic intensity in European countries and is also used in a number of countries outside Europe. The category of disaster to apply this model is primarily for earthquake and post-earthquake disaster such as tsunami, landslide, and flooding. However, this model only applies to reinforced concrete type of buildings. The first scale has 12 divisions for seismic loads, but for flood disaster, the damage classification scale is only classified into six divisions: Grade 0, Grade 1, Grade 2, Grade 3, Grade 4, and Grade 5. The grade takes into consideration structural and non-structural elements. Structural elements are the main structures such as foundation, beams, columns, roofs, floors, and load-bearing walls, whereas non-structural elements are gutters, chimneys, plaster ceilings, siding, and others.

According to the EMS-98, *Grade 5* refers to destruction which means very heavy structural damage. The attributes for *Grade 5* include structures that are totally destroyed or nearly collapsing. The function of the affected house is no longer usable and restored. For *Grade 4*, EMS-98 indicates that the building structures received very heavy damage which consist of heavy structural damage and very heavy non-structural damage. The attributes for *Grade 4* are serious failure of walls and partial failure of roofs and floors. Meanwhile, in *Grade 3*, the structures dealt with substantial to heavy damage which means the affected house has moderate structural damage and heavy non-structural damage. The attributes are fractured at the roofline, failure of non-structural elements like partitions and gable walls. There is a large and extensive crack in most walls. Roof tiles detached. *Grade 2* damage scale means the affected house is moderately damaged with slight structural damage and moderate non-structural damage. The attributes are cracks in many walls, fall of fairly large pieces of plaster, and partial collapse of chimneys. Last but not the least is *Grade 1*. In *Grade 1*, there is no structural damage but only slight non-structural damage. The attributes are hairline cracks in very few walls, fall of small pieces of plaster, and loose stones from upper parts of buildings in very few cases.

2.2 Green Alert Damage Assessment Manual

The Damage Assessment Manual by Green Alert in the UK is based on Windshield Survey (2004) that provides information to determine the severity of the disaster and type of disaster assistance that may be required. In this manual, the person responsible will assess the affected house caused by natural or man-made disasters. The type of building structure is for masonry and wood frame buildings. The degree

of damage is destroyed 80 %, major 30 %, minor 5 %, affected but habitable, and inaccessible [9].

Destroyed 80 % indicates that the building structures no longer exist or are severely damaged to the extent that it is no longer usable and that restoration is not technically possible or economically feasible. The attributes for destroyed 80 % damage are moved off foundation, two exterior walls collapsed, second floor is gone, structure leveled above foundation, or two or more basement walls collapsed. *Major* damage indicates the structure cannot be used or may be used under limited conditions or reduced levels of service or may be restored to a mere dwelling with extensive repairs. The structure damage is over 10 % but less than 80 % and averages at 30 %. The affected house cannot be occupied within a short period, if ever, because the necessary repairs are too time-consuming or not practical. The attributes for major damage may constitute utility damages such as well, septic system, electrical service, or gas. One or more rooms destroyed, one exterior wall collapsed, or exterior frame damaged. Roof off or collapsed and foundation damaged, bowed or collapsed wall. *Minor* damage means the structure may still be used for its intended purpose or may be repaired with minimal repairs, and the damage is less than 10 % and averages about 5 % damage. The affected house with minor damage may be occupied after repairs have been accomplished. These repairs should be accomplished within one or two weeks. The attributes for minor damage may constitute roofing/shingles removed or exposing sheathing, exterior or interior wall cracks. *Affected but habitable* damage is the affected house is habitable with no repairs needed. The attributes for affected but habitable damage are cosmetic damages such as shutters, gutters, shingles, and siding. *Inaccessible* degree of damage is the condition when the affected house is not accessible due to damage to a road or bridge, or the affected house is surrounded by water and only accessible by boat.

2.3 *Florida Division of Emergency Management*

In Florida (USA), as it is vulnerable to a host of natural and man-made disasters, local governments may contact Florida Department of Community Affairs, Division of Emergency Management, to initiate assistance for damage assessment. Immediately following a disaster, an initial damage assessment must be carried out by them to estimate the type and extent of damages [10]. The degree of damage model they use is sorted into five degrees of damage levels: destroyed, major, minor, affected but habitable, and inaccessible. The model is influenced by the Federal Emergency Management Agency (FEMA) of USA, however, with few improvements on the structure damage attributes.

The most sever level of damage is *destroyed*. According to the Florida Emergency Management Division, destroyed indicates that the structure of a particular affected house is not economically feasible for reparation, permanently inhabitable. The damage will consist of a complete failure of major structural

components or attributes such as collapse of basement, foundation, walls, basement walls, or roof. For *major* degree of damage, they outlined that the affected house has sustained significant damage to the building structures, becomes inhabitable, and requires extensive repairs. The damage on the structures will take more than 30 days to repair. The damage will have substantial failures to walls, floors, foundation, or roof that has more than 50 % damage to the structure. *Minor* degree of damage, as it is the most common type of damage, exists when the affected house has less than 50 % damage to structure like floors and walls that are habitable after repairs in 30 days. *Affected* degree of damage means that the affected house is still habitable with some damage to structure and contents. The affected house may be hit by flood, but only damage its contents. In the event of *inaccessible* degree of damage, the house is inaccessible by normal means due to road closure and road covered by water; the road is impassable of a landslide or bridge collapse.

2.4 Earthquake Engineering Field Investigation Team of Japan (EEFIT)

EEFIT was formed as a joint venture between industries and universities. Each country has their own team that will visit affected regions for data collection to improve the understanding of structural behavior of natural disasters especially seismic loads. In Japan, EEFIT mission team made some modification to the damage assessment model from EMS-98. The degree of damage is divided into 5: no damage (DM0), light damage (DM1), moderate damage (DM2), heavy damage (DM3), and collapse (DM4).

DM4 or destroyed refers to complete structural damage or collapse. The attributes are foundations are visible, floor slabs are exposed, heavy foundation damage, collapse of large sections of foundations, and structures due to heavy scouring. Next is *DM3*. *DM3* or heavy damage refers to inhabitable after disaster. The attributes are collapse of masonry wall panels beyond repair and structural integrity compromised. Most parts of the structure suffered collapse. There is excessive foundation settlement tilting beyond repair. The wall sections collapsed due to scouring and the damage is non-repairable. The affected house requires demolition since it is not suitable for occupancy. Then, *DM2* refers to moderate damage which the structures dealt with collapse of parts of masonry wall panels without compromising structural integrity. The attributes include that most parts of the structures are still intact with some parts suffering heavy damage. Scouring at corners of the structures leaving foundations partly exposed but could be repaired by backfilling. Cracks caused by undermined foundations are clearly visible on walls but not critical. The affected house is not suitable for immediate occupancy. Light damage or *DM1* refers to slight non-structural damage. The damage attributes are only limited to chipping of plaster on walls, minor and very few visible cracking, damage to windows and doors. The damage is repairable and the building can be occupied immediately and

therefore no damage. There is no visible damage to the building main structures during the survey.

2.5 National Disaster Management Agency of Indonesia (BNBP)

In the event of natural disaster in Indonesia, especially earthquakes which are more common than floods, the National Disaster Management Agency (BNPB) will lead in coordinating and facilitating the recovery, reconstruction, and rehabilitation process. Preliminary damage and needs assessment are necessary in the delivery of assistance addressing the specific needs for particular vulnerable groups of affected victims. In assessing the damage, BNPB uses a model that distinguishes three degrees of property damage: light damage, moderate damage, and heavy damage [11]. *Heavy damage* refers to total collapse or destruction that it seems economically unwise to restore the condition of the affected house. The attributes that belong to heavily damaged degree of damage are large openings at the ground floor or collapse of first floor and leveled building structure. *Moderate damage* means the building structure is still habitable with major reparation and is economically wise. However, no attributes or detailed description of this degree of damage were given. *Light damage* indicates that the affected house is still habitable with only minor damage to non-structural elements. Attributes for the non-structural damage were also not provided.

2.6 New Jersey State Police Office of Emergency Management

New Jersey State Police Office of Emergency Management produced a preliminary damage assessment in any event of natural disasters, especially in the event of a hurricane. Based on FEMA Preliminary Damage Assessment (PDA), they did some modification on damage scale and only categorized it into 4 degrees: affected, minor, major, and destroyed. The attributes are similar with the FEMA's PDA and therefore only discuss the damage scale descriptions. The only missing damage scale is inaccessible damage scale as in FEMA's PDA, and inaccessible is one of the damage scale that constitutes the damage assessment model. *Destroyed* means the structures of the affected house are totally loss or damaged to the extent that it does not function as a place to dwell and also not economically repairable. Next is *major*. The structures are damaged to the extent that it is no longer usable and may return to its existing functions only with extensive repairs. *Minor* damage is when the structure is slightly damaged but may be occupied under limited conditions, whereby restored within a short period of time. Lastly, it is *affected*. Some damage

to the structure but still habitable and only slight damage to building contents. This kind of damage requires no repair and can be occupied immediately.

2.7 Henry B. Hodde III Damage Assessment Model

Although FEMA has prescribed specific guidelines for the damage assessment procedure, Henry [2] stressed that most communities or state organizations use slightly different protocols and methods in assessing property damage caused by natural disasters. In his research, he laid several damage assessment models from thirteen local governments and came out with an improvised degree of damage assessment. He further categorized the damage into four degrees: category 1, category 2, category 3, and category 4. However, this category of damage only described the structure damage but did not explain the details of structure damage attributes. In *category 4*, the structures identified have been completely destroyed and/or washed away. In *category 3*, the structures identified to have major damage and considered to be unsafe and/or experienced substantial damage. By all means, the affected house needs major repairs or rebuilding, whereas in *category 2*, the structures identified with some damage could be considered to be safe and structurally sound. The damages would not be considered as being substantially damaged. Lastly, *category 1* is identified as minimal damage on structures.

2.8 Federal Emergency Management Agency (FEMA) Operations Manual

This operation manual was developed by FEMA to standardize the procedures in preliminary damage assessments nationwide. This manual was prepared and reviewed by FEMA regional officers with vast experience in performing damage assessment through many types of disasters. The model these manuals use to distinguish the type of damage is categorized into destroyed, major, minor, affected, and inaccessible [8].

Destroyed degree of damage means the structure is a total loss to such an extent that repairs are not economically feasible. It may constitute two or more walls destroyed. The roof has totally collapsed or substantially damaged and could no longer function as it is. The damage might have washed all building structures and only the foundation remains. The affected house is pushed off the foundation. Major degree of damage exists when the affected house has sustained more than 50 % structural damages, becomes inhabitable, and requires extensive repairs. It may constitute walls, roof, floors, and foundation substantial failure to function. *Minor* degree of damage generally is not habitable after flood damage, but may be made habitable in a short period of time with house repairs. It may constitute windows or

doors blown in. The furnace or water heater at the basement is broken. *Affected* degree of damage includes dwellings with minimal damage to structure and/or contents, and the house is habitable without repairs. *Inaccessible* degree of damage is the condition when the affected house is not accessible due to damage to a road or bridge.

3 Methodology

This paper seeks to perform a comprehensive assessment on the degree of housing damage after a flood. This research involves only qualitative description in the analysis. It involves reviews on eight (8) models from the literature study and experts' views, i.e., interviews with parties involved in MERCY in order to assess the housing damage post-flooding. In order to obtain validation of proposed model of degree of housing damage, the researcher has conducted a "model validation" by forming focus groups among selected panels to evaluate and provide personal views on the proposed model. These focus groups consist of ten (10) technical experts involved in MERCY Malaysia to assess the housing damage post-flooding.

4 Findings and Discussion

From the eight (8) reviews of the attribute model, with a comprehensive summary based on the feedback from experts, the frequency of the degree of housing damage attributes and the suitability of flood disaster and building structure in the Malaysian context suggested that degree of housing damage is as follows (Table 1).

In this paper, eight (8) attribute models of damage assessment from UK, USA, Indonesia, Japan, and European countries were reviewed and came out with a suggested degree of housing damage. This conceptual model is categorized into four degrees of damage: inaccessible, minor, major, and destroyed.

First degree of damage is inaccessible. This degree indicates that the residence is not accessible by normal means with supporting attributes, for example, due to the building being flooded or submerged, road or bridge being out, and the flood-affected area becoming ground zero. It is recommended for the relevant authorities to assist in the preliminary damage assessment.

Next is minor. The damage is described as slight damage to building structure; however, the building still can be occupied within a short period after some minor reparation. The attributes of damage are only minor damage to partitions, infills, ceilings, doors, and windows that are repairable within one to two weeks.

Major is the third degree of damage. The building has sustained structural or significant damage that made it unsuitable to be occupied. Despite that, the building can be occupied after extensive repairs. The recommendation is that the affected building with major degree of damage is to undergo extensive repair and could be occupied after 30 days.

Table 1 Suggested degrees of housing damages

Suggested degree of damage	Description of damage	Attributes of damage	Recommendation
Inaccessible	The residence is inaccessible by normal means	The house is flooded or submerged	Authorities to assist
		Road and bridge is out	
		Ground zero	
Minor	Slight damage to building structure can be occupied within a short period after minor reparation	Minor damage in partitions, infills, and ceilings	Can be repaired within one to two weeks
		Minor damage to door and windows	
Major	The building has sustained structural or significant damages, becomes inhabitable, and requires extensive repairs. Could be occupied after extensive repairs	Substantial failure of walls, floors, foundation, or roof	Habitable after extensive repairs more than 30 days
		Utilities damaged (Electrical, surface water drainage, sewerage reticulation system, water reticulation)	
Destroyed	Total loss	Null	Recommended for temporary shelter

The last degree of damage is destroyed. The description for this degree of damage is that a particular building experienced total loss or has been completely destroyed. It is recommended as a temporary shelter.

5 Conclusion and Future Research

In this paper, based on the qualitative description analysis, we have explored various literatures on eight (8) models of degree of housing damage as a tool to develop a conceptual model that is applicable to the Malaysian context. This suggested model is not being tested yet as this is only the preliminary study. With this suggested model, it will allow the researchers to examine and develop a housing damage assessment model in evaluating the degree of housing damage after a flood in the Malaysian context.

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