Jurnal Kejuruteraan SI 6(1) 2023: 01-16
https://doi.org/10.17576/jkukm-2023-si6(1)-01

Review on Guideline Pertaining to Flood Resistance Design for Residential Architecture in Malaysia and UK

(Semakan Garis Panduan Berkaitan Reka Bentuk Rintangan Banjir untuk Seni Bina Kediaman di Malaysia dan UK)

Sharika Tasnim*, Nayeem Asif & Srazali Bin Aripin

Department of Architecture, Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia

**Corresponding author: sharikatasnim11@gmail.com*

Received 28 September 2023, Received in revised form 28 june 2023
Accepted 1 October 2023 , Available online 31 October 2023

ABSTRACT

Flooding is a crucial issue for structures all around theglobe. The classification and evaluation of damage methods and the design of strategies to optimize flood resilience are thus critical components of flood risk management. The paper presents an in-depth analysis of the guideline for flood resistance design for residential architecture in Malaysia and the UK. Both Malaysia and the UK are at risk of flooding because of rainfall and rising sea levels surrounding their coastal cities due to climate change. Qualitative research methodology is adopted for this research by analysing the contents of guidelines of Malaysia and the UK. Therefore, it has implemented content analysis from secondary sources, including documents, briefing papers, studies, and print and online sources of building and planning guidelines. The output from this paper is that there are measures of flood resistance design in Malaysia. Measures include design strategies such as using floodproof materials, avoiding floodplain zones for residential properties, etc. However, those measures are insufficient and need to be more comprehensive on flood-resistant residential buildings in Malaysia. The output from this paper also compares the guidelines on flood resistance design for residential architecture and the different approaches incorporated between Malaysia and the UK. It needs further exploration of why there is an inadequate effort to develop guidelines for residential architecture despite considerable residential property damages occurring yearly due to flooding in Malaysia.

Keywords: Flooding; flood risk management; flood resistance design; guideline; residential architecture

ABSTRAK

Banjir adalah isu penting untuk struktur di seluruh dunia. Klasifikasi dan penilaian kaedah kerosakan dan reka bentuk strategi untuk mengoptimumkan daya tahan banjir adalah komponen penting dalam pengurusan risiko banjir. Kertas kerja ini membentangkan analisis mendalam mengenai garis panduan untuk reka bentuk rintangan banjir untuk seni bina kediaman di Malaysia dan UK. Kedua-dua Malaysia dan UK berisiko dilanda banjir kerana hujan dan kenaikan paras laut di sekitar bandar pantai mereka akibat perubahan iklim. Metodologi penyelidikan kualitatif diguna pakai untuk penyelidikan ini dengan menganalisis kandungan garis panduan Malaysia dan UK. Oleh itu, ia telah melaksanakan analisis kandungan daripada sumber sekunder, termasuk dokumen, kertas taklimat, kajian, dan sumber cetakan dan talian panduan pembinaan dan perancangan. Output daripada kertas kerja ini ialah terdapat ukuran reka bentuk rintangan banjir di Malaysia. Langkah-langkah termasuk strategi reka bentuk seperti arahan untuk menggunakan bahan kalis banjir, mengelakkan zon dataran banjir untuk hartanah kediaman, dsb. Walau bagaimanapun, langkah tersebut tidak mencukupi dan perlu lebih menyeluruh ke atas bangunan kediaman kalis banjir di Malaysia. Output daripada kertas kerja ini juga membandingkan garis panduan mengenai reka bentuk rintangan banjir untuk seni bina kediaman dan pendekatan berbeza yang digabungkan antara Malaysia dan UK. Apa yang masih perlu diteliti ialah mengapa tidak ada usaha yang mencukupi untuk membangunkan garis panduan untuk seni bina kediaman walaupun merekodkan kerosakan yang ketara dalam hartanah kediaman setiap tahun yang mungkin disebabkan banjir di Malaysia.

Kata kunci: Banjir; pengurusan risiko banjir; reka bentuk rintangan banjir; garis panduan; seni bina kediaman

INTRODUCTION

Malaysia suffered significant overflows in the following years: 1926, 1963, 1965, 1967, 1969, 1971, 1973, 1979, 1983, 1988, 1993, 1998, 2005, 2006, 2007, 2010, 2014, 2017, 2021, and 2022 (Shah et al., 2017; Monihuldin, 2023). In December 1926, during the northeast monsoon, British Malaya saw one of its worst flooding disasters in recorded history. The 1926 floods encouraged the government to engage more in hydraulic planning, albeit this change could have been smoother and more beneficial. According to a resident of Pekan, the flood height was five feet higher than the previous record, which had been set in 1924. They detailed the tragedy's catastrophic losses, particularly for the Malay farming community, who were enduring immense problems after having their houses, animals, and all they own swept away (Williamson, 2016). According to a different study, Malaysia experienced 39 catastrophes between 1968 and 2004. Nineteen big natural disasters (49%) occurred, resulting in 1460 fatalities and 821 injuries. According to statistics on natural disasters, floods (06 occurrences) were reported to happen most frequently, followed by landslides (05 events), storms, epidemics, mudslides, and tsunamis (01 event each) (Shah et al., 2017).

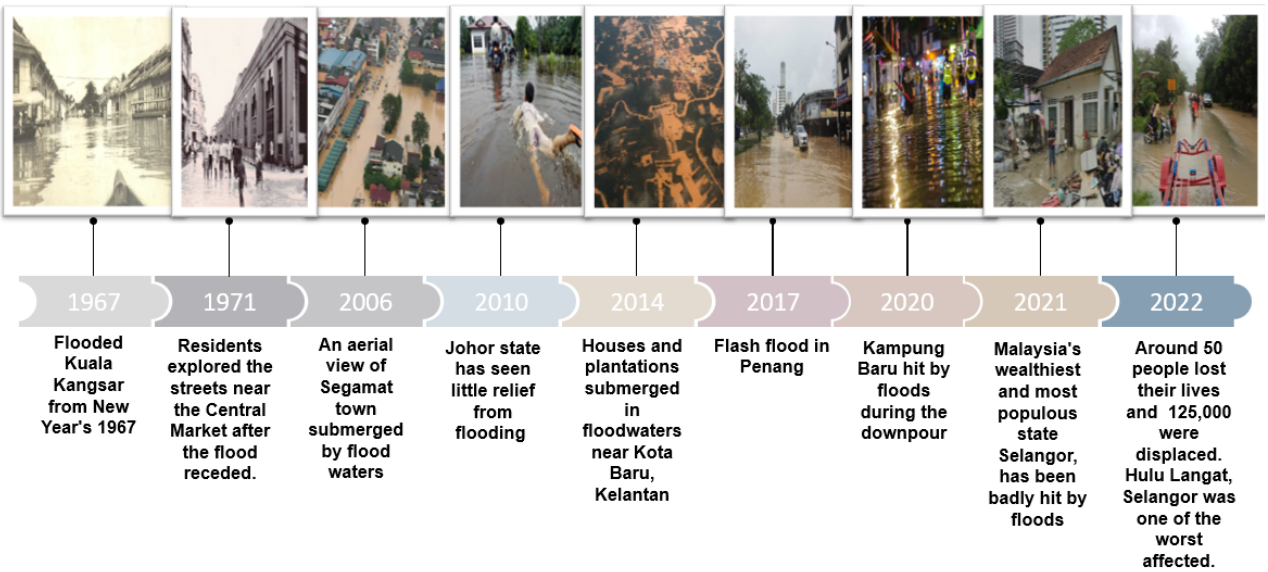

FIGURE 1. Timeline of Flood Occurrences in Malaysia. Source: Tew et al. (2022), reproduced by the author

Floods in Malaysia in December 2006 and January 2007 are also regarded as the worst ever. 2.75 meters of water, the highest level ever measured since 1950, was caused by these floods. Over 100,000 people were evacuated during the incident, and the death rate was 18% Similarly, among the worst were the floods that ravaged Malaysia in December 2014 and January 2015. Over 100,000 flood victims had to abandon their homes during these devastating incidents (Shah et al., 2017). Over 40,000 people were affected by recent flooding in eight Malaysian states in December 2021, and 50 died as a result. According to the Malaysian Department of Statistics, total flood damages were projected to be over RM6.1 billion (USD1.46 billion). This figure uses approximations to calculate public property and infrastructure, housing, commercial buildings (primarily for facilities), manufacturing, and agriculture (Tasnim et al., 2022).

Malaysia's coastal lowlands and riverine regions are regarded as some of the most heavily built-up and densely inhabited places subject to flooding. Nearly every year, flooding on Malaysia's East Coast severely impacts the states of Pahang, Terengganu, and Kelantan (Shah et al., 2017). Floods, which are frequent during the annual monsoon season, which usually lasts from November to March, in southern regions of Malaysia and along the east coast, are now also occurring in unanticipated locations as a result of overdevelopment, deforestation, and climate change (Al Jazeera, 2023; Tasnim et al., 2022).

While in the UK, major floods hit in the following years: 1952, 1953, 1990, 2002, 2004, 2005, 2007, 2007, 2009, 2012, 2013, 2019, 2021, and 2022 (UK Floods - case studies of Causes and effects of flooding policies, n.d.). Although significant floods have occurred in England for thousands of years, the threat is growing in frequency and intensity, worsened by climate intimidation with potentially devastating effects. (Bang & Burton, 2021).

FIGURE 2. Timeline of Flood Occurrences in UK. *Source*: FloodList (2022), reproduced by the author

Several severe flooding incidents occurred in the UK between June 2019 and February 2020. As a result, many river flows exceeded their highest-ever records in northern England, the Midlands, and on both sides of the English/ Welsh border. Some barriers were overrun. In order to assist with flood relief and defenses, the army and emergency services were positioned in some areas of Wales and England. According to preliminary estimates, more than 3,300 properties in England (as well as many in Wales) experienced flooding due to the two storms, causing extensive destruction to residences, shops, and businesses (Major hydrological events, 2021). The Gloucestershire town of Tewkesbury was among the several areas of central and southern England that experienced floods in July 2007. Therefore, significant infrastructural damage occurred, thousands of houses were inundated, and water and power supplies were interrupted (The Guardian, 2007). Among the significant flood occurrences, East Glasgow experienced severe flooding on the afternoon of July 30, 2002. Due to inadequate drainage and sewage infrastructure, an extended (10-hour) and heavy downpour caused floods. In addition to the severe disruption of transit caused by the flooding of more than 500 residences, the cost of cleanup reached £100 million (Cashman, 2008).

The affairs of Muslim societies are governed by Shariah, an international legal code (Mohd et al., 2020). Protecting life, property protection, health protection, religion, and dignity are Shariah's five Maqasid (objectives) (Duguri et al., 2021). The massive floods that wreaked havoc in major cities in Malaysia in December 2021 have raised the question of whether reconsidering flood-resilient residential properties could help prevent similar damage in future disasters (Zulkifli, 2022). Flood risk management at the building scale is often referred to as 'property flood resilience' (PFR) (Barsley, 2020).

Based on a study conducted by Construction Research Institute of Malaysia, in terms of critical infrastructure, the residential area is ranked first. This is because residential areas are places where people live and reside. If residential areas are destructed, this might have further negative implications. Floods cause residential areas to be damaged, which causes personal property losses. Residential areas also interact significantly with communities and society (Construction Research Institute of Malaysia, n.d). Following the frequent flood disasters in Malaysia, homeowners in flood-prone areas might have trouble selling their homes. According to property consultant Natasha Gideon (Zulkifli & Jamal, 2022), flooding may make selling any unsold residential properties in flood-prone locations difficult. She added that while single-story residences are less common in flood situations, apartments and condominiums are also impacted because elevators and underground parking spaces would be damaged (Zulkifli & Jamal, 2022).

This paper exclusively focuses on guidelines for flood resistance design in residential buildings. Flood disasters and their associated damage continue to be an alarming issue worldwide, which requires immediate attention for this generation and the generation to come (Glago, 2021). Malaysian guidelines remain to be the main focus. Hence, this study reviews and assesses guidelines in residential architecture to explore the effectiveness and highlight examples of flood resistance design. However, the UK's guidelines are also discussed and looked into to compare the critical conditions and efficacy of the directives. As per the findings, evidence of guidelines specifically for residential architecture on flood-resistant design in Malaysia is absent.

In contrast, the UK has made significant progress in confronting the issues by enacting or altering guideline that directly influences the design, planning, and using construction materials in high-risk flood zones for residential architecture. It then stresses the significance of implementing these guidelines in residential architecture in flood-prone communities. At last, the paper concludes by identifying differences, shortcomings, or areas of improvement for flood resistance design in residential architecture between Malaysia and the UK.

REVIEW OF GUIDELINE IN MALAYSIA

A guideline titled "Garis Panduan Perancangan, Bandar Berdaya Tahan Bencana di Malaysia," which assists as a guide, informs all parties engaged in the planning and development process in Malaysia on the need to take flood hazards into account at every level of the planning and design process.

Low-risk areas (Level 1), which are flood-prone, have specific characteristics. The areas are usually flood-free or located outside the floodplain or zones possessing an average recurrence interval of 100 years and more. In these low-risk areas, as per the specific guidelines, it is advised that the commercial, residential, and recreational properties should be suitable for environmental and physical settings. Furthermore, optimizing the proportion of recreational areas and green spaces in these low-risk areas is recommended, as decreasing the proportion of impervious surfaces in the development zones.

Then it is also advised to implement the LID (LID is Low Impact Development - a stormwater management strategy that replicates the natural hydrologic cycle by catching, treating, and infiltrating runoff on-site) concept and fulfill the requirements of MSMA (Urban Stormwater Management Manual for Malaysia) for management of stormwater. Through planning transportation and road networks, LID is intended to treat and regulate large water flows. LID may be adapted for both redevelopment and new development. Permeable pavers and bioretention are two approaches that may be used to accomplish LID. Besides that, these guidelines are subject to prevailing regulations and laws, and it is instructed to look up to the guidelines of MSMA requirements, which JPS (Department of Irrigation and Drainage) issues (Garis Panduan Perancangan, Bandar Berdaya Tahan Bencana di Malaysia, 2019).

Urban Stormwater Management Manual for Malaysia, or MSMA, is a manual that instructs professionals, notably engineers, on how to build environmentally good drainage infrastructure, utilizing the concept of quantity and quality control at the source level.

Consequently, the goal is to manage devastating floods and enable the safe passage of less frequent but more severe flood events. Onsite stormwater detention (OSD), which temporarily stores stormwater runoff during prolonged and heavy rainfall in urban settings, is crucial for reducing the pace at which runoff reaches the drainage system or other properties. Additionally, it aids in regulating water flow and reducing the likelihood of floods downstream. Any structure erected on property less than 5 hectares is required to provide onsite retention, including underwater storage and rainwater harvesting. On the other hand, it is recommended to include a dry pond in a development of 5 to 10 hectares. For developments greater than 10 hectares, a wet pond is suggested as a storage option. Therefore, it is urged to restore wetlands and include retention/detention basins in community development in flood-prone areas to prevent financial damages from floods.

The preparation of the erosion and sediment control (ESCP) strategy in the construction industry is another significant stage. During the construction phase, a thorough temporary measure will be implemented in accordance with an ESCP plan. Reduced soil erosion, protection of topsoil and other assets, management of access routes and sites, run-off management, sediment prevention management, control of earthwork and erosion, stabilization of slopes, and site maintenance are some of the ESCP parameters (Urban Stormwater Management Manual for Malaysia, n.d.).

Moderate risk areas (Level 2) that are flood-prone have specific characteristics, such as the areas are usually floodplain regions or zones with an average recurrence interval of 50 to 100 years. In these moderate risk areas, as per the specific guidelines, leisure zones and landscaped open zones, buffer areas, tourism with lower density, and suitable agriculture are permitted on a conditional basis. It is also stated that the development is regulated and limited by the JPS's (Department of Irrigation and Drainage) evaluation of the flood hazards.

Furthermore, promoting various uses that do not cause water pollution is recommended. The design of the buildings needs to consider floodproof and flood risk; the buildings that are specifically allowed to be constructed should be low-density and confirm that the water channels are not obstructed by the buildings built. Additionally, efficient drainage arrangements and strong flood mitigation measures must be adopted. Finally, constructing developments in the river reserve region is prohibited and must adhere to the MSMA, JPS, and JPS River Integrated Basin Study guidelines.

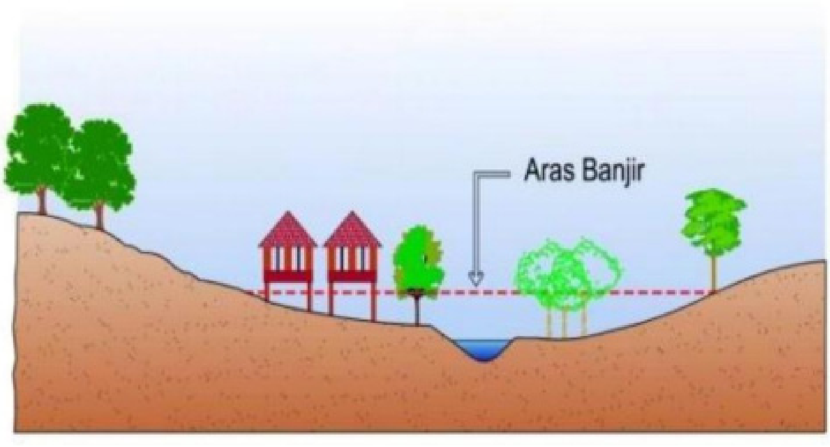

FIGURE 3. Development raising the floor level above flood level. Source: KSAS Conservation and Development Planning Guidelines, 2017

High-risk areas (Level 3) that are flood-prone have specific characteristics, such as the areas are usually flooded zones with an average recurrence interval of 50 years or less. In these areas, as per the specific guidelines, preservation of areas, leisure zones, landscaped open zones, suitable agriculture are permitted on a conditional basis. Furthermore, it is recommended to use flood-proof materials in building structures; if non-structural solutions are less successful, constructing flood structures such as mitigation dams, flood bypasses, embankments, strengthening drainage systems, and creating water reservoirs is a backup plan. Development in the river reserve region is prohibited and must adhere to the MSMA and the Integrated Basin River Study by JPS. No permanent structures are permitted, and any non-permanent structures created must not hinder the path of waterways.

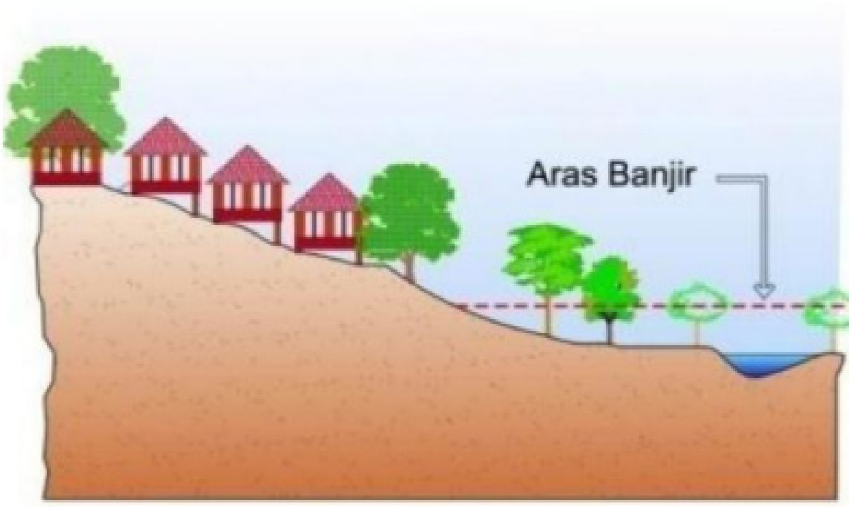

FIGURE 4. Development that uses the zoning control method in the floodplain channel zone. Source: KSAS Conservation and Development Planning Guidelines, 2017

Some kinds of development for low-risk levels include the basement level, and moderate-risk levels include residential buildings. As per the guidelines, structures in flood-prone regions are urged to relocate to higher, safer locations or adopt floodproofing techniques, such as incorporating rust-resistant construction materials and flood protection walls. A building can use poles rather than excavating the ground to elevate the floor level above the flood level as a floodproofing measure (Garis Panduan Perancangan, Bandar Berdaya Tahan Bencana di Malaysia, 2019). The traditional Malay houses are built on stilts on a stone or concrete base to avoid flooding and as animal protection. Additionally, it is simple to maintain and can provide the user with a sense of seclusion (Husen et al., 2021).

FIGURE 5. Bioretention in the Parking area (TLK) Source: Garis Panduan Perancangan, Bandar Berdaya Tahan Bencana di Malaysia, 2019.

FIGURE 6. Bioretention along the roadside. Source: Garis Panduan Perancangan, Bandar Berdaya Tahan Bencana di Malaysia, 2019.

In order to create an environmentally friendly region around the development area, bioretention, sometimes called rain gardens, is incredibly efficient and effective. Based on the kind of rock, the site's characteristics, and the land usage, bioretention systems are created. A multipurpose combination of elements is included in the bioretention area to transfer contaminants, lessen surface runoff, and increase water absorption rates.

FIGURE 7. Example of permeable pavement/ porous pavement. Source: Garis Panduan Perancangan, Bandar Berdaya Tahan Bencana di Malaysia, 2019.

Another approach is the permeable pavers technique. Accelerating the rate and duration of water absorption reduces the rise in peak discharge. When combined with a bioswale, the usage of permeable pavement has a very high level of efficacy. Gravel-filled interlocking concrete blocks, soil and grass-filled interlocking concrete blocks, gravel-filled plastic cell networks, and soil and grass-filled plastic cell networks are a few examples of water-permeable materials that may be utilized on the pavement surface—surfaces that are permeable let rainfall to soak into the soil in addition to treating water-borne contamination. Waterproof materials are advised to use on footpaths, walkways or alleys behind the home, shared driveways, parking, crosswalks, the curb and the emergency lane. In addition, to prevent and minimize damage from floods, the height of the road level should be specified depending on local conditions.

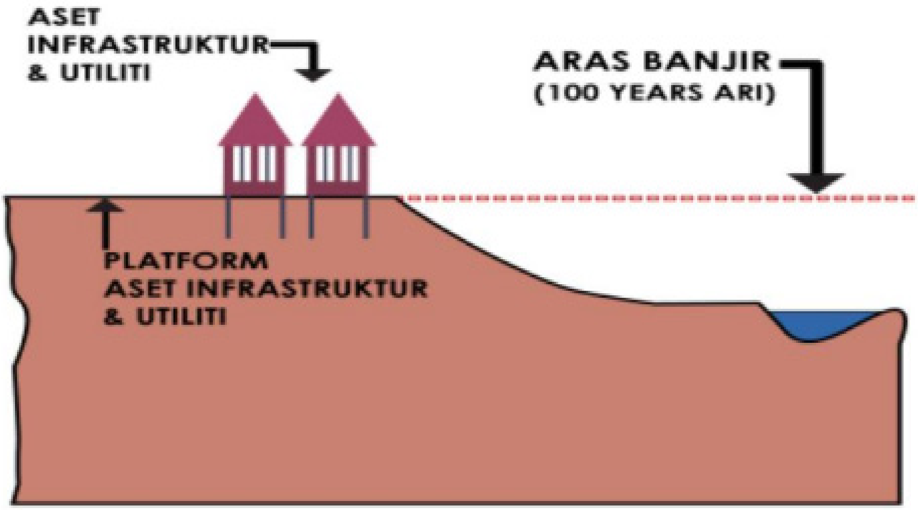

FIGURE 8. Illustration demonstrating the location of telecommunications and cyber resource assets in flood-prone locations.
Source: Garis Panduan Perancangan, Bandar Berdaya Tahan Bencana di Malaysia, 2019.

As per the guideline, to avoid assets or resources from ceasing to operate due to flood catastrophes, electricity supply source like PMU, PPU, and PE need to be positioned in high locations (fulfilling the 100-year ARI design criterion). Likewise, water supply resource such as water treatment plants, storage tanks, and pump houses need to be positioned in a safe and high location (fulfilling the 100-Year ARI design requirements) to avoid disruptions and supply cuts during flood catastrophes. In addition, solid waste/garbage disposal sites and centralized sewage treatment plants need to be situated in high, flood-free regions (fulfilling the 100-Year ARI design standards) to prevent these waste disposal facilities from inundating during floods. Furthermore, telecommunication and cyber resource must be located in high places (fulfilling the 100-Year ARI design requirements) to avoid having these assets destroyed during floods (Garis Panduan Perancangan Bandar Berdaya Tahan Bencana Di Malaysia, 2019).

REVIEW OF GUIDELINE IN UK

A guideline titled "Retrofitting for Flood Resilience," which assists as a guide to building and community design, explores how new and existing residential buildings may be adapted to be flood resistant. It emphasizes a number of spatial methods for adaptation and resilience at the building level.

Before deciding on a strategy, building type needs to be considered. In addition, buildings may include garages or basements, all of which should be evaluated as possible water entry points. Detached building types are isolated, where considerations regarding the safety of ingress and egress are required in flood events. Semi-Detached building types are required to create a combined space to prevent water leakage between adjacent spaces of two semi-detached buildings. Terraced houses may be susceptible to flooding through party walls; when terrace owners and occupants should take a comprehensive, integrated approach to minimize flood risk. Buildings with a flat roof require safe exits and entry points that can be used in the case of flooding, and make sure each resident has their flood plans. For bungalows, roof lights may be necessary for lofts susceptible to abrupt flooding to offer a point of escape from rising floodwaters.

Evaluating the habitable areas' location is critical when contemplating how a new residential building is adapted to be flood resilient. This applies to living rooms, kitchens, and bedrooms. One of the difficulties is many residential buildings include habitable areas in ground floor. Therefore, adaptation must take this into account. Ground floor levels are often raised or designated as sacrificial/recoverable zones in countries where flooding occurs regularly. Changes to the residential building's usage (such as relocating main functions) or establishing management plans that may be executed as soon as a flood warning is issued are approaches for existing buildings. Additionally, habitable spaces can be elevated by raising floor levels.

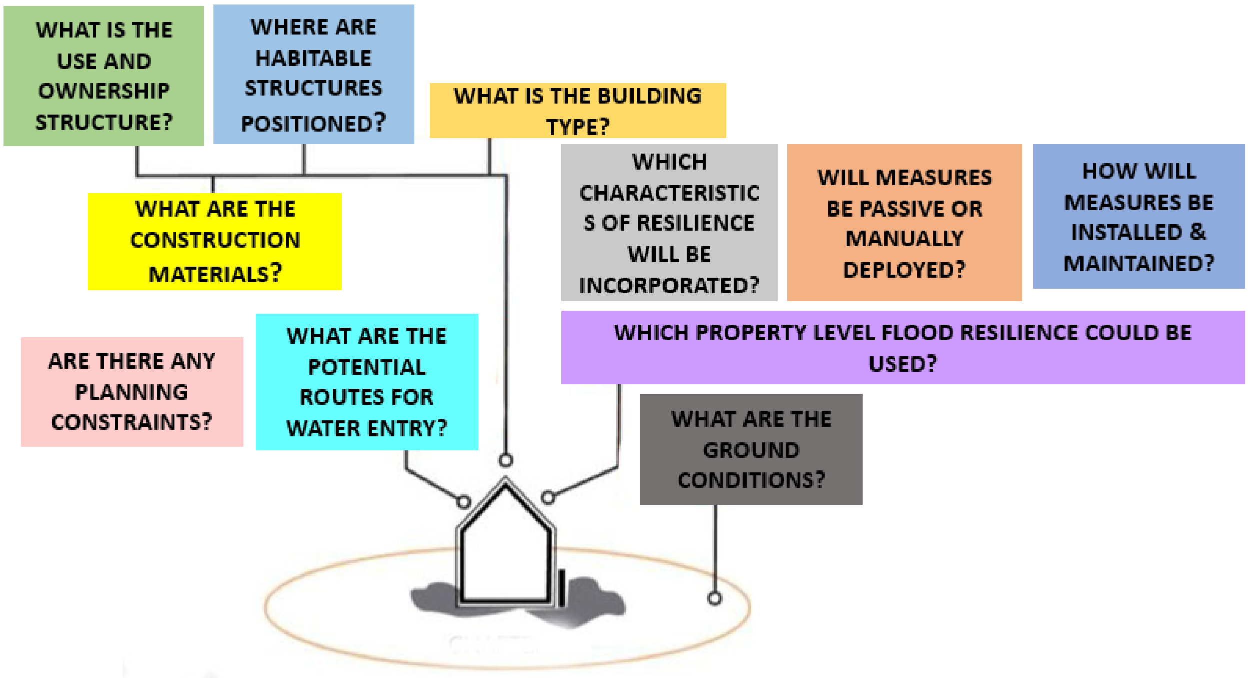

FIGURE 9. Factors to consider for flood resistance design of residential buildings. *Source*: Barsley, 2020

The strategies for increasing the flood resilience of electrical systems at residential properties include wiring/electric cables that can be fed from the top-down and split ring mains (between the ground and first floors) so that power can be kept in the upper levels of a property. In contrast, the ground floor is turned off or isolated. A minimum of 450 mm, ideally more, above flood levels is where sockets can be placed. TVs may be set up at a height of more than 1200 mm (Barsley, 2020). Fuse boxes can be installed at a higher position (Department for Levelling Up, 2022).

In order to improve the plumbing and gas systems' flood resilience, drainage channels should be placed around the rooms' perimeter. Ground-floor bathrooms may be equipped with pumped systems rather than gravity-draining ones. The bathroom might be made into a wet room, on water and drainage pipes where water might backflow (such as washing machines), and non-return valves can be installed. Sinks and toilets may both employ bungs. A sump and pump can be employed with perimeter subfloor drainage to eliminate extra water entering the residential buildings.

The tactics and set up to increase the flood resilience of fixtures and fittings include the following: Interior doors must be designed to open in one or both directions to minimize pressure buildup. Windows necessitates positioning on a higher level or making them resistant on a lower level. Large-sized furniture should be elevated on bricks or metal trestles to minimize flooding. Freestanding furniture is highly recommended instead of fitted furniture. Stairs should be constructed wider with a steady rise. The stairs can be replaced with open treads/create lower concrete or steel treads. As water levels increase, air vents installation is beneficial in the ceiling to relieve pressure from trapped air.

There are various techniques to make a kitchen flood-resistant. For example, worktops should be easily removable to be relocated before a flood occurs. More cabinets should be placed on the wall (at higher levels). It is required to allow an air space between the cabinet and the wall to help in drying. Quick-release hinges can be installed on cabinet doors— appliances placed in a secondary, lower-risk area. Other than the above strategies, using tables and chairs that are easy to disassemble/fold and move is advised (Barsley, 2020). Instead of a standard door, it is best to install a flood door (National Flood Resilience Review, n.d.).

A garage may be made flood-resistant in many ways.

Vehicles should be moved to higher ground/safe locations. The floor can be designed with a gradual slope to direct flood water to the drainage inlet. It is crucial to have a backup generator with fuel (at a high level) and a drain installed to remove silt and flood water during/after the event.

An "avoidance-based" strategy to reduce the exposure of inhabited spaces to flood waters might involve raising finished floor levels (Flood-resilient building, n.d.). However, changing finished floor levels may impact the building's level of access. Lowering flood risk by physically relocating or removing the building is also possible. This method is used when realigning properties due to coastal erosion is necessary. Another approach might be to relocate the habitable areas within the building (e.g., moving the kitchen/living room to the first floor). Nevertheless, this can reduce the volume of the habitable area, so it may be considered in conjunction with adding an extra story. The property's exposure to flood risk may be changed by building higher in situations where it is not possible to make the lower-level flood resistant or recoverable.

If a property's ground-floor walls/floors are susceptible to flood water, they can be replaced with resistant/ recoverable materials (for example, timber-frame walls/ floors replaced with concrete blockwork/steel frame). Limitations apply after flood depths reach 1.5 meters or more. Sockets may only be elevated so far, and flooding may be too frequent or severe to tolerate regularly. More frequently, vertical adaptation is taken into account where the building is elevated.

In order to facilitate vertical adaptation to flood hazards, buildings can be altered to be buoyant or amphibious so that they float during a flood. The goal is to create a system that can be readily replicated, implemented by locals, employs locally available low-cost resources, and offers a feasible alternative to elevating buildings on stilts.

As mentioned earlier, the solutions will be ineffective for particular home types, construction materials, or flood risk scenarios. Perimeter protection is a strategy for new buildings. In order to do this, blockades (either permanent or temporary) must be used, such as flood walls and gates, to stop floodwater from entering the property. In addition, the site's landscape design, which includes modification of the landforms and level variations, may offer protection (Barsley, 2020).

In order to make a new building flood recoverable (wet-proof) means, it is designed to allow water entry, and there will be minimal consequences if flood water enters the building. Various techniques can be employed in a newly constructed, "dry-proof" building to prevent flood water penetration. Elevating the building on a bund is an avoidance-based approach (Flood-resilient building, n.d.). Higher ground levels can be constructed by cutting and filling to balance out ground take, but the bund/ landform can also feature cellular storage crates. In flood-prone locations, building can be raised on low-level stilts (less than 2m). The advantage of this strategy over the bund is that it creates room for water by utilizing the void/ undercroft beneath the structure as a location for penetration and storage of flood water/rainfall.

A building can also be made future-proof by elevating habitable spaces (on stilts greater than 2m) and drastically raising thresholds. In such cases, habitable zones are located on the first floor and above. The raised 'causeway' at the first-floor level allows for safe exit and access during a flood disaster, which lowers the demand for emergency services. Water and electrical utilities are raised to the first-floor level to ensure service continuity during a flood disaster.

The Waterstudio. blue-designed ARKUP floating home is a hybrid/evolution of floating and amphibious home technologies. With an electric engine that propels it and a console in the main living room for control and monitoring, it may operate as a vessel. A transitional strategy to living may be necessary for locations where levels of flood risk may rise over the short to medium term. The primary rationale behind this tactic is that the building's purpose is fixed for a specific time. A design component, such as the structural frame, may be permanent and allow for the customization of constructed forms on top of and surrounding it (Barsley, 2020).

Due to the absence of cavities that may harbor moisture, solid walls are among the modest wall constructions for flood-resistant residential buildings. Solid walls can be insulated inside, externally, or not at all. If cavity wall is used, cavities may need help drying up, especially if inadequate insulation has been installed, and they may wind up being filled with silt and sediment (Garvin et al., 1970).

Framing-based construction methods (precast, metal, or wood) are common. resistant or recoverable and may be constructed without cavities (for example, using polycarbonate or fiber cement walls with hardwood frames) (Barsley, 2020).

Regarding internal stud partitions, timber can be removed and replaced with galvanized steel or aluminum-framed systems (Garvin et al., 1970) Foundations can be reinforced, and steel reinforcing bars can be installed in interior, exterior, or hollow regions (Barsley, 2020).

Understanding the many types of materials used to construct a building is crucial, as are their characteristics related to flood resistance and recoverability (Department for Levelling Up, 2022).

For example, timber, masonry, and concrete are permeable and porous materials, whereas plastics and metals are impermeable and non-porous (Barsley, 2020).

Solid floors (such as concrete), beam and block floors, and suspended floors (such as wood) are the three primary types of floors used in the construction industry (Garvin et al., 1970). Concrete or other solid flooring is not floodproof. A solid floor is permeable to water, especially if damp-proof coverings are not installed (Barsley, 2020).

In order to guide floodwater toward building drains or openings, it is recommended to create a fall or a slight gradient on the floor. For a polished finish, a flood-resilient concrete screed with an acid wash can be used. Additionally, it is advised to use a waterproof treatment/sealant (e.g., epoxy resin waterproof screed). Heavy-duty damp-proof membranes can be employed between the floor screed layers when using waterproof, closed-cell insulation inside the floor build-up.

Rising water levels can cause beam and block systems to elevate and become unstable. Typically, sand: cement, chipboard: insulation, and screed: insulation finishes are used to line beam and block floors. For greater accessibility, interior floor finishes must be designed to be removed easily, and drying subfloor linings are recommended. Heavy-duty damp-proof membranes need to be installed to restrict water ingress. Flood-resistant concrete screeds and resilient (closed-cell) insulation can also be used. Installing resistance measures (such as automated air bricks) and a sump and pump system can restrict the amount of water and the pace at which floodwater enters underfloor voids (Barsley, 2020).

Timber flooring that is suspended might sustain various damages from flood water (Ministry of Housing, 2010) Floorboards may lift due to hydrostatic uplift forces, and some swelling and bending will occur as water is absorbed. Expansion joints should be used to prevent boards from swelling or buckling. Solid wood floors like oak, will absorb moisture less rapidly and dry out more quickly than other types of wood (Barsley, 2020).There are several approaches that may be employed to prevent floodwater from crossing a property's boundaries. Considering the particular site condition is advised because this strategy is only workable in some circumstances.

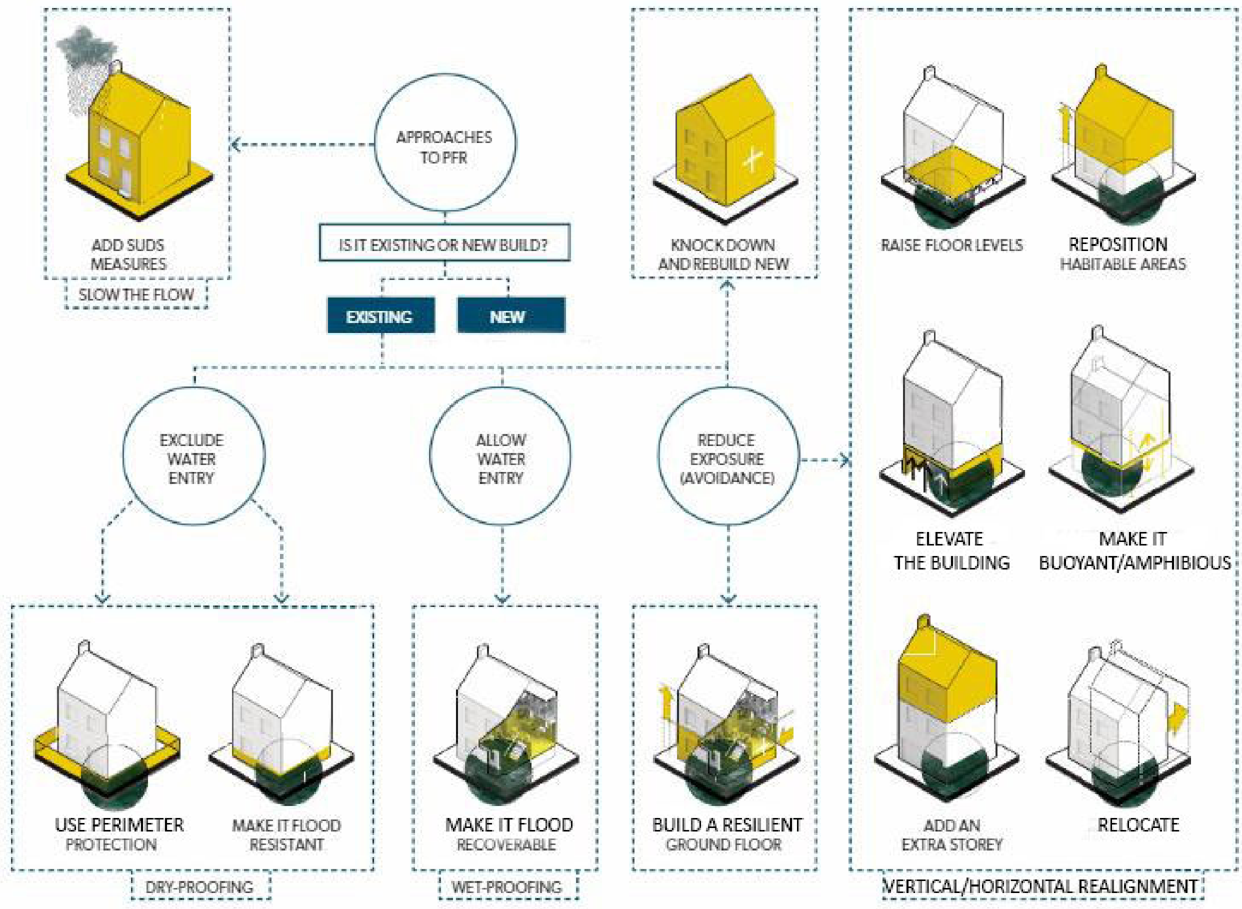

FIGURE 10: Approaches to Property Flood Resilience (PFR)
Source: Barsley, 2020

Several flood-resistant measures can be implemented to safeguard property. This includes products and techniques that prevent water intrusion and is called "dry proofing," a building (Barsley, 2020). Temporary flood barriers, which might be in the shape of flood boards or external door guards, act as a resistance measure (National Flood Resilience Review, n.d.).

Flood doors serve as flood barriers as well as doors. Ground-Up flood barriers are located below the surface of the earth and may be lifted into position mechanically, manually, or by using the buoyancy given by rising floodwaters. They are used where barriers cannot be stored or are necessary for proper operation without active intervention. Alongside internal/external walls or a perimeter boundary, hinged barrier systems are positioned perpendicular to the ground plane. The barrier's position may be changed from vertical to horizontal before a flood.

A *flood skirt* is a waterproof membrane that may be placed around a building›s perimeter to hold out floodwater. Because they are designed to withstand water up to 1200 mm deep, they are only appropriate for properties with structurally reinforced walls. If an outdoor window is located within 600mm of the ground floor, it may need to be flood resistant. Single-glazed windows are susceptible to flooding. Flood-resistant windows offer additional protection.

Essential goods can be shielded from floodwater using a smaller device, such as utility box covers. To safeguard items if floodwaters penetrate a property, utility box covers might be mounted on a building's exterior envelope or placed inside. The pace at which flood waters enter a house wall can be decreased by external render. However, it can also keep water in a building's outside envelope, delaying drying. Sealants like damp-proofing masonry creams or water-repellant coatings can be employed to restrict water penetration into the building fabric (Barsley, 2020).

Automated or passive flood air bricks avoid many issues with manual covers because they operate without human involvement (Ministry of Housing, 2010) Non-return valves prevent sewage or flood water from surging back into the system (National Flood Resilience Review, n.d.) They can also be added to the piping of appliances like toilets, washing machines, dishwashers, showers, and sinks. On exterior walls, weep holes and micro air vents are often installed above the level of flashing and assist in ventilating cavity walls and lessening dampness (Barsley, 2020).

Sandbags must be disposed of properly to avoid polluting local ecosystems. Leakage might occur if waterproof membranes are not properly lapped amid the bags. Bungs can be installed on toilets and sink as a flood-resistance precaution to prevent backflow water from entering the channels. It also prevents sewage from entering. Sump and pump systems can remove flood water from a building or underfloor void (Barsley, 2020).

Adapting or designing a building to be completely flood-resistant (dry-proof) is not always possible or desirable. Instead, occasionally designing for "recoverability" could be a more suitable strategy. The building design for recoverability, often known as "wet-proofing," can lessen the harm flood water does within a building.

Tanking is a technique (often applied in basements) that can be used to restrict the transition of water from external or internal sources. Surfaces are sealed using membrane systems and excess water drained or pumped away. Flood water can do substantial damage to insulation of buildings. Closed-cell and spray-applied insulation are more strong than mineral wool because they do not absorb moisture as much. Standard plasterboard, which is made of gypsum, will generally absorb flood water when it comes into touch with it. Water-resistant plasterboards such as cement-based and magnesium oxide boards, fiber cement (FC) sheeting, flood-resistant wall board, or detachable (preservative-treated) timber paneling can be utilized (Barsley, 2020).

When it comes to plasters, using lime and cement-based plasters (or renders) might minimize the number of layers that must be removed during the recovery period (Ministry of Housing, 2010) Surface materials such as non-ceramic tiles with waterproof adhesives and grout can be used. Water can enter through fractures in masonry walls and mortar joints. Waterproof sealant can be applied to masonry parts to minimize discoloration and moisture uptake. Compared to cement-based mortars, appropriately pointed lime-based mortars can limit water transfer.

Flood water may readily destroy carpets, necessitating removal, and disposal. If carpets must be used, they should be designed and fitted so they can be rolled up in the case of a flood. Cheap carpets that can be replaced at a low cost can be utilized. Otherwise, the carpet can be replaced with a more recoverable floor type, such as tiled or solid flooring.

Linoleum flooring may suffer significant damage if it comes into touch with floodwater. Linoleum flooring can be replaced with ceramic tiles with waterproof grout, vinyl/rubber sheets, epoxy/resin floors on concrete, vinyl/rubber tiles, and polished concrete floors with loose carpets.

Laminate floors can sustain serious damage from flood. To lessen the exposure of the materials, floor levels might be raised. Additionally, non-porous flooring options like resin, solid wood flooring, or sealed tile floors can be used to replace the existing flooring. To reduce water penetration, the floors can be sealed, and additional sub-floor bracing can be installed to reduce warping (Barsley, 2020).

METHODOLOGY

This section will discuss the methodology of this research. This research inspects guideline of flood resistance designs in Malaysia and contrasts them with those in the UK. It stresses a crucial part: reviewing guidelines on flood resistance design for residential architecture. Hence, this section will highlight the data collection process. As per the above discussion, qualitative research methodology is adopted. Therefore, it has executed the investigation of content from secondary sources, including documents, briefing papers, and studies, as well as print and online sources of building and planning guidelines.

A comparative analysis between the guideline of Malaysia and the UK is done. Therefore, the scope of the inquiry for the study was limited to the guidelines of Malaysia and the UK.

RESULT

This section presents the data in an organized form from the content analysis. The data were analyzed qualitatively. The comparative analysis between the two countries' guidelines is shown in the table, with several substantial dissimilarities and very few similarities.

TABLE 1. Comparative analysis of guideline pertaining to flood resistance design for residential architecture in Malaysia and UK

No	Parameter	Countries	
		Malaysia	UK
1	Adaptation strategies according to building types:		x
	Detached		x
	Semi-detached		x
	Terraced		x
	Flat roof		x
	Bungalows		x
2	Elevating floor levels	x	x
3	Relocating Habitable Spaces in Ground Floor		x
	Living room		x
	Bedroom		x
	Kitchen		x
4	Management Plan for Ground Floor (existing buildings)		x
5	Flood Resilient Construction		x
	Solid walls		x
	Cavity walls		x
	Framed walls		x
	Internal Stud Partitions		x
	Structural Reinforcement		x
6	Construction materials usage		x
	Timber		x
	Masonry		x
	Concrete		x
	Plastic		x
	Metals		x
	Flood Proof Materials	x	x
7	Adaptation strategies according to floor types:		x

continue ...

... *cont.*		Malaysia	UK
	Solid floors		x
	Beam and Block floors		x
	Suspended floors		x
8	Property level strategies (perimeter protection)		x
	Flood gates	x	x
9	Dry-proofing measures		
	Temporary Barriers – Flood boards/External Door Guard		x
	Parameter		x
	Flood doors		x
	Ground-Up Flood Barriers		x
	Hinged Barrier System		x
	Flood Skirt		x
	Flood Resistant Window		x
	Utility Box Covers		x
	External Render		x
	Automated or Passive Flood Air Bricks		x
	Non-return Valves		x
	Weep Holes		x
	Sandbags		x
	Bungs		x
	Sump and Pump Systems		x
10	Wet-proofing measures		
	Tanking System		x
	Insulation		x
	Plaster Board		x
	Plaster		x
	Exposed Masonry		x
	Tiled Walls		x
	Carpets		x
	Tiled Floors		x
	Linoleum Flooring		x
	Laminated Floor Boards		x
11	Resilient Electrics		x
12	Resilient Plumbing and Gas		x
13	Resilient Fixture and Fittings		x
14	Resilient Kitchen		x
15	Resilient Garage		x
16	Conditions of Resilient House (Before Flood)		x
17	Conditions of Resilient House (After Flood)		x
18	Avoidance – Based Approaches (Property Level Strategies)		

continue ...

... *cont.*		Malaysia	UK
19	Raised Finished Floor Levels		x
20	Relocate Habitable Areas		x
21	Relocate/Remove the Building		x
22	Build a Resilient Ground Floor Structure		x
23	Elevate the Building		x
24	Add an Extra Storey		x
25	Make the Building Buoyant/Amphibious		x
26	Knock down and Rebuild as New		x
27	New-Build Strategies		
28	Perimeter Protection		x
29	Dry-Proofing		x
90	Wet-Proofing		x
31	Elevate the Building on a Bund		x
32	Elevate the Building (less than 2m)		x
33	Elevate the Building (more than 2m)		x
34	Make it Amphibious		x
35	Design Building to Float		x
36	Design Building as a Self-Elevation Building		x
37	Design Building to be Transitional		x

DISCUSSION

The study highlights the existing guidelines on flood-resistant design for residential architecture in Malaysia and the UK. From the content analysis, the following findings are: When carrying out a comparative analysis between Malaysia and the UK, it has been observed that there are guidelines in Malaysia for flood resistance design. However, the guideline is not sufficient considering the seriousness of the situation. On the other hand, The United Kingdom has made significant progress in confronting the issues by upgrading the guideline that directly influences design, planning, and the use of construction materials for flood-resistant residential buildings.

Developing the guidelines for Malaysia's flood-resistance residential buildings is significant. Some directives from the guideline include relocating to higher, safer locations, using poles to elevate the floor level*, using flood-proof rust-resistant construction materials, flood protection walls, and avoiding floodplain zones for constructing development. These strategies* must be narrower and clearer to provide a focused response required for flood-resistant residential buildings in Malaysia. Consequently, evidence of guidelines for residential buildings on flood-resistant design in Malaysia is absent.

CONCLUSION

To sum up, from the findings, this research identified and documented the existing guidelines on flood-resistant design for residential buildings in Malaysia and UK. This vital information can be utilized as input to reexamine the effectiveness and limitations of implementing the guideline in the development and planning process. As the first step, a comparative analysis has been done to understand the relevancy, intent, direction, and practicality of the guideline. While the data collected from the secondary sources give a clear picture of the guideline, it remains to be investigated about the issues involved in developing this guideline considering the seriousness of the situation. Although Malaysia may undergo drought, landslides, earthquakes, and storm surges, floods are mainly responsible for its losses. Furthermore, residential buildings are the primary shelter for people during catastrophic events. Therefore, for a wholesome understanding, the study will focus next on the challenges in preparing guidelines for flood-resistant residential buildings in Malaysia.

ACKNOWLEDGEMENT

The authors would like to extend heartfelt gratitude to International Islamic University Malaysia for their financial support.

REFERENCES

Al Jazeera. 2023, March 6. *Thousands forced from their homes amid southern Malaysia floods*. Floods News | Al Jazeera. https://www.aljazeera.com/news/2023/3/6/malaysia-floods-17

Barsley, E. 2020. Retrofitting for Flood Resilience. doi:10.4324/9780429347986

Bang, H. N., & Burton, N. C. 2021, May 8. *Contemporary Flood Risk Perceptions in england: Implications for flood risk management foresight*. Climate Risk Management. https://www.sciencedirect.com/science/article/pii/S2212096321000462

Cashman, A.C. 2008. Institutional Responses to Urban Flooding: Case Studies FROM Bradford and Glasgow. In: IAHR/IWA Joint Committee on Urban Drainage, *11th International Conference on Urban Drainage.* Edinburgh, Scotland 2008. Edinburgh: IAHR/IWA.

Department for Levelling Up, H. and C. (2022, August 25). *Better flood protections for New Homes*. GOV.UK. https://www.gov.uk/government/news/better-flood-protections-for-new-homes

Duguri, Usman Safiyanu, Mohd Afandi Salleh, Isyaku Hassan, and Mohd Nazri Latiff Azmi. 2021. "The Application of Maqasid Al-Shari'ah in the Foreign Policy of Islamic States." *International Journal of Academic Research in Business and Social Sciences* 11(3):88–96. doi: 10.6007/ijarbss/v11-i3/8559.

Flood-resilient building: Part 2 - Building in flood-risk areas and designing flood-resilient buildings (DG 523-2) : BREbookshop.com. (n.d.). https://www.brebookshop.com/details.jsp?id=326888

Garvin, S., Reid, J., & Scott, M. 1970, January 1. *Standards for the repair of buildings following flooding*. CIRIA report C623, ISBN 0860176231. https://repository.tudelft.nl/islandora/object/uuid%3A2eed4dfa-8f65-4585-af40-a313a2323a28

Glago, F. J. (2021, June 30). Flood Disaster Hazards; Causes, Impacts and Management: A State-of-the-Art Review. IntechOpen eBooks. https://doi.org/10.5772/intechopen.95048

Guardian News and Media. (2007, July 23). *Tewkesbury's survival of the Flood is an inspiration*. The Guardian. https://www.theguardian.com/artanddesign/artblog/2007/jul/23/letsstartbuildinghomesinp

Husen, N. A., & Mohamed, M. F. 2021. Comparison of green design strategies in five traditional Malay houses. *Jurnal Kejuruteraan* 33(1): 47–53. https://doi.org/10.17576/jkukm-2021-33(1)-05

Major hydrological events. National River Flow Archive. 2021, June 18. https://nrfa.ceh.ac.uk/occasional-reports

Map showing location of major UK floods - UK floods-case studies of causes and effects and flooding policies. Map showing location of major UK floods - UK Floods-Case studies of causes and effects and flooding policies. n.d. https://sites.google.com/site/ukfloods/map-showing-location-of-major-uk-floods

Ministry of Housing, C. & L. G. 2010. *Drying flood-damaged buildings: Current guidance*. GOV.UK. https://www.gov.uk/government/publications/drying-flood-damaged-buildings-current-guidance

Monihuldin, M. 2023. *Floods cost Malaysia rm600mil in 2022, says stats dept*. The Star. https://www.thestar.com.my/news/nation/2023/02/23/floods-cost-malaysia-rm600mil-in-2022-says-stats-dept#:~:text=In%20the%20department's%20special%20report,%25%20and%20manufacturing%20at%201%25.

Mohd, A. T., Yunus, A. M., Hassan, I. 2020. Ideology, Communication, and Response to Terrorism: A Sharia-based Perspective. *International Journal of Academic Research in Business and Social Sciences* 10(3): 124-130.doi: doi:10.6007/IJARBSS/v10-i3/7029 Plan Malaysia. (2019). "Garis Panduan Perancangan, Bandar Berdaya Tahan Bencana di Malaysia."

National Flood Resilience Review - gov.uk. (n.d.-a). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/551137/national-flood-resilience-review.pdf

Shah, S. M. H., Mustaffa, Z., & Yusof, K. W.(2017, January 20). Disasters Worldwide and Floods in the Malaysian Region: A Brief Review. Indian Journal of Science and Technology; Indian Society for Education and Environment. https://doi.org/10.17485/ijst/2017/v10i2/110385

Tasnim, S., Aripin, S., & Asif, N. (2022). Understanding Flood Vulnerability Issues in Hulu Langat Residential Zone: A Study of Taman Sri Nanding, Hulu Langat, Malaysia. Journal of Advancement in Environmental Solution and Resource Recovery, 2(2), 56–63. Retrieved from https://publisher.uthm.edu.my/ojs/index.php/jaesrr/article/view/12617

Urban Stormwater Management Manual for Malaysia. Department of Irrigation and Drainage. (n.d.). https://www.water.gov.my/index.php/pages/view/897monihyukdin

Williamson, F. 2016. The “Great Flood” of 1926: Environmental change and Post-disaster ... https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ehs2.1248

www.cidb.gov.my. n.d. https://www.cidb.gov.my/wp-content/uploads/2022/11/Dev-of-Flood-Risk-FVI-for-CI.pdf

Zulkifli Jamal, A. M., & Jamal, A. A. 2022. *Homes in flood-prone areas could be a market washout*. MalaysiaNow. https://www.malaysianow.com/news/2022/01/06/homes-in-flood-prone-areas-could-be-a-market-washout

Zulkifli, A. M. 2022. An architectural solution to Malaysia’s chronic floods? MalaysiaNow. https://www.malaysianow.com/news/2022/01/15/an-architectural-solution-to-malaysias-chronic-floods