EXPLORING STRATEGIES FOR EFFECTIVE FLOOD-RESILIENT RETROFITTING IN RESIDENTIAL PROPERTIES: A LITERATURE REVIEW

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ABSTRACT

Riverine flooding has grown to be a disastrous threat to residential properties across the globe and Australia, notably in flood-prone areas. These incidents have been exacerbated by the frequently changing climate. Recently, the state of Victoria has experienced numerous riverine flooding incidents, which have caused considerable damage to the residential properties. Thus, flood-resilient retrofitting has emerged as a significant method to protect residential properties against emerging risks from riverine flooding. However, the implementation of these retrofitting activities often encounters many challenges. This study intends to provide a review of the existing literature for successful strategies to address these issues. Moreover, this review emphasises the importance of collaborative efforts between policymakers, homeowners, and industry participants to mitigate these challenges successfully. This paper also provides practical suggestions and insights that could assist in driving policy measures, enhancing community involvement, and promoting the wider delivery of flood-resilient retrofitting measures.

Keywords: Flooding, Flood Resilience, Retrofitting, Residential Properties, Flood Risk Management, Australia

1. INTRODUCTION

Flooding is one of the most prevalent natural hazards that causes billions of dollars in damage and places so many vulnerable communities at risk in almost every corner of the world (Alabbad et al. 2022; Gordon and Yiannakoulias 2020; Hartmann et al. 2019; Zinda et al. 2023). Therefore, floods can be recognised as the most common and frequent natural disasters in the world compared to other natural disasters (Dottori et al. 2018; Vu and Mishra 2019). Climate change and changing built environments are altering the frequency and severity of floods (Liu et al. 2015; Wilby and Keenan 2012; Zinda et al. 2023). Thus, flood incidents are capable of causing severe damage to socio-economic development through the loss of life and damage to assets, property destruction, financial damages and impacts on the well-being of the impacted communities (Alabbad et al. 2022; Bonanno et al. 2010; Zhang and Villarini 2021; Zhong et al. 2018). For example, almost 93,000 deaths were recorded and over one billion people were impacted in the period 2001-2018 by floods around the world (Dottori et al. 2018; Vu and Mishra 2019). Floods are also massively impacting food production, agriculture and environmental sustainability (Dottori et al. 2018; Mishra et al. 2021; Vu and Mishra 2019).

Australia is considered to be one of the most vulnerable countries to a wide range of natural disasters, including floods, bushfires, droughts, cyclones, hurricanes and heat waves-related hazards (de Vet et al. 2019). According to Australian Bureau of Meteorology (BOM) and Commonwealth Scientific and Industrial

Research Organisation (CSIRO), out of these, floods are known as the second most common type of Australian natural disaster (BoM & CSIRO 2022). BOM and CSIRO (2022) further stated that although Australia's daily extreme rainfall pattern is not uniform, there has been a noticeable rise in sub-daily extremes throughout the past few decades. Therefore, this will have considerable impacts for the occurrence of riverine floods (BoM & CSIRO 2018).

Accordingly, approximately, 20% of Australian natural disaster fatalities over the period 1900-2022 have occurred from these floods (Australian Government 2023). Based on the Victoria State Emergency Service (VICSES), Victoria’s recent riverine flooding incidents have caused widespread destruction of homes, businesses, and essential facilities, disrupting daily life and economic activity, significant losses in agriculture, and affecting both primary producers and rural populations (VICSES 2022). Accordingly, the state of Victoria’s existing housing has experienced significant impacts from such severe weather conditions such as the 2022 the state of Victoria floods, leaving households in extreme danger (Atkinson et al. 2023). Atkinson et al. (2023) further stated that much of this can be seen as most of Victoria's existing housing stock is outdated and unprepared for such catastrophic weather incidents.

As a result, flood risk management (FRM) has become a challenge for several communities (Berndtsson et al. 2019); however, the emphasis on its importance is increasing daily due to the increasing trend of impacts of flooding (Salathé Jr et al. 2014). Therefore, the implementation of effective mitigation actions is currently required to enhance flood resilience among residential neighbourhoods (O’Donnell 2020). Accordingly, flood-resilient retrofitting has emerged to be a vitally important technique to mitigate the disastrous flooding impacts in existing residential buildings (Meng et al. 2020; Tagg et al. 2016). Retrofitting is the process of renovating or improving existing buildings to increase their resiliency and performance towards certain dangers or risks, like floods (Nguyen et al. 2019; Shamout et al. 2021). Flood-resilient retrofitting, as defined by Aerts (2018) may require a variety of methods and approaches, such as modifications to the structure like elevating properties or placing flood barriers, as well as non-structural improvements like strengthening the drainage system and utilising flood-resistant materials.

It has been recorded that private precautionary measures can lessen losses resulting from flood hazard events (Hudson et al. 2014; Poussin et al. 2015; Sairam et al. 2019), but implementation of these measures is often low and only normally increase after a flooding event has occurred (Joseph et al. 2015; Owusu et al. 2015). Accordingly, a minimum of effort was put forward to mitigate the damage before the crisis occurred (de Vet et al. 2019). The implementation of flood-resilient retrofitting measures experiences various challenges (Alabbad et al. 2022; Gordon and Yiannakoulias 2020; Kousky and Kunreuther 2018). The common and well-cited barriers toward its widespread adoption include insurance constraints, financial limitations, technical inadequacies, and lack of awareness among both homeowners and policymakers (Barendrecht et al. 2020; Hartmann et al. 2019; Kousky and Kunreuther 2018; Price and Dupont 2023; Silvis et al. 2024). In order to overcome these challenges, a detailed analysis of different strategies that may culminate in successful retrofitting programs is required (Priest et al. 2016). Despite the existence of empirical evidence regarding flood resilience and related retrofitting strategies, there is a considerable knowledge gap related to the comprehensive understanding of the strategies that can be adopted to mitigate various challenges in implementing such measures in the state of Victoria's residential properties.

This paper presents some preliminary literature review of a larger research project that is currently being conducted. This study discusses about the existing knowledge on appropriate strategies to overcome different barriers that are experienced in implementing flood-resilient retrofitting in housing. Therefore, this review focuses on practical measures, which can reduce the current barriers and strengthen community resilience to riverine flooding in the state of Victoria. The paper is structured as follows: the following section gives a detailed review of riverine flooding in Australia focusing the state of Victoria, flood-resilient retrofitting and its relevance; then, the methodology used to select and review relevant literature is described. Afterward, the identified measures are stated, along with a conclusion on how to encourage the implementation of flood-resilient retrofitting in homes.

2. UNDERSTANDING RIVERINE FLOODING RISK

2.1 Riverine Flooding in Australia

Riverine flooding is a common and disastrous natural phenomenon throughout the world (Merz et al. 2021; Tanoue et al. 2016). Riverine flooding refers to the overflowing of the banks of a river to surrounding areas due to heavy rainfall, snowmelt, or even the bursting of a dam (Hudson 2016). According to the Australian Institute for Disaster Resilience (AIDR), riverine floods are probably the most common and significant category of flooding in Australia, regularly striking the communities and the infrastructure along its extensive river systems (AIDR 2024). AIDR (2024) also contends that heavy rainfall events and infiltration of water into the land are two of the most relevant causes of riverine flooding in Australia. AIDR (2024) further states that riverine flooding is capable of spreading to thousands of square kilometres in inland areas of flat terrain in Australia and warnings of such floods can sometimes be given several months in advance.

In the last two decades, a number of major riverine flooding events have occurred in Australia, causing millions of dollars in damages and claiming countless lives and economic losses (Australian Climate Service 2023). When considering the state of the Australian Capital Territory (ACT), riverine floods occur across all waterways within the state, from the Molonglo to the Murrumbidgee and Queanbeyan rivers (ACT Government 2024). ACT Government (2024) further states that this flood water will subsequently back up into the lower reaches of several major side creeks, including Jerrabomberra, Sullivans, Woolshed, and Yarralumla Creeks. There is a real potential for flooding in parts of the Northern Territory and the two most populated areas regularly affected are Katherine and Alice Springs (NT Emergency Service 2024).

When considering the state of Queensland, flooding is a natural part of living in the state of Queensland (Queensland Government 2024). Queensland Government (2024) further elaborates that riverine flooding can extend for many thousands of square kilometres in some areas of inland Queensland for periods of weeks and occasionally for months. For example, the 2011 Queensland floods, which devastated large portions of the state, inundated thousands of homes and left major infrastructure wrecked (Wenger 2013). Wenger (2013) also stated that it is identified as one of the worst disasters in Australia which caused 33 deaths, impacts for over 200,000 people, and damages totalling AUD 2.38 billion. Wenger (2013) further contended that over 28,000 homes and businesses were affected, resulting in huge losses in infrastructure.

According to New South Wales State Emergency Service (NSWSES), flooding in the state of New South Wales (NSW) causes millions of dollars in damage each year to property and critical infrastructure, including roads and railways, along with the smaller, less populated surrounding and remote communities (NSWSES 2024). Caused by Cyclone Oswald, the floods hit most parts of Queensland and New South Wales during January 2013 (AIDR 2013). These floods resulted in displacement of thousands of people with the city of Bundaberg having suffered severe damages (Walker and Barrett 2013). In Bundaberg, 2000 residences and 200 businesses swamped with floodwater (AIDR 2013). Tweed Valley, Grafton and Maclean in the state of New South Wales were also considerably impacted by these events (Walker and Barrett 2013). Six fatalities were recorded, and the Insurance Council of Australia evaluated the worth of damages as AUD 121 million in New South Wales and AUD 977 million in Queensland (AIDR 2013). Prolonged rainfall during February and March 2022 caused catastrophic flooding throughout the states of Queensland and New South Wales (Barnes 2023). Barnes (2023) also stated that record rainfall fell throughout the region and thousands of residents were displaced. According to the Centre for Disaster Philanthropy (CDP), this event killed more than 20 people and damage costs were estimated as AUD 3.35 billion (CDP 2022). It is considered as one of the costliest floods in recent Australian history (Barnes 2023).

2.2 Riverine Flooding in the State of Victoria

Riverine flooding is identified as one of the most frequent and expensive natural hazards in the state of Victoria as well because of the diverse climatic conditions and river networks presented in this state (Gu et al. 2020; Wenger 2014). Flooding has often been reported down around major rivers such as Murray, Yarra, and Goulburn, affecting both rural and urban people (Hart et al. 2020; Wilby and Keenan 2012). Flooding in the state of Victoria caused approximately AUD 432 million in damages in 2022 (Deloitte Access Economics 2023). Whereas flooding is a natural incident which generates both negative and positive environmental alterations such as property destruction, community displacement, nutrition deposition etc., whenever the manifestation of flooding has occurred to any of the properties its influence is predominantly detrimental (Adedeji et al. 2018; Government of South Australia 2024). Flooding of a property will include water penetrating the building from outside using various methods and this penetration can prompt catastrophic destruction to the property along with its contents as well as the structure (Adedeji et al. 2018). Over the years, the riverine floods have caused damage to infrastructural properties in the state of Victoria, houses, and agriculture; examples of such disastrous riverine floods are in the year 2011 and 2022 (VICSES 2022). Thus, a summary of various historical riverine flooding events that have happened in the state of Victoria and their impacts can be depicted in Table 1 below.

Table 1: *Overview of historical riverine floods in the state of Victoria*

Year	Overview of Riverine Flooding Incidents	References
1934	Central Victoria and Gippsland received significant rain in November 1934 with 140 mm dropping in Melbourne for two days. More than 350 mm of rain fell in South Gippsland, which is east of Melbourne. Due to a storm, flooding occurred from the Yarra and various other rivers. Latrobe River district, Yarra Valley, and South Gippsland regions were flooded. 18 individuals drowned, with an additional 18 dying from buildings that collapsed and other hazards. In total 36 deaths were recorded. 400 homes were destroyed in Melbourne, and 6000 individuals became homeless.	(AIDR 2022a; Carbone and Hanson 2012; VICSES 2010)
1991	The largest flooding incident documented for the Gnarr Creek system occurred in December 1991 in Ballarat. Within a brief period of 2 hours, 76 mm of rainfall caused the occurrence of this flood. This flooding incident caused flood waters to destroy residential and commercial properties in Ballarat. The Insurance Council of Australia projected the destruction as AUD 24 million. AUD 1 million worth of direct damages and AUD 400,000 worth of indirect damages happened to residential properties.	(AIDR 2019c; Water Resources Commission 1992)
1993	Excessive precipitation fell over 24 hours in October, resulting in severe flooding in the state of Victoria's northeast region. Rainfall throughout this period totalled 200 mm, with Benalla receiving 165 mm. The flood impacted several districts, including Violet Town, Benalla, Myrtleford and Euroa. The flood water surrounded 40,000 square kilometres and lasted for several weeks. The flood had an extensive effect, affecting 8,000 people, 3,000 homes, and 95% of commercial properties in the Benalla district. The Insurance Council of Australia assessed the cost of damage in 1993 at AUD 12 million.	(AIDR 2019e)
1998	One of the other larger-scale events was in June of 1998 in the Shire of East Gippsland when a one-in-100-year flood event declared a State of Emergency in eastern Victoria. 150-300 mm of rainfall in 24 hours caused the occurrence of this event. Approximately AUD 78 million worth of damages were caused to East Gippsland and 1 death also was recorded.	(Monson 2004; Yeo 2002)
1999	In December 1999, heavy rains in Melbourne's northern areas resulted in local flooding. Over the same period, the local catchment region in Carisbrook, central Victoria, obtained the highest rainfall totals in over a century. Overland flows that originate from the Craigie catchment and Mosquito Flat areas, which lie between Carisbrook and Maryborough, flooded the southwest portion of the city. Several properties in town experienced damage. The Insurance Council of Australia calculated the destruction as AUD 10 million worth.	(AIDR 2019d)

2007	In late June 2007, Gippsland in Victoria encountered serious flooding. The Macalister River had its biggest flooding incident in 105 years. The major flooding occurred in major areas such as Bairnsdale, Sale, Lakes Entrance and Gippsland Lakes region. There were 360 evacuees in the relief centres. After the previous one, heavy rain once again hit during November 2007 and caused further flooding along Macalister River; with inflows into Lake Glenmaggie recorded at more than 68,500 megalitres per day. These floods inflicted damages of millions of dollars to residences, businesses, and agricultural land. Hundreds of people had to be rescued and evacuated as floodwaters rose quickly. One person was killed. The Insurance Council of Australia projected the 2007 destruction as AUD 15 million.	(AIDR 2019b; VICSES 2008)
2010	The state of Victoria experienced heavy rainfall beginning in September, resulting in flooding in the state's central, northeast, and northwest regions. Following that, there was a cycle of excessive precipitation, which resulted in additional flood response efforts in November and December. The average monthly rainfall of the state was 100 mm. About 7,000 homes were impacted. The Insurance Council of Australia evaluated the damage as AUD 1.3 billion.	(AIDR 2020)
2011	In January 2011, massive quantities of tropical air paired with a low-pressure trough caused torrential rainfall in parts of southeast Australia. Western and northwestern Victoria received record rainfall. The catchments and floodplains were already soaked, thus resulting in serious flooding. Many weather stations recorded the highest monthly total ever for these towns: Rupanyup, Kyneton, and Maryborough. Rivers like the Loddon, Avoca, and Wimmera also recorded significant flood levels. Bridgewater, Charlton, Horsham, and Rochester were severely impacted by these floods. 100-200 mm of rainfall was received by many parts of the state. The Insurance Council of Australia evaluated the damage as AUD 126 million. 01 death was recorded.	(AIDR 2020)
2012	Broken Weir close to Benalla had the most rainfall, with 167 mm. In Numurkah, Broken Creek increased and flooded the city. Several Gippsland locations received an entire month of precipitation in a single day. Residences in Traralgon's low-lying areas suffered flooding due to overflow from Traralgon Creek. Severe flooding alerts have been issued for the Traralgon Creek, Thomson, Buchan Rivers, Avon, Tanjil, Mitchell, and Macalister. The Yallourn coal mine was also inundated when the Morwell River's embankment broke at the beginning of June. The Insurance Council of Australia evaluated the damage as AUD 108 million. Around 40 residential and commercial properties were damaged.	(AIDR 2019a; AIDR 2022b)
2022	In October 2022, a system of low pressure moved east across Australia, generating heavy storms and rainfall. It resulted in one of Victoria's most disastrous flooding incidents in history. Over the last few weeks in November 2022, excessive precipitation persistent rainfall and dam releases have resulted in significant flooding in Echuca, Wakool Junction, Barham, Torrumbarry, and Moama. Furthermore, significant flooding warnings were announced for the Murray, and Edward Rivers, Euston, Boundary Bend, Mildura, Yarrawonga, Wentworth Stevens Weir, and Tocumwal. Most parts of the state received 150-300 mm of rainfall during 13-14 October. This incident severely impacted the communities, with entire cities and neighbourhoods having to be evacuated, isolated, or overwhelmed with floodwater. AUD 432 million worth of damage happened because of this flooding incident. 5017 houses were destroyed, and 2 deaths occurred.	(Deloitte Access Economics 2023; Evans and Marin 2022; VICSES 2022)

Source: *Compiled by author*

3. UNDERSTANDING FLOOD-RESILIENT RETROFITTING OF RESIDENTIAL PROPERTIES

3.1 Introduction to Flood-Resilient Retrofitting

There are different ways that risk reduction and mitigation initiatives related to flooding could be introduced at a range of scales (Priest et al. 2016). Over recent decades, the awareness of the necessity to modify the course of FRM towards a more integrated and adaptive approach has gained more attention (Barendrecht et al. 2020). Thus, private precautionary measures have gained focus in FRM approaches which are undertaken on the properties to reduce damage from floods to building structures and contents (Kreibich et al. 2015). Various categories of private precautionary measures can be identified in the context of FRM (Barendrecht et al. 2020). Accordingly, resilience in the framework of flooding has emerged as a significant emphasis of FRM policy which is generally comprised of land-use planning, emergency management, flood mitigation, warning techniques and flood forecasting, and design of infrastructure based on the local flood situation and associated risks (Adedeji et al. 2018; Australian Institute for Disaster Resilience 2017).

Accordingly, resilience can be described as the ability of a person, society, town or country to endure, recover or absorb from a sudden collapse or event incident such as heavy flooding, and/or successfully adapt to a recent problem or a change in conditions or situations promptly and effectively (Rezendea et al. 2019). Thus, the principle of flood resilience comprises the capability of buildings to endure, adjust to, and retrieve from flood incidents whilst reducing destructions and interruptions (Proverbs and Lamond 2017). Retrofitting is the process of renovating or improving existing buildings to increase their resiliency and performance towards certain dangers or risks, like floods (Nguyen et al. 2019; Shamout et al. 2021). For example, in flood-prone regions, buildings may be raised higher than the initial flood level to reduce inundation destruction (de Moel et al. 2014; Proverbs and Lamond 2017). Furthermore, the retrofitting process may include raising the walls of an existing structure to increase the level of the floor, building a new floor over the old floor, elevating the entire structure on a novel foundation reinforcing foundations, sealing flooding entry points, constructing flood barriers, and establishing flood-resistant windows and doors (FEMA 2016).

3.2 Rationale of Adopting Retrofitting to Enhance the Resilience of Residential Properties against Flooding

Emphasising retrofitting as a proactive strategy to improving the resilience of existing residential properties towards flooding is critical because of its success in minimising flood hazards and weaknesses (Adedeji et al. 2018). Retrofitting strategies in flood resilience seek to improve the capability of infrastructure and buildings against flooding to mitigate the effect of flooding incidents on buildings and residents (Barsely 2020). Flood-resilient retrofitting performs a significant function in strengthening the overall resilience of people by lowering susceptibility and enhancing adapting capability (Barsely 2020). Flood-resilient retrofitting in existing houses provides several advantages to minimise the susceptibility of properties and neighbourhoods to flood hazards (Meng et al. 2020; Tagg et al. 2016). These advantages go beyond just safeguarding property and include socioeconomic and environmental considerations (Ortiz et al. 2020). One of the main advantages of flood-resilient retrofitting is reduced damage from flooding with related losses (Mechler et al. 2014; Tagg et al. 2016).

Retrofitting initiatives, like elevating buildings over the initial flood height, establishing flood barriers, and enhancing drainage systems, assist in minimising the penetration of water into properties throughout flooding incidents (Jha et al. 2011; Proverbs and Lamond 2017). Furthermore, flood-resilient retrofitting encourages adaptation to climate change by improving communities' ability to deal with altered environmental circumstances and more common severe weather conditions, such as floods (Ahmed 2023; Rijke et al. 2016). Combining climate-resilient design concepts into retrofitting initiatives may assist societies improve their sustainability in the long run and responsiveness for foreseeable difficulties (Sayce et al. 2023; Scott et al. 2021). Overall, flood-resilient retrofitting of existing residential properties provides numerous advantages, such as safeguarding property, resilience in the community, sustainability of the environment, and climate change adaptations, all of which contribute to more secure more resilient, and environmentally friendly communities (Adedeji et al. 2018; Ahmed 2023; Meng et al. 2020; Proverbs and Lamond 2017).

3.3 Flood-Resilient Retrofitting Measures for Residential Properties

There is a wide range of ways in which flood mitigation and risk reduction activities may be introduced and at a range of scales; from individual household-level measures to community resilience schemes, up to regional or national strategies (Priest et al. 2016). Over recent decades, the awareness of the necessity to modify the course of FRM towards a more integrated and adaptive approach has gained more attention (Barendrecht et al. 2020). Thus, private precautionary measures have gained focus in FRM approaches which are undertaken on the properties to mitigate flood loss to contents and building structures (Kreibich et al. 2015). There are various types of private precautionary measures (Barendrecht et al. 2020).

Low-cost options for mitigation including dry floodproofing and wet floodproofing are the rapid options of floodproofing applications that are feasible alternatives to mitigate flooding impact (Alabbad et al. 2022). According to the authors, dry flood-proofing refers to the prevention of water from reaching the home. This is achieved through sealing (The building is waterproof, which means that its exterior walls act as a barrier to flood water) or shielding (The floodwater is unable to reach the building itself as barriers are placed at an appropriate distance from a building or a collection of properties) (Manojlović 2016). The wet floodproofing measures help flood water enter a home with low adverse impacts (Alabbad et al. 2022). This is performed by applying water-resistant materials, altering the occupants, or using easily detachable inventory in lower portions of the building (Manojlović 2016).

However, elevation and relocation options also feasible for a permanent reduction in the long term (Alabbad et al. 2022). According to the authors, elevation refers to raising the home to such a level where the risk of flood will be zero or low. This method involves the vertical movement and temporary positioning of the building on cribbing until a new foundation is constructed beneath (Manojlović 2016). Relocation involves the movement of vulnerable houses to a safe area from floods (Alabbad et al. 2022; Manojlović 2016). This measure requires new land to be bought, making the measure expensive (Alabbad et al. 2022). Moreover, flood barriers are also used as a retrofitting method in which structures prevent or reduce the effects of flooding by impeding the spread of water and safeguarding property and infrastructure (Manojlović 2016). These barriers may appear in numerous forms and be used in a variety of applications including cities and rural areas (Wei and Jones 2022).

3.4 Barriers to Flood-Resilient Retrofitting Implementation in Residential Properties

The role of individuals in protecting their houses has become more vital in minimising flood impacts (Alabbad et al. 2022). Adoption of protective measures differ in their demands of money, time, and skill; their visibility to neighbours; the ways and extents to which they protect against loss from flooding; and many other attributes (Zinda et al. 2023). Therefore, many property owners and renters in hazard-prone areas are showing reluctance to take cost-effective mitigation measures (Kousky and Kunreuther 2018). Resource-constrained households tended to adopt low-cost or legally mandated measures, whereas costly measures were adopted by homes with higher values and/or with longer tenure (Zinda et al. 2023). Thus, residents always reluctant to adopt retrofitting methods due to their high initial cost (Alabbad et al. 2022). Moreover, lack of awareness and information regarding such precautions also can be identified as barriers (Barendrecht et al. 2020). Understanding perceived barriers supports mitigation decisions to improve the protection of people and infrastructure to reduce flood-related damages (Alabbad et al. 2022).

4. METHOD

This study uses a traditional literature review approach to investigate strategies for improving the implementation of flood-resistant retrofitting in residential homes. Such review technique provides for a thorough synthesis of existing knowledge, drawing on a variety of sources to offer insights and recommendations (Kumar 2018). Relevant sources were discovered using searches in academic search engines such as Google Scholar, Scopus, and Web of Science, along with gray literature, which included company reports and governmental publications. This enabled the incorporation of both theoretical insights and practical recommendations. Searches were undertaken without stringent publication date filters to catch both fundamental studies and contemporary advances in the field.

Unlike in systematic studies, no strict inclusion or exclusion criteria were used. Instead, literature was chosen based on its suitability for the research focus. The findings were combined to form a coherent narrative about how these techniques can overcome barriers to retrofitting and encourage effective implementation. The narrative aspect of this review poses some limitations, such as the possibility of selection bias and the lack of rigorous criteria for literature inclusion. However, the flexibility of this technique allowed for the incorporation of a diverse set of perspectives and practical insights, making it appropriate for the exploratory nature of this work.

5. STRATEGIES TO OVERCOME BARRIERS TO FLOOD-RESILIENT RETROFITTING OFRESIDENTIAL PROPERTIES

All barriers to the uptake of mitigation measures will require different strategies if these barriers are to be overcome (Priest et al. 2016). Thus, only the collaborative attempts of the government, residents, and (insurance) industry can decrease all expenses and damage mitigation in the future (Manojlović 2016). There is, however, good potential for recovery mechanisms to incentivise the uptake of flood mitigation and loss-reduction measures and undertake adaptation in building community resilience (Priest et al. 2016). The strategies that are identified through the existing knowledge are depicted in the Figure 1 below.

Figure 1: *Strategies to overcome barriers to flood-resilient retrofitting of residential properties*

Source: Compiled by author

5.1 Enhancing Access to Obtain Flood-Proofing Technologies and Materials

Increased access to flood-proofing technologies and materials considerably supports retrofitting (Gordon and Yiannakoulias 2020). Thus, flood mitigation information should be communicated to households so that the viability of the initiatives can be understood (Barendrecht et al. 2020; Priest et al. 2016). The details from the historical flood web tools such as Australian Flood Risk Information Portal (AFRIP) and United States Federal Emergency Management Agency (FEMA) website could be used by potential homeowners to construct safer and stronger homes(FEMA 2024; Geoscience Australia 2024; Mostafiz et al. 2022). Moreover, both official and unofficial resilience techniques such as; elevation, dry floodproofing, wet floodproofing, and relocation of structure etc. can be learned by the households in the food awareness campaigns (Silvis et al. 2024). In essence, this access makes technologies more available and affordable for those living in flood-hazard areas, thereby allowing homeowners to make use of these solutions (Gordon and Yiannakoulias 2020; Messager et al. 2021). This can be attained through collaboration between governments and private organisations (Gordon and Yiannakoulias 2020; Mbajiorgu 2019).

5.2 Distributing Subsidies or Financial Incentives for Retrofitting Costs from the Government

Although government initiatives and rewards exist for installing flood mitigation techniques like levees, there is a compelling requirement to transition from city-scale defense to property-scale defense (Alabbad et al. 2022). As a result, if funding efforts from government are available, they can assist households in overcoming various financial constraints. (Barendrecht et al. 2020). Financial assistance for the execution of flood resilience initiatives is a tactic utilised by government organisations or local governments and also by the industry (e.g. insurance firms) (Barendrecht et al. 2020; Manojlović 2016). For example, the government of England also pre-emptively (ex-ante) provides funding for private precautionary initiatives to manage the flood risk of properties under certain circumstances (Barendrecht et al. 2020). However, such initiatives do not exist in many other countries around the world and it is assumed that individuals privately finance their precautionary measures (Surminski and Thieken 2017). This strategy means that homeowners are given a particular sum of cash if they implement flood resistance efforts in their houses (Manojlović 2016). Manojlović (2016) further stated that in addition to financial incentives, non-monetary rewards, such as vouchers for public transportation or extra-governmental services, can be utilised to motivate the use of resilient systems on residential premises.

5.3 Providing Loans with Low-Interest Rates for Retrofitting Projects of Houses

The governments could assist homeowners take steps to floodproof their houses by implementing low-interest mortgage programs, originally financed by both municipal and state government donations (Priest et al. 2016). Thus, a loan linked with the property or mortgages would gradually spread out the expense of the investment over time, making the investment mitigation more profitable to the homeowners (Kousky and Kunreuther 2018).

5.4 Implementing Simplified Rules for Retrofitting Existing Houses through Building Codes or Zoning Regulations

In Australia, although all planning systems have taken natural hazards into account, they have never been prioritised over other policy goals (Dovers 2020). Therefore, although strict land-use planning laws may exist, houses will always be susceptible to some degree of natural hazard (Wenger 2015). Thus, it is essential to enact better-enforced building codes and land-use regulations by local councils to eliminate regulatory barriers related to floodproofing of homes (Kousky and Kunreuther 2018). Moreover, flood prevention management may need collaboration across various departments in government such as; emergency management agencies, housing and building regulatory bodies, local councils, urban planning and infrastructure departments and meteorological agencies etc (Wenger 2013). Wenger (2013) further contended that local government cooperation can significantly encourage the ability of local authorities to adjust to climate change in which these organisations can encourage collaborations, assist in leveraging investment, support adaptive methods and be its counterparts for regionally important research and implementation. For example, in New Zealand, FRM is highly delegated to the level of local government level, which is further split into two categories: territorial and regional councils inside the regional boundaries (Lawrence et al. 2014). Lawrence et al. (2014) also stated that the Local Government Act 2002 in New Zealand provides the governing authority by incorporating mandated community input on long-term strategies. Moreover, Lawrence et al. (2014) further elaborated that public entities in New Zealand have legal responsibilities to manage the risk of flooding and prevention, mitigate hazards, and evaluate the consequences of climate change.

There are considerable improvements possible in the ways standards and building codes are developed and applied in Australia (Wenger 2015). Within Australia's constitution, state governments hold the main accountability for natural resources, hence flood management resides within the purview of local and state governments (Wenger 2013). In Australia, there are various regulatory measures which can be undertaken to reduce disaster risks significantly, namely; implementing uniform regulations, enhanced land-use planning systems, and more stringent building codes (Wenger 2015). In the three tiers of the Australian government, reforms should be implemented so that flood management will be enhanced (Wenger 2013). Wenger (2013) further contended that the state and territory governments should consider the application of more conservative planning tools concerning increased floor levels, building materials, and design in flood-prone areas. Moreover, Australian local governments must ensure that they have sufficient flood risk data for them to make choices and that this data is incorporated into planning schemes (Wenger 2014).

5.5 Increasing the Conduction of Awareness Sessions for the Public to Promote Flood Resilience Knowledge

Many countries throughout the world adopt non-structural preventative strategies such as creating public education and awareness to mitigate catastrophe risks via planning and preparation (Forsyth et al. 2023). Specifically, raising awareness on response and recovery options along with communicating context-specific measures that can be adopted by individuals/households rather than generalised and centralised mitigation measures should gain more focus (Glaas et al. 2017). In Australia, the local governments possess a massive role to perform in society education related to property level flood risk mitigation (Wenger 2013). Accordingly, municipal personnel can illustrate the advantages of official mitigation steps to homeowners and create support within the community, facilitating the execution procedure of retrofitting measures (Silvis et al. 2024). For example, in the USA, the Federal Alliance for Safe Homes (FLASH) is a not-for-profit disaster security awareness entity (Kousky and Kunreuther 2018). Kousky and Kunreuther (2018) further stated that FLASH is comprised of over 100 federal and state emergency preparedness firms; (re)insurers, companies, charities, and others who develop disaster awareness initiatives, distribute home security and insurance manuals and provide an extensive selection of materials such as videos, peril diagrams, and tools for homeowners to implement security enhancements on their own.

5.6 Enhancing Access to Obtain Technical Assistance or Expert Advice Regarding Flood-Resilient Retrofitting of Houses

Most people are very reluctant to retrofit mainly because of their inability to access technical knowledge (Galvin 2014; Galvin and Sunikka-Blank 2014). Thus, enhanced technical details would decrease the technical barriers to flood-resilient retrofitting of homes (Galvin and Sunikka-Blank 2014). Galvin and Sunikka-Blank (2014) further contended that more householders may assist flood mitigation measures through floodproofing and retrofitting their homes if it was adequately clarified to them. Therefore, the state governments should provide greater technical assistance to local governments so they can generate flood details, evaluate risk and support the communities to identify the necessary retrofitting measures to floodproof their homes (Wenger 2013).

5.7 Enhancing Access to Flood Data to Understand the Risk from Floods to Houses for People Living in Flood-Prone Areas

The knowledge of flood data is required for accomplishing community resilience targets (Wenger 2013). Thus, Wenger (2013) further stated that homeowners need access to accurate, fine-scale data about flooding as a way to understand their risk and, in turn, make appropriate retrofitting decisions. Government agencies should ensure that more detailed flood mapping is made accessible and that updates are more frequent to show the evolution of the climate (Kousky and Kunreuther 2018; Wenger 2015). Accessible flood data, as well as mitigation, could result in enhanced public understanding by boosting their capacity to respond effectively to create an increasingly resilient society towards flooding events (Alabbad et al. 2022). In this regard, flood preparedness can be improved through enhanced communication of flood risk itself, specifically actionable information regarding past, current, and future flood damages and risks, as well as means for hazard mitigation and adaptation and cost-benefit analysis (Mostafiz et al. 2022). Thus, well-enforced mandatory hazard disclosure laws can ensure that all property owners have information about disaster risks at the time when it is most relevant to their decisions (Kousky and Kunreuther 2018). Many websites allow for access to general flood information concerning educating the public about general flood impacts (Mostafiz et al. 2022). For example, New York City has developed the website http://www.floodhelpny.org to convey flood risk and mitigation option information to residents (Kousky and Kunreuther 2018) and the Australian Government BOM offers services related to flood warnings and text dealing with flood preparedness and understanding floods (Mostafiz et al. 2022).

In Australia, flood overlays are one of the most important spatial planning tools that councils resort to in developing their policies for controlling land use in areas that are susceptible to flooding (Department for Trade and Investment 2024). Flood overlays provide essential information about the hazards of flooding and assist in the effective management of land use so that properties and infrastructures are kept safe (Melbourne Water 2024). These overlays indicate development approval with consideration of flood risks in the urban landscape (Department for Trade and Investment 2024; Melbourne Water 2024). They identify any flood-prone areas and develop strict development controls to protect the community, ensuring that any new construction or alterations to existing properties are made considering the hazard potential (Department for Trade and Investment 2024).

For example, in the state of Victoria, there are 04 overlay types, namely; Special Building Overlay (SBO), Land Subject to Inundation Overlay (LSIO), Floodway Overlay (FO) and Urban Floodway Zone (UFZ) (Melbourne Water 2024). Melbourne Water (2024) also stated that SBO refers to the overlays that consist of planning controls to detect overland flooding-prone regions and special approval is needed to build buildings in those areas. Melbourne Water (2024) further elaborated that LSIO refers to the overlays that consist of planning controls to detect regions susceptible to floods from open drainages and waterways and special approval is needed to build buildings in those areas. Melbourne Water (2024) also contended that FO refers to the overlays that consist of planning controls to detect regions with active flooding from open drainages and waterways. Melbourne Water (2024) further asserted that UFZ refers to overlays that regulate both land utilisation and development, with land utilisation limited to activities with low intensity including recreational and agricultural. Melbourne Water (2024) also highlighted that development is largely discouraged in the UFZ. All these overlays are very important in assisting local councils and developers in assessing the viability of projects in flood-prone areas and mitigating the danger of disastrous destruction from eventual flooding (Department for Trade and Investment 2024).

Generally, the flood overlay is important to homeowners in flood hazard areas because of the information that forms a basis on which retrofitting and flood resilience can be considered (Melbourne Water 2020). Melbourne Water (2020) further stated that in practice, using these overlays affords residents a sense of risk awareness that may be reached by taking necessary precautions, such as raising homes or reinforcing their foundations. Regular updates of the flood overlays with the latest data regarding climate change and flood risks are necessary, so these tools continue to be useful and valid (Department of Energy Environment and Climate Action 2024). Department of Energy Environment and Climate Action (2024) further contended that more activity by residents in flood mitigation would depend on better access and improvement to the information carried in the overlays. Department of Energy Environment and Climate Action (2024) also stated that it is not just the overlays protecting individual property; they also offer community resilience through better guidance of sustainable urban planning and reduce longer-term social and economic impacts of flooding. They are also very useful tools for supporting retrofitting efforts towards flood-resilient communities through the ability to provide preparedness and adaptation against future flood risks (Melbourne Water 2020).

5.8 Increasing the Involvement and Participation of the Community through Different Programs

The other key driver of flood resilience is community engagement (Keating et al. 2017; McEwen et al. 2018). Activities that build collaborative activities at the neighbourhood level, for example, involving practice floods or collective retrofitting, are likely to enhance participation (Kiss et al. 2022; Ramsey et al. 2019). These practice floods help to prepare communities for actual flooding by practicing emergency procedures, reviewing vulnerabilities, and educating residents about risks associated with flooding (Atanga 2020). Atanga (2020) further stated that this will ensure community bonding while they are working together to protect shared assets. Collective retrofitting is a neighbourhood-wide process where groups of houses are flood-resiliently retrofitted together (Kiss et al. 2022; Ramsey et al. 2019). Kiss et al. (2022); Ramsey et al. (2019) further stated that this is usually done with funding from a local authority or via community-led fundraising. Participation of community groups in different programs has a good impact on low-cost prevention strategies, and this impact is higher amongst floodplain inhabitants (Zinda et al. 2023).

5.9 Mitigating Insurance Constraints

Insurance is an approach that has been utilised in managing natural catastrophes, such as floods, for years, and for example, the United Kingdom began to include floods in the set of policies in 1961(Manojlović 2016) . Most insurance systems, especially those in the public category perform an important role in the communication of risk alternatives on how to prevent losses in the future (Kousky and Kunreuther 2018). The National Flood Insurance Program (NFIP) was established in the USA in 1968 to address the lack of personal flood insurance and increase aid for disasters (Knowles and Kunreuther, 2014). Extreme floods in the United Kingdom, especially in 1953, prompted the formation of the first United Kingdom cooperation with businesses for insurance against floods (Kousky and Kunreuther 2018). Furthermore, the Government of Canada has cooperated with insurance companies to provide insurance against flooding for its inaugural attempt as an essential element in the overall transition to FRM (Thistlethwaite et al. 2020). When considering Australia, the insurance sector plays a significant function in assisting natural catastrophe management (Wenger 2015). Wenger (2015) further contended that the Australian general insurance sector offers financial security in the event of a disaster. Wenger (2015) also stated that the policyholders in a community contribute a premium to an insurance fund which finances the recovery of flood damages.

Insurance is a crucial aspect of home and communal disaster resilience as it promotes investments in affordable mitigation strategies enabling the restoration of damaged assets and the subsequent rehabilitation (Kunreuther et al. 2013a; Kunreuther et al. 2013b). If households are aware that they may not obtain recompensation for each of their damages, it could incentivise individuals to make efforts to mitigate their risk by implementing household-level damage reduction actions during floods (Priest et al. 2016). Government disaster insurance policies can encourage or finance hazard reduction (Kousky and Kunreuther 2018). For example, the NFIP in the USA has an explicit goal of risk reduction, and FEMA offers grants that incentivise homeowners to protect properties that flood repeatedly (Kousky and Kunreuther 2018). Insurance coverage has significant power to incentivise the implementation of flood protection and loss-reducing initiatives, conduct adaptation, and improve the resilience of communities (Priest et al. 2016). Therefore, in the setting of FRM, a considerable focus is placed on the function and business structure of insurance firms (Manojlović 2016).

Insurance providers could be more willing to grant a premium decrease when the risk-reduction activity appears to be permanent, such as elevating the floor whereby any decrease in risk continues to be beneficial in a prolonged period (Priest et al. 2016). Therefore, the ways for applying insurance premium reductions to incentivise investment in effective, cost-saving mitigation measures have to be considered by the insurers (Kousky and Kunreuther 2018). For example, the community rating system developed by FEMA in the USA encourages communities to implement additional floodproofing measures that result in discounts on flood insurance premiums (Alabbad et al. 2022; Priest et al. 2016). In Australia, the government has worked towards access to more affordable flood insurance for the higher risk houses (Standing Committee on Economics 2024). Efforts such as the National Flood Insurance Database (NFID) also try to make it more transparent for the owners of properties regarding their respective flood risk (Insurance Council of Australia 2021). Insurance Council of Australia (2021) further stated that the NFID consists of a database listing 13.7 million properties with their estimated flood risk calculated from governmental maps of flooding. Insurance Council of Australia (2021) also elaborated that this is used by most insurers to determine the appropriate flood risk of a given building and their premium rates, factoring in a broad range of other variables: type of building, location, and claims history.

In Australia, many homeowners who's homes are susceptible to a 1% or higher flood risk are unable to obtain insurance against flooding at actuarially acceptable rates (Standing Committee on Economics 2024). As the risk profile of Australia against natural hazards is increasing, the amount of insurance premiums is also increasing (Standing Committee on Economics 2024; Wenger 2015). Therefore, under-insurance persists since many homeowners are taking cover with lower coverage or no insurance at all because of the cost factor (Wenger 2015). Further reforms on government subsidies or the establishment of a national pool may be needed to spread the risk burden across regions (Standing Committee on Economics 2024). The insurance industry might additionally help to improve the resilience of households by operating educational initiatives on the significance of property readiness to disaster maintenance, more engaging in standards for building and urban design and providing funds to public education on risk awareness (Booth 2018). Moreover, they can enhance household resilience by supporting national gathering of data, studies, and evaluation of disasters, and collaborating with governments and other agencies on disaster management for the identification and evaluation of risks and hazards (Coppel and Chester 2014; King et al. 2013).

6. CONCLUSION

Incidence and severity of riverine flooding are increasing significantly, particularly in flood-prone areas like Victoria in Australia. Therefore, the implementation of flood-resilient retrofitting in residential properties has been emphasised in the world to mitigate the damages from such events. Although benefits of these measures are already witnessed, the practical implementation of these measures are challenging due to numerous reasons. Therefore, this review which presents literature review of a broader research project that is currently being conducted has attempted to comprehensively discuss the identified strategies that have been successful in overcoming these challenges. Moreover, this study emphasised the importance of multi-stakeholder collaboration. The core theme identified in the literature is the need for concerted action on the part of policymakers, industry professionals, and homeowners. Such collaboration is essential to be able to overcome these economic, regulatory, technical, and social barriers to the implementation of flood-resilient retrofitting. For example, there is a need for improved access to financial incentives to offset some of the high upfront costs that prevent property owners from retrofitting their buildings. These include subsidies, low-interest loans, and insurance reforms. Simpler regulatory frameworks, including flexible building codes, go a step further in easing the retrofitting process by making compliance less burdensome for homeowners.

Community engagement in retrofitting programs also forms a very crucial part of achieving success in these programs. Creating a more flood-resilient culture is achieved by improving public awareness through education campaigns and information among stakeholders. More knowledge and tools for homeowners to take proactive actions will equip them with better ways of engagement, which, in return, will raise a sense of trust in the process of retrofitting. In this regard, the review highlights the need for clarity and accessibility in information concerning the hazards arising from riverine flooding and any benefits emanating from retrofitting. It also highlights how long-term policy measures will be required that support sustainable retrofitting solutions. The study calls upon policy makers to place flood resilience at the heart of housing policy and urban planning, in which retrofitting is the norm rather than an optional extra. This may mean placing retrofitting imperatives into the zoning laws, building codes, and urban development plans of high-risk areas.

Moreover, the findings of this review further imply that a broadening of adoption in flood resilience measures within residential property has got to be a multi-facet approach underpinned by interventions in finance, technology, regulation, and the social fields. The suggested review strategies, implemented through stronger collaboration, can help protect homes and livelihoods from the dangerous effects of future riverine floods by policymakers, industry participants, and communities. Thus, this research contributes to the building sector in advancing the discourse on flood resilience, provides bases for future research and policy development, and also provides actionable recommendations in response to specific flood-prone regions such as Victoria. These successful implementation strategies will be highly instrumental in transforming the most vulnerable residential communities into resilient ones that can withstand the coming threat of riverine flooding in a climate-altered future.

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