MEASURING PROPERTY FLOOD RESILIENCE (PFR) IN UK HOMES

ABSTRACT

Purpose

Despite the present focus on improving the resilience of homes to flooding in UK flood risk management policy and strategy, a general measurement framework for determining levels of flood resilience in UK homes does not exist. In light of this, the aim of this study was to develop a means to evaluate the levels of resilience in flood-prone homes from the perspective of homeowners.

Design/Methodology/Approach

A quantitative research methodology was employed, with empirical data obtained through a postal survey of homeowners who had experienced flooding. The responses received were then analysed using a combination of statistical techniques including agreement / reliability tests and multiple regression to develop a model of flood resilience.

Findings

A predictive model was developed that allows the resilience of a property to be quantified and measured as perceived by homeowners. The findings indicate that the main factors found to influence the level of flood resilience were: property type (PT), presence of cellar/basement (C/B), property wall type (PWT), property ground floor type (PGFT), kitchen unit type (KU), flood experience (FE), flood source (FS), and flood risk level (FRL).

Implications

The resulting model provides unique insights to resilience levels to the benefit of a range of stakeholders including policy makers (such as Defra / Environment Agency), Local Authority flood teams, property professionals, housing associations and homeowners. As a result, homeowners will be in a better position to determine which interventions should be prioritised to ensure better flood protection.

Originality/value

This is the first study of its kind to have rigorously quantified the level of flood resilience for individual homes. This study has quantified the effectiveness of individual resilience measures to derive the first reliable means to measure the overall levels of resilience at the individual property level. This is regarded as a significant contribution to the study of flood risk management through the quantification of resilience within individual UK homes, enabling the prioritisation of interventions and the overall monitoring of resilience.

Keywords: flooding, resilience, flood risk, property flood resilience, flood risk management

INTRODUCTION

Flooding is the most prevalent natural cause of property destruction in the United Kingdom, and the personal and economic losses are substantial (DEFRA, 2016). The frequency of floods and the damage they cause has increased dramatically since the mid-twentieth century. In the last two decades, the three most significant flood events were the summer floods of 2007, the winter floods of 2013/14 and 2015/16, with damages worth more than USD 11.5 billion (Surminski, et al., 2020). A recent review of the direct and indirect impacts of flooding by the Environment Agency shows the following costs of flood-related damages: residential properties (GBP 1.5 billion during the 2007 floods), transport losses (GBP 341 million during the 2015/26 floods), health costs (GBP 340 million in 2007), to name a few (Environment Agency 2018). The greatest proportion of these damages corresponds to residential properties (Met Office, 2014; Environment Agency, 2016). According to Sayers et al. (2015), the expected direct annual damages to residential properties is estimated at £270m. This emphasises the need for refocusing efforts to reduce the risk of flooding to residential properties.

Historically, flood risk management was viewed as a stand-alone task with the sole objective of protecting both people and assets against flood damage, mostly through the use of structural barriers to keep the water out (Merz, et al., 2010). Despite the steps taken to reduce flood risk and minimise its impacts on homes through structural flood defences, and an increasing amount of resources committed to prevention and warning, flooding remains a severe concern across the country (DEFRA, 2012; Surminski, et al., 2020). Devastating flood events in the United Kingdom in recent decades, with structural flood defences collapsing or being overtopped, reinforce the widely held belief that flood protection is not absolute (Surminski, et al., 2020). While engineered flood defences, flood warnings, and upper catchment measures can help, it is critical that individual properties have resilience built into them (Jha et al., 2012). This has coincided with a growing realisation that it is not technically nor economically viable to protect all properties against flooding (Environment Agency, 2009).

Flood resilience can be achieved in buildings in a variety of methods, such as avoiding inundation by lifting items such as electrical connections above predicted flood levels; or utilising resilient materials that do not distort or disintegrate when exposed to floodwater, such as cementitious materials (Rose, et al., 2016). In all circumstances, it's critical to ensure that water can be swiftly ejected from the building, and that adequate air circulation around the exposed elements is maintained to allow for reasonably quick drying (Rose, et al., 2016). In recent years, the term Property Flood Resilience (PFR) has emerged as a phrase used to describe how flood risk and impacts are managed at the individual level (Kelly, et al., 2019) and this has prompted the need to be able to measure and quantify resilience within individual homes. Hence, the purpose of this research is to explore the development of a statistical model to measure levels of resilience in flood-prone homes using appropriate statistical analysis to identify the key variables and their importance.

PROPERTY FLOOD RESILIENCE (PFR)

The definition of 'Property Flood Resilience' or what was previously referred to as Property Level Protection (PLP) in government guidance, has changed to reflect measures involving resilient floors, walls, and interiors designed to minimise the impact of floodwater entering a property (Pettit and Kerr, 2020). While flood resistance technologies such as aperture barriers that keep water out of a building previously received a lot of attention, the concept of PFR expands on this approach to incorporate resilience technologies and materials that can reduce the internal damage caused by flood events (May, et al., 2015). Following the 2007 floods, which had an extraordinary impact on thousands of properties in the UK, the Pitt Review emphasised the significance of enhancing property resilience and resistance to flooding (Pitt, 2008; Surminski, et al., 2020). Property Flood Resilience (PFR) measures can drastically reduce the amount of damage and disturbance caused when flood water enters a structure (Pettit and Kerr, 2020). PFR measures can help make a property more resilient to the physical effects of flooding, speed up recovery and in so doing, reduce the emotional toll that flooding can have on people (Pettit and Kerr, 2020). The coping ability and capacity for quick recovery of buildings are often achieved through the combined application of engineering design norms, materials, construction techniques, and retrofit strategies (Kallaos et al., 2014). These capacities are developed to protect the physical integrity of the building and to enhance its ability to withstand flooding (Kallaos et al. 2014).

In recent years, PFR has grown in popularity as a means of decreasing the impact of flooding on properties and new technologies have emerged as the PFR market has grown (May, et al., 2015). Hence, it has become critical to be able to assess the impact of these technologies and practices on flood resilience.

According to the Code of Practice, PFR measures are separated into two categories: resistance and recoverability (formerly known as resilience) measures (Kelly, et al., 2019).

i. Resistance Measures: the goal of flood-resistance measures is to keep floodwater out of the house. Door guards, airbrick covers, waterproofing of walls, non-return valves, and a sump pump are just a few examples of the resistance measures that can be applied at property level. Resistance measures can be manually operated or automated. Manual resistance measures must be installed by the homeowner or tenant prior to a flood event, whereas automatic resistance measures do not.
ii. Recoverability measures: these are measures designed to limit the damage caused by water entering a building. Waterproof plaster, raised electric sockets, solid concrete flooring, and tiled floor coverings are examples of such measures. These techniques do not prevent water from entering a home, but they do lessen flood damage and speed up the recovery process.

The PFR measures are summarised in table 1 as identified from literature and existing evidence.

Table 1: PFR Measures

Resistance	Recoverability
Door guard	Raised floor above predicted flood level
Window guard	Boiler mount on wall
Airbrick cover	Washing machine on first floor or above
Sewage bung	Oven with raised under type
Toilet pan seal	Electric metre above predicted flood level
Sump pump	Raising electrical sockets above likely flood level
Floodgate	Gas metre above predicted flood level
Non-return valve (utility waste pipe)	Having a flood plan
Non-return valve (overview pipe)	Moving vulnerable items to first floor
sandbags	Lightweight moveable furniture

MEASURING PFR

In order to manage and raise the resilience of system to floods, it is important to be able to measure how much resilience resides in the system (Carpenter et al., 2001; Walker et al., 2002). Therefore, as important as it is to have a resilient property, it is essential to know the level of resilience present in these individual homes. Bahadur et al. (2013) clearly stated that the demand for ways to measure interventions and progress has not diminished, and in fact may be even stronger than ever. The ability to measure the level of resilience is one of the most common forms of monitoring the progress of any system response to disturbance (Bahadur et al., 2013). However, without having this means of assessing the performance of the PFR measures in place, it will become challenging to meticulously identify areas with weaknesses, and thus the capacity to take optimal action to fortify these shortcomings.

Meanwhile, in quantifying resilience and designing means to evaluate performances of interventions toward resilience, researchers have proposed several framework and approaches like the ecological models (Cumming, et al., 2005; Bahadur et al., 2015) and community disaster resilience (Mayunga, 2007; USAID, 2009) among other resilience models. Whilst there has been extensive research on the development and adaptation of buildings to the risk of flooding, together with the application of the concept of resilience in the flood risk management domain, it would appear that there is no previous research towards measuring PFR.

The foregoing discussions have highlighted the significance of the PFR measures in minimising flood impacts. The conclusion drawn from these discussions is that given the significance of the PFR measures, therefore, there is a need to develop a means to evaluate the effectiveness of these PFR measures in order to improve their capacity. There is a lot of support for this conclusion in the literature (Lamond, et al., 2017). For example, Defra have demonstrated that the typical range of the PFR measures for properties has a cost benefit ratio in excess of £5 for every £1 invested in terms of reduced damages (DEFRA, 2016). Also, the benefit, both tangible and intangible on humans, is enormous and possibly immeasurable (Joseph, 2014). In order to gain a better understanding of how buildings behave when subjected to floodwater, Escarameia et al. (2007) conducted a series of tests on building materials to provide a baseline for information on seepage and drying rate. While this is directed to building walls, it can also be applied to floor construction made of similar materials. However, it is essential to evaluate, not just the wall and floor construction but, the effectiveness of the PFR measures. It is against this background that this study sort to shed new light on the flood risk management (FRM) domain by applying the concept of resilience as a fresh perspective for evaluating the effectiveness of PFR measures. Consequently, according to the Department for Business, Energy and Industrial Strategy, what can be measured can be controlled and eventually it can be properly managed (BEIS, 2017). Therefore, being able to measure the PFR at household level offers the opportunity to monitor, control and improve the level of protection in individual homes with significant flood risk exposure.

DATA COLLECTION

In dealing with the issue of measuring the flood resilience level of households, the most appropriate source of data for the analysis was the collection of primary data from households with flood experience. This is because the most effective means of gaining first-hand information from homeowners on their perceptions of the effectiveness of PFR measures was to ask them directly. The approach employed the use of a postal questionnaire survey as a tool for collecting the required data. When it comes to using a questionnaire in research, there is no one-size-fits-all rule, however, the study aim, type of information to be gathered and the available resources are usually the factors to consider in the selection. In this particular study, questionnaires were deemed particularly suitable for the following reasons:

i. the need to gather lots of data about many different residential properties in diverse geographical regions which could then be used to generalise as far as possible to the wider population.
ii. the need to conceal the identity of the participants to enhance participants' chance of providing honest responses, due to the relative sensitivity of the topic.
iii. the extent to which a researcher can be a part of the context being studied is also a factor that plays an important role in the choice of questionnaire survey.

SAMPLE FRAME

The study focused on households in flood-prone areas in the United Kingdom. Meanwhile, it had been reported that around 5.2 million properties in England alone are at risk of flooding (Environment Agency, 2014). This figure reflected around one out of every six properties (approx. 17%). Because of time and resource restrictions, it was difficult to include all the properties in the sample size, it was deemed necessary to select a sample for the study (Cresswell, 2003). Also, the main advantage of sampling is the ability to achieve measurement reliability and to generalise about an entire population by making inferences based on sample data selected from that population (Rea and Parker, 1997). The locations selected for the empirical stage of the study were chosen from areas that had been flooded in the last ten years. The rationale was simple: PFR is a new FRM strategy that emerged in the last few decades, and its adoption is still being promoted (Rose, et al., 2016). However, it is rapidly becoming the focus of flood risk protection at the property level.

TARGETED RESPONDENTS

With the help of flood hazard maps (Environment Agency, 2013), it is possible to identify residential properties in flood prone areas. However, this only identifies those properties at risk, rather than those properties that had actually been subjected to flooding. In order to do this, postcodes of homes in locations affected by recent flooding were generated, and then addresses that fall within these areas were obtained. In this case, it was assumed that all homes within these postcodes had been subject to one or more flood events, which was not always the case. The most challenging aspect was identifying homeowners who had experience with internal property flooding. Therefore, to significantly reduce the likelihood of sending a survey to the wrong audience, the following steps were taken:

i. The flood hazard maps were used to identify flood prone areas based on output from flood maps for coastal, river, and surface water flooding.

ii. Previous flood events in the United Kingdom were obtained from news archives. The flood events chosen were Storm Desmond and Eva in 2015/16, the Summer Flood in 2018, and the Yorkshire Flood in 2019. The selection of these flood events was based on their widespread impact across the UK, with significant impacts on lives and property. Online news archives and documented reports, including videos, images, and published reports, were used to obtain the postcodes of affected areas.

iii. The postcodes of the flood-affected areas were carefully obtained from news reports. This was the most challenging aspect of the entire process. To obtain postcodes from signposts seen in videos, reports, or published images of the flood events, careful observations of the report under investigation were required. In some cases, locations were visited for additional validation, such as Cumbria, which was visited before the COVID-19 pandemic.

iv. These postcodes were then entered into an address finder *(doogal.com)* to obtain the addresses that corresponded to these postcodes. While this approach did not guarantee that all addresses within these postcodes would have experienced these flood events, it provided a more accurate and streamlined search than simply sending surveys to addresses within flood risk postcodes (from (i) above). Furthermore, only house type residential properties were targeted, flats were excluded as many flats are owned by either Local Authorities or Housing Associations.

v. The questionnaires were sent to the addresses within these postcodes, along with a message informing recipients to return the questionnaire if they had not experienced flooding or to forward the survey to someone they knew who had.

QUESTIONNAIRE DESIGN AND ADMINISTRATION

The questionnaire used in this research contained a total of five sections with questions divided into two broad categories: (1) multiple choice questions addressing the physical attribute of the properties (relating to the building material and construction); flood characteristics; and insurance status and socioeconomic factors (including age, gender, education, and income); and (2) Likert scale questions that were designed to address the issues related to the effectiveness of the resistance and recoverability measures. Close-ended multiple-choice questions were included in the questionnaire in order to obtain a high response rate. The final questionnaire design was sent using the postal service.

In total, 760 questionnaires were distributed to addresses believed to have had some experience of flooding. A sizeable sample of 83 completed responses were returned, representing a response rate of approximately 10.9%. While these response rates are lower than the ideal for survey analysis, they are not unusual rates for voluntary postal questionnaire surveys (see Sutrisna, 2004; Ankrah, 2007; Samwinga, 2009). In addition, the situation at the time when the survey was administered, the nationwide lock-down, caused by the covid-19 pandemic made unlikely to acquire a higher response rate.

During the course of administering the survey, many of the respondents were trying to cope with the difficult circumstances caused by the pandemic; the inability to meet with family members; the fear of contacting the virus; pain caused as a result of losing loved ones, among other issues. Consequently, the low response rate was partially expected and was sufficient to meet the statistical analytical requirements.

DATA ANALYSIS

The collated data was analysed using IBM SPSS Statistics 25 software and incorporating both descriptive and inferential data analysis. The validity of the survey instrument was checked using the agreement and reliability test. Based on the recommended guidelines, a survey instrument retains a high internal consistency (reliable) if the estimated Cronbach's alpha is above 0.70. Regression analysis was adopted to develop the PFR model based on the ability of the statistical tool to estimate the value of one or more influencing factors. The analyses and the outputs are discussed in the next sections.

Descriptive Analysis

A five-point Likert scale ranging from 'very effective' to 'not effective at all' was used to collect data on the effectiveness of PFR measures, which included resistance and recoverability measures. Each level of agreement was given a weighting index, with 'very effective' equaling 5, 'quite effective' equaling 4, 'don't know' equaling 3, 'not very effective' equaling 2, and 'not effective at all' equaling 1. When the responses were gathered, agreement and reliability tests were performed. Tables 2 and 3 show the results of the analysis of homeowners' ratings of the effectiveness of PFR measures for resistance and recoverability, respectively. From the results, the standard deviations are small when compared to the mean ratings, indicating that the data has little variation (Blaikie, 2010). This is also supported by the fact that the mode and median numbers are nearly equal, as well as the fact that the mean and median ratings are approximately the same. According to Field (2009), these show that the mean ratings are a good fit for the data.

Table 2: Descriptive summary of the resistance measures rating

Resistance Measures	**Mean**	**Median**	**Mode**	**Std. Deviation**	**Min**	**Max**
Demountable door guard	2.77	3	1	1.468	1	5
Demountable window guard	3.06	3	2	1.338	1	5
Airbrick cover	2.92	3	2	1.45	1	5
Sewage bung	3.05	3	5	1.481	1	5
Toilet pan seal	3.04	3	4	1.493	1	5
Sump pump	3.12	3	4	1.356	1	5
Floodgate	2.72	3	1	1.459	1	5
Non-return valves utility waste pipe	2.98	3	5	1.49	1	5
Non-return valves overflow pipe	2.51	2	1	1.347	1	5
Use of sandbags to prevent water entering	2.7	2	1	1.552	1	5

Table 3: Descriptive summary of the recoverability measures rating

Recoverability Measures	**Mean**	**Median**	**Mode**	**Std. Deviation**	**Min**	**Max**
Raised floor above predicted flood level	3.18	3	5	1.433	1	5
Boiler mount on wall	3.65	4	5	1.542	1	5
Washing machine on first floor or above	2.98	3	3	1.405	1	5
Oven with raised under type	2.96	3	2	1.469	1	5
Electric metre above predicted flood level	3.47	4	5	1.451	1	5
Raising electrical sockets above likely flood level	3.27	4	5	1.57	1	5
Gas metre above predicted flood level	3.28	3	5	1.484	1	5
Having a flood plan	3.14	3	5	1.499	1	5
Moving vulnerable items to first floor	3.35	4	5	1.534	1	5
Lightweight moveable furniture	3.14	3	4	1.38	1	5

Agreement and Reliability Test

Inter-rater agreement and inter-rater reliability were used to aggregate matched pairs data (for the resistance and recoverability measures). The inter-rater agreement denotes the extent to which respondents' ratings are interchangeable; that is, it reflects the extent to which raters provide essentially the same rating, i.e the consensus (LeBreton and Senter, 2008). Significant agreement indicates that the aggregated (mean) ratings are credible representations of the respondents' individual agreement with each of the statements on homeowners' measures of effectiveness for the PFR measures.

The consistency of inter-rater reliability refers to the degree to which different respondents' ratings are proportional when expressed as deviations from their means (Bliese, 2000; LeBreton et al., 2003). As a result, for each variable, the inter-rater agreement was assessed using the single-item inter-rater agreement index (R_{wg}) (James et al., 1984, 1993) (see Table 4). The rule of thumb value for R_{wg} is 0.60 (James, 1982), and the more commonly acceptable value is 0.70, indicating that respondents are in strong agreement. The R_{wg} of 0.638 indicates that respondents agreed on the effectiveness of the resistance and recoverability measures.

The ICC(b) value is 0.932 for the building resilience scale, which is higher than the 0.60 cut-off point recommended by Glick (1985). This indicates that the respondents can be reliably differentiated in terms of all of the variables in this study. Based on the above results, the matched pair response data were aggregated into resilience level scale.

Also, table 4 illustrates the Cronbach's coefficient alpha values that were estimated to examine the internal consistency for the building resilience scales. Cronbach's coefficient is 0.951 for the building resilience measurements, (which is a combination of the resistance and recoverability measures). Hinton et al (2004) have suggested four cut-off points for reliability, which includes excellent reliability (0.90 and above), high reliability (0.70-0.90), moderate reliability (0.50-0.70) and low reliability (0.50 and below). The aforementioned values suggest that the building resilience is excellently reliable (Table 4).

The high Cronbach's alpha values for this variable implies that it is internally consistent. That means all items rated for each variable are measuring the same content. In brief, the higher the Cronbach's coefficient value of a construct, the higher the reliability is of measuring the same construct.

Table 4: Descriptive statistics and inter-rater agreement indices for factors that can influence the PFR measures

Variables	**Operationalisation**	**ICC(a)**	**ICC(b)**	**R_{wg}**	**Alpha**	**Reliability type**
Building resilience	Average score for 20 resistance and recoverability measures	0.56	0.932	0.638	0.951	Excellent

THE PFR MODEL

The multivariate analysis involved the stepwise removal of variables from an initial list of 17 variables, (see figure 1), covering building characteristics (9); flood characteristics (5) and flood insurance (3) covering 50 categories, until the remaining categories were considered to be significant. The cut-off for *significance* was taken as the probability that the observed relationship occurring by chance was less than *0.05 (5%)*. The stepwise removal method in regression analysis is widely used for developing models (Everit and Dunn, 1991; Bryman and Cramer, 1999; Norsusis, 2003). The analysis was carried out using the SPSS based on mathematical criteria.

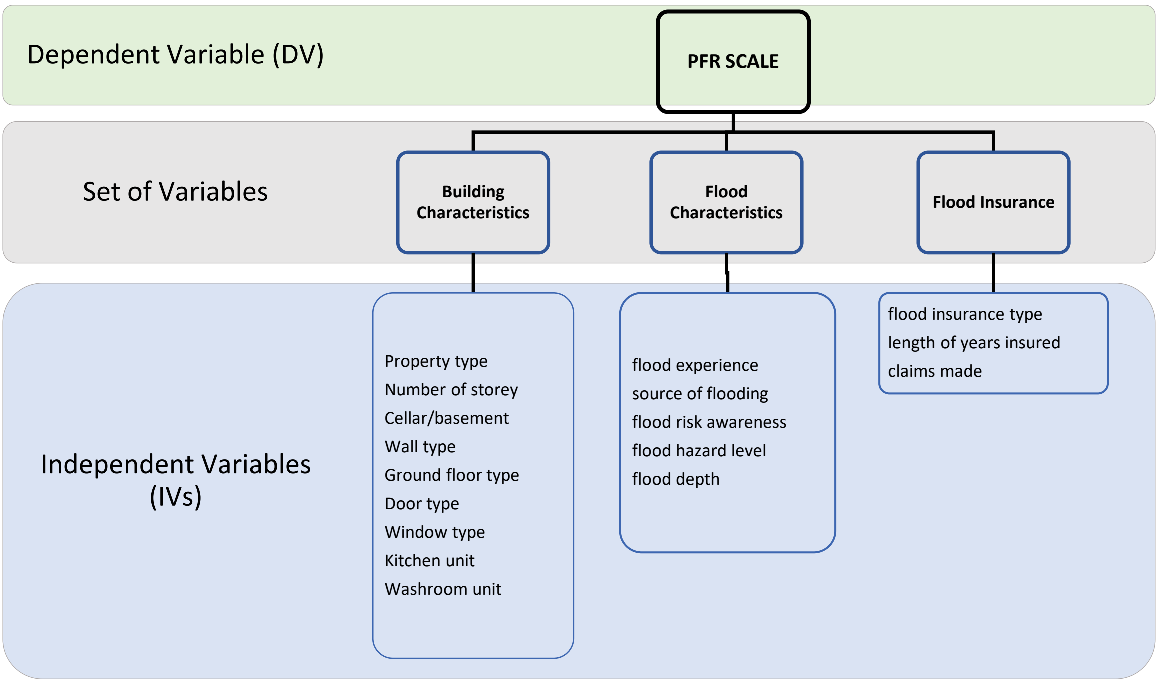

Figure 1: Factors captured in the questionnaire to measure the building resilience scale

The Regression Model (Model Accuracy)

The analysis resulted in eight variables with 12 significant categories (factors) as shown in Table 5. This table provides the R, R^2, adjusted R^2, and the standard error of the estimate values, which can be used to determine how well the regression model fits the data.

Table 5: Model Summary (Building Resilience Scale)

Model	**R**	**R^2**	**Adjusted R^2**	**Std error of the estimate**	**Durbin-Watson**	**Sig**
PFR	0.702	0.492	0.414	0.07307	1.840	0.000

The ‘R’ represents the multiple correlation coefficient and can be considered to be one of the measures of the quality of the prediction of the dependent variable; in this case, the building resilience. R is a measure of the strength of the relationship between the building resilience scale and its predictors. It ranges from -1 to +1 inclusive. Values close to zero indicate a weak relationship, or perhaps no relationship. A value of 0.702 in this case, indicates a positive correlation and fairly good level of prediction.

The R^2 value (also called the coefficient of determination), represents the proportion of variance in the building resilience scale that can be explained by the independent variables. From the table 5, the R^2 value (also called the coefficient of determination) is 0.492. This shows that the independent variables explain 49.2 % (almost a half) of the variability of dependent variable, the building resilience. This is quite high, in comparison to the results from other studies in related fields (Joseph, (2014) with R^2 value of 0.17; EA/DEFRA (2005), with R^2 value 0.26). Therefore, predictions from the regression equation are fairly reliable and can be considered satisfactory. Although, this implies that 50.8% of the variation is still unexplained. This however, is caused by factors other than the predictors included in this model, so adding other independent variables could improve the fit of the model. Apart from the natural variation from person to person in their response to a particular set of circumstances, other variables not accounted for in the analysis might include those other factors that were insignificant from the initial list of 17 variables.

At first glance, the R^2 seems like an easy-to-understand statistic that indicates how well the regression model fits the data set. However, it does not tell the whole story, to get the full picture, the R^2 value is considered in combination with other statistics. The ’Adjusted R^2’ (adj. R^2) is another important factor. A value of 0.414 (reported in table 5) indicates that truly 41.4% of variation in the outcome variable is explained by the predictors which are to be kept in the model. The adj. R^2 value of 0.414 shows that more than a third of the variability in the building resilience scale is predicted by the property type (PT), presence of cellar or basement (C/B), wall type (WT), ground floor type (GFT), kitchen unit (KU), flood experience (FE), flood source (FS) and flood risk level (FRL) (the IVs). A high discrepancy between the values of R^2 and the Adj. R^2 is a sign of a poor fit of the model. High discrepancy in the values of both the R^2 and the Adj. R^2 can be as a result of the addition of useless variables to a model as this will cause the value of the adj. R^2 to fall. However, for any useful variable added, the adj. R^2 value will increase. Therefore, the level of discrepancy in this result is low with a difference of 0.078 (about 15%).

The standard error (in this case is .07307) of a model fit is a measure of the precision of the model. It is the standard deviation of the residuals. It shows how wrong one could be if the regression model is used to make predictions or to estimate the level of building resilience to flood. As R^2 increases the standard error will decrease. On average, the estimates of building resilience with this model will be wrong by 0.07307. This value is low and does not raise issue for concern.

The Durbin-Watson Statistic

One of the assumptions of regression is that the observations are independent. In testing for independence of the error terms, the Durbin-Watson statistic was produced. If observations are made over time, it is likely that successive observations are related. If autocorrelation is present, then the usual t and F tests across the regression analysis may not be valid. Testing to see if autocorrelation problem exist is done using the Durban-Watson (DW) test. (Gujarati, 2003). If there is no autocorrelation (where subsequent observations are related), the Durbin-Watson statistic should be between 1.5 and 2.5. The Durbin-Watson statistic obtained is 1.840 (see table 5) which ends up in the non-rejection zone for autocorrelation. Therefore, the data is not auto-correlated.

Table 6 shows the result of the multivariate regression analysis carried out to measure the PFR. This was developed after incorporating the related concepts of resilience from the FRM literature reviewed by Adedeji et al., (2018) and analysing the data collected from homeowners with flood experience. Hence, the model identified the significant factors which influence the PFR and their weightings. The significant factors were the property type (PT), presence of cellar/basement (C/B), property wall type (PWT), property ground floor type (PGFT), kitchen unit (KU), flood experience (FE), flood source (FS) and flood risk level (FRL). These factors are classified under construction type (PT and C/B) and material type (PWT, PGFT and KU) and flood characteristics (FE, FS and FRL). Of all the factors, the kitchen units have the least impact while the flood source has the most impact on the building resilience.

Table 6: Regression Coefficients

Independent variables	Parameters	Unstandardised Coefficients B	Unstandardised Coefficients Std Error	Standardised Coefficient Beta	t - value	sig (p)
Slope	Constant	0.309	0.038		8.14	0.000
Property Type (PT)	semi-detached	*Reference*				
	Detached	-0.057	0.018	-0.285	-3.135	0.002
	Terrace	*Not Significant*				
Cellar/Basement (C/B)	cellar or basement	*Reference*				
	No cellar/Basement	0.067	0.02	0.312	3.304	0.001
Property Wall Type (PWT)	timber frame	*Reference*				
	Cavity	0.047	0.02	0.227	2.36	0.021
	Concrete	*Not Significant*				
Property Ground Floor Type (PGFT)	Timber	*Reference*				
	Concrete	0.062	0.018	0.327	3.5	0.001
Kitchen Unit (KU)	Wood	*Reference*				
	Plastic	0.057	0.025	0.224	2.306	0.024
	Ceramic	*Not Significant*				
Flood Experience (FE)	Once	*Reference*				
	None	-0.037	0.018	-0.191	-2.104	0.039
	more than once	*Not Significant*				
Flood Source (FS)	river flood	*Reference*				
	surface water flood	0.086	0.024	0.428	3.59	0.001
	ground water flood	0.076	0.023	0.399	3.343	0.001
Flood Risk Level (FRL)	high risk	*Reference*				
	very low risk	0.097	0.028	0.457	3.418	0.001
	low risk	0.066	0.028	0.315	2.377	0.020
	medium risk	0.058	0.027	0.278	2.184	0.032

Estimated Model Coefficients

Table 6 shows five parameters generated for each IV in the regression table: the unstandardized coefficient (B), the standard error for the unstandardized coefficient (SE B), the standardized coefficient (β), the t test statistic (t), and the probability value (*p*). Table 6 gives interesting information about the regression model. It begins with the coefficients of the significant factors required to predict the building resilience level. This is generated from the unstandardized coefficients. Since all the coefficients are significant, with *p* values less than 0.05, the PFR model is given as:

> *PFR Level = 0.309 - 0.057 (detached property type [PT]) + 0.067 (no cellar or basement C/B) + 0.047 (cavity property wall type PWT) + 0.062 (concrete property ground floor type PGFT) + 0.057 (plastic kitchen unit KU) - 0.037 (zero flood experience (FE)) + 0.086 (surface water source of flooding FS) + 0.076 (ground water source of flooding (FS)) + 0.097 (very low flood risk level (FRL)) + 0.066 (low flood risk level (FRL)) + 0.058 (medium flood risk level (FRL)).*

The regression intercept (labelled Constant in SPSS) takes the value of 0.309, is the predicted value for the building flood resilience if all independent variables fall on the reference point, property type = semi-detached, cellar or basement = present, property wall type = timber frame, property ground floor type = timber, kitchen unit = wooden, flood experience = once, flood source = river flood, and flood risk level = high flood risk. That is, we would expect an average building resilience to flood of 0.320 (that's about 32%) when all the reference predictors are present within the property.

Standardised Coefficients (Weight of each Factor)

Accordingly, standardized coefficients are called beta weights, given in the beta column. The beta weight measures how much the building resilience increases (in standard deviations) when the predictor variable is increased by one standard deviation assuming other variables in the model are held constant. These are useful measures to rank the predictor variables based on their contribution (irrespective of sign) in explaining the level of the building resilience scale. The IVs in table 7 are arranged in increasing order of the beta weight with the very low risk category of the (FRL) being the highest contributing (.457) predictor to explain the building flood resilience, and the next is the surface water flood category of the FS IV (.428), while the least is the zero prior flood experience (-0.191).

Table 7: Standardised coefficients (Weight of each Factor)

Parameters	Standardised Coefficient
	Beta
constant	
very low risk (FRL)	0.457
surface water flood (FS)	0.428
ground water flood (FS)	0.399
concrete (PGFT)	0.327
low risk (FRL)	0.315
no cellar/basement (C/B)	0.312
detached (PT)	-0.285
medium risk (FRL)	0.278
cavity (PWT)	0.227
plastic (KU)	0.224
none (FE)	-0.191

DISCUSSION OF THE PFR MODEL

Property flood resilience is clearly influenced by a variety of factors. This section analyses these factors in light of existing literature, with the goal of determining if the model is appropriate for the research investigation's purpose.

Property Type

Several studies have found that property type (e.g., detached, semi-detached) influences flood resilience (Keating, et al., 2015). These studies, however, did not specify which property type is more resilient to flood damage. According to the result (Table 6), detached properties appear to be less resilient than semi-detached properties. One possible reason the detached property is less resilient may be due to cost of reinstating the property from flood damage. According to the report by Keating et al. (2015), detached properties have the highest average cost for reinstating after a flood event, while the terrace has the lowest. This suggests that protecting a detached home from flood damage costs more on average than protecting a semi-detached or terraced home (Keating, et al., 2015). These finding are consistent with the report by Keating et al (2015). This means that detached property owners will have more to worry about in terms of the financial resources required to protect their properties and deal with the flood risk that comes with it.

Cellars and Basements

According to research by the Environment Agency towards developing practical guidance to help households prevent flood impacts from groundwater, basements are particularly prone to flooding, (Environment Agency, 2011). As a result, the Environment Agency has issued advice on basement projects in flood zones, noting that basements should be avoided in certain places due to the risk of flooding. This advice was given to help developers minimise potential flood impacts to new buildings in flood risk areas.

As a result, a home without a cellar or basement will be more resilient than properties with cellars or basements. This study has provided robust evidence to support the claims of the Environment Agency and confirmed that homes without cellars or basements are more resilient. Properties without cellars or basements were found to be 7% more resilient to the impacts of flooding.

Property Ground Floor Type

Many researchers consider raising the floor levels above the predicted flood level to be one of the most effective options for improving resilience – see examples (ODPM, 2003; Bowker et al., 2007). However, this approach brings up a number of issues to consider. This, for example, necessitates some assurance that floodwaters would not rise much higher than existing floor levels, that the predicted flood level is well understood, and that the property has sufficient ceiling height to accommodate this raised floor level. However, this comes with certain additional costs that not all households can afford. Meanwhile, when comparing the two types of floors studied (concrete and timber), the research revealed that the concrete floor is more resilient than a timber-framed floor.

Concrete floors, according to research conducted by the Association of British Insurers (ABI) (2009), are more resilient than timber floors. In fact, it has been recommended that timber floors should be replaced with solid concrete, especially if the property is frequently flooded (Bowker, et al., 2007). Although less sustainable, a concrete floor is preferred because it provides an effective seal against rising flood water. One thing the ABI report did not specify is the extent to which the concrete floor is more resilient.

The findings of this research have helped to establish a value in this regard. The results from the analysis states further that the concrete floor is 6.2% more resilient than the timber floor type as it relates to flood resilience and flood impact reduction. Furthermore, Lamond et al. (2017) advised that properties with timber floors may consider replacing the timber floor with concrete where the property is frequently flooded and where existing timber flooring needs replacement. Timber floors are prone to swelling and distortion when exposed to flood water for an extended period of time. Furthermore, timbers that become wet and take a long time to dry may be prone to decay in the long run. Meanwhile, when masonry and concrete come into direct contact with floodwater, they are unlikely to be severely damaged. This is reiterated in a report carried out by Dhonau et al. (2020) on a Victorian terrace house in Yorkshire. Here, in a bid to improve resilience to flooding, existing suspended wooden floorboards were replaced with concrete floors. The finding of this study has shown that this replacement will significantly increase resilience.

Wall Type

The comparison for the wall type variable compared timber frame and cavity walls. Since the 1920s, masonry cavity walls have been the most popular choice for UK housing. There is some agreement on wall constructions based on PFR guidance and reports, with support for the use of masonry cavity because it appears to reduce water penetration, however, it is acknowledged that this type may inhibit drying of the internal building fabric (Tagg et al., 2007). Cavity walls help to reduce moisture transfer from the outer to inner leaf and provide space for insulation, which can be fully or partially filled. Furthermore, according to the Concrete Centre (2007), masonry is more flood resilient than other construction materials since it does not deform, degrade, or lose structural integrity as a result of flooding.

According to Tagg et al. (2007), the concept of avoiding cavities is quite interesting, as this is an important feature in preventing rain penetration. However, evidence from the literature suggests that closed cell foam is the preferred cavity insulation, though other forms may be equally suitable if used on the external wall (Tagg et al., 2007). As a result, the property wall type variable (masonry cavity wall being more resilient than timber-framed walls) is consistent with existing literature findings and the discussion on ground floor type variables. As a result, this research has contributed by defining the extent to which the masonry cavity wall is more resilient than the timber wall. This research demonstrates that masonry cavity walls are 4.7 percent more resilient to flood impact than timber walls. Further, the study carried out by

(Lucchi, et al., 2019) on the hygrothermal will be helpful to monitor the moisture ability of wall when applied to the property wall at the design stage.

Type of Kitchen Unit

The findings show that the plastic kitchen unit is more resilient to flood damage than the wooden kitchen unit. Kitchen cabinets, which are often made of chipboard, give little to no protection against flood damage (Wassell et al., 2009). However, Dhonau et al. (2020) described how a solid wood kitchen can be completely washed away after a flood, further emphasising the poor resilient nature. According to Hunter (2015), kitchen units below flood level should be made of waterproof materials such as plastic or stainless steel hardware. Although these are not the most appealing in terms of aesthetics, however, in terms of resilience, they outperform traditional wooden kitchen cabinets. Moreover, plastic kitchens can be costly, and homeowners have been frequently hesitant to install them (Lamond, et al., 2016).

In terms of aesthetics, the Poly-Vinyl Chloride (PVC) kitchen unit is a better choice. PVC, a plastic composite, can be easily cleaned and dried when it comes in contact with water (FIRA, 2015). Metals can also be used, and they are considered to be easy to decontaminate because they are robust to powerful cleaning methods (Lamond, et al., 2016). Ultimately, choice will depend on cost and aesthetics with flood resilience in mind (Lamond, et al., 2016). This study found that kitchen units made of plastic are more resilient. In comparison to a wooden kitchen unit, a plastic kitchen unit can be easily cleaned and dried after being exposed to flood water. Also, the risk of swell and rot, if it exists, is avoided with plastic kitchen units. This aligns with the findings of this study with the plastic kitchen unit contributing more to the overall building resilience.

Flood Experience

In research conducted in a variety of countries, past flood experience has been found to be a critical determinant for greater risk preparation (Burningham et al. 2008; Gow et al. 2008; Kung and Chen 2012; Wachinger et al. 2013; Bubeck et al., 2018). According to Tapsell et al. (2010), flood recurrence in a given area might raise inhabitants' awareness of the risk and lead them to take steps to mitigate the effects. Put simply, the experience motivates them to improve their flood preparedness in the future. However, it is worth noting that such experience often comes with an intangible cost to home owners, such as increased anxiety about future flooding (Werrity et al., 2007).

Flooding experience was discovered to be a significant factor in prompting the implementation of protective and loss-reducing actions in response to a flood warning and during a flood event (DEFRA/EA, 2009). In contrast, not knowing what to do increases the stress experienced during a flood event (Fielding et al., 2007; Carroll et al., 2009). As a result, those who have been through a flood event should be better prepared to deal with the effects of a subsequent flood (DEFRA/EA, 2009). This implies that property owners with prior flood experience are more likely to take steps to strengthen their properties against flooding than their counterparts with no prior experience. This is consistent with the findings of this study, which found flood experience (FE) to be a significant variable (see table 6).

Meanwhile, findings in Scotland indicate that prior experience may impede response and preparedness in some circumstances (Owusu et al. 2015; Harries et al. 2018). According to these reports, some people may not expect a worse event than the one they had already experienced. It also suggests that some flood victims may simply want to forget their experiences and move on with their lives; for them, preparation increases anxiety and worry about future flooding; while others, particularly if they have previously suffered significant damage, may conclude that their actions will not reduce damage or make any difference (McCarthy, 2004). However, it is clear that, in most cases, prior experience motivates better preparedness for future flood events (Nye et al., 2011; Kuang and Liao, 2020).

Flood Source

The findings indicate that, of the three flood sources considered, river flooding has the greatest impact on the resilience. This finding supports the findings of Sayers et al. (2020), who reported that river flooding is the dominant risk in recent times and contributes the most to economic damage, while groundwater continues to have a limited contribution on a national scale, despite being important locally. Although structures such as embankments, walls, and dams can reduce the risk of flooding from rivers and surface water, it is currently impossible to build effective defences to prevent widespread groundwater emergence. This could explain why it had a greater impact on building resilience than surface water flooding.

Furthermore, when comparing surface water and groundwater flooding, many reports agree that groundwater flooding is more difficult to prevent (Environment Agency, 2011). The precautions and options available to property owners to mitigate groundwater flooding are rather limited (Environment Agency, 2011; Environment Agency, 2014), making it difficult to develop and improve resilience.

The most effective method of dealing with groundwater flooding is to install a drainage or pump system to keep the water away from the property (Environment Agency, 2011). The efficiency of the pump can be optimised when a sump is installed at its inlet. This implies the presence of a low point into which water can drain. However, one of the major challenges is determining where the water will be pumped to avoid flooding elsewhere. One important piece of advice is to ensure that water is pumped out only when flood levels outside the property begin to fall below those inside. This is critical because it reduces the possibility of structural damage. It is critical to seek the advice of a structural engineer when dealing with these challenges. All of these considerations will have to be resolved prior to flood events; they cannot be considered during flood events (Environment Agency, 2011).

Flood Risk Level

Flood risk levels (based on the terminology used in the UK flood map) in the UK are classified as very low, low, medium, and high based on the Environment Agency flood risk maps. By risk, it means not only the likelihood that flooding will occur, but also the potential flood impacts. As a result, *high flood risk* means that there is a 3.3 percent or greater chance of flooding each year (Environment Agency, 2011). While *very low flood risk*, means that there is less than a 0.1 percent chance of flooding each year. According to the findings of this study, properties in high flood risk areas are less resilient than properties in very low risk areas. This outcome corresponds to the interpretation of the flood risk map. The most effective way to reduce risk is to build houses away from high-risk flood zones. However, where properties already exist, a comprehensive flood risk assessment must be completed.

Improving the PFR Model

It is evident that in improving flood resilience, financial investment is required which some property owners may not be able to afford. Previous research has revealed the expense of reinstating property from flood damages as well as recommendations on how to improve resilience. A progressive improvement, on the other hand, will be easier for the homeowner. In considering the building resilience model (table 6), it appears that the variables relating to the flood characteristics have the most negative impacts on the building resilience. This suggests that the first step toward improving resilience is to relocate to a less flood-prone area. This option may not be feasible, and it comes with its own set of financial challenges, as well as the fear that the property will be unsellable or extremely difficult to sell.

The most significant factor was discovered to be replacing timber floors with concrete floors, which increased resilience by 6.2 percent. There are also ways to improve the resilience of floors by using water-resistant floor coverings such as clay or concrete tiles, or vinyl sheets with chemical-set adhesive. Carpets, vinyl, and wood flooring all slow the drying process and are therefore not recommended for use as floor covering on concrete floors. Meanwhile, ceramic and quarry tiles are recommended since they absorb less water and do not impede the drying process significantly.

The presence of a cellar or basement was the next important factor to consider. Tanking, a popular method of flood proofing basements, can be used to improve the resilience of a building with a cellar or basement.

Prior flood experience was also discovered to be an important factor in increasing resilience. Homeowners should be encouraged to educate themselves and become more aware of flood risk. They can also learn from the experiences of others, which can be obtained in most cases by interacting with those who have flood experience. They can also join flood-related organisations and participate in community forums on flood risk and resilience, such as those hosted by the National Flood Forum (NFF). They can learn by reading about other people's experiences in journals and news archives to help them prepare for potential flood events. It may be difficult to predict exactly the kind and intensity of a potential flood event. However, it is preferable to be aware of an impending threat and hence prepare for it than to be unaware. The implication is that the flood event may come as a huge shock to unprepared homeowners, accompanied by devastating consequences from which they may struggle to recover. Understanding the devastation that flooding can cause will also provide insights into how to improve resilience. Furthermore, being aware of the flood risk and taking pre-flood precautions such as determining whether a property is at risk, understanding flood warning codes, and knowing what to do if a warning is issued will greatly improve a household's flood resilience.

When there is a flood, the kitchen is often the most expensive item to replace (Dhonau, 2020). Since the kitchen is the most expensive part of the house, improving its resilience will require a significant financial investment. As a result, it is critical to keep flood damage to a minimum so that kitchens can be fully functional as soon as the flood water has receded. Moving from wooden kitchen units to plastic kitchen units is thus a good investment for properties at risk of flooding. The best option will be to move the kitchen to a higher floor level such as to the first floor and well above the expected flood level. However, this is likely to be very expensive, and may not be feasible or even possible in some properties such as in bungalows. The adoption of flood-resistant materials is a better option in these circumstances. Steel and ceramic units, for example, are materials that can be easily cleaned and dried after coming in contact with water. Plastic kitchen units are water-resistant and easy to clean and dry. Table 8 summarises the key findings and the key improvements for the building resilience model.

Table 8: Key Findings and Improvement of the Building Resilience Model

FACTORS	FINDING FROM RESEARCH	KEY IMPROVEMENTS
Property Type	Semi-detached appears to be more resilient than detached property type	Resistance and resilience measures should be put in place and taken seriously in detached property as flood may cause more economical damage to the detached property
Cellar/Basement	It is preferred if this can be avoided.	This involves sealing the basement with a water-proof membrane to prevent water seeping through the walls and floor.
Property Wall Type	Cavity (masonry) is preferred to timber-framed wall	The closed cell foam is the preferred form of cavity insulation. Also, wall finishes can be added to enhance resilience (while maintaining aesthetics) such as water-resistant paints
Ground Floor Type	Concrete is preferred to timber-framed	This can be enhanced by including floor covering that are water-resistant such as clay tiles, ceramic tiles.
Kitchen Unit	Plastic kitchen unit is preferred to wooden unit as the plastic can be easily cleaned and dried and soak and swell can be avoided.	The best option is to relocate the kitchen to higher floor if possible. Other option is to go for a steel kitchen unit which may be better for both water and in case of fire outbreak.
Flood Experience	Prior experience is an advantage for better preparation	The experience does not necessarily have to come through directly but can be acquired through others flood events experience and learn from how they cope. Some flood group and national flood forum.

Flood Source	river water is the least vulnerable as structures (embankment; flood wall) are erected at river banks to prevent against flood	Awareness of risk associated with each kind of flood
Flood Risk Level	Awareness is the key	Awareness of risk level is essential and this can be obtained through flood risk map; environment agency website. Understand the predicted flood level and the measures required to minimise flood impacts.

IMPLICATIONS

The findings of this research have several important implications for PFR stakeholders, insurance companies and homeowners. The practical implications of the findings are discussed below:

i. Homeowners: The research will provide valuable information on the flood resilience levels currently present in the building for the benefit of homeowners. This is important as homeowners are partly responsible for protecting their properties against the impact of flooding. This is achieved through quantifying current resilience levels by identifying any measures that have been put in place to reduce the impact of flooding and the effectiveness of measures put in place.

ii. Property Experts and Surveyors: Information on the level of resilience will also aid in property valuations at the point of sale and/or for mortgage purposes, allowing any existing measures to be considered in this process. Also, through interaction with the framework, surveyors can benefit by carrying out an appraisal of the amount of resilience present in a property. This is necessary for surveyors to provide sound advice on designing interventions to improve resilience and making recommendations on the best combination of measures for a specific home.

iii. Insurers: The study provides an evidence-based tool to inform insurers about the levels of resilience present in a given property and how this would reduce damage costs. These expenses are frequently shared by premiums and excesses (Edmonds, 2017). In this case, increased resilience could result in lower premiums and excesses. With a better understanding of flood risk, insurers can offer premiums that encourage property level flood risk adaptation through resilient reinstatement.

LIMITATIONS

As a self-administered postal questionnaire, the responses may be subject to self-selection bias. Return rate for the questionnaire was 11% which, whilst good for this kind of study, with respect to similar studies in the same field and also considering the problem posed by the COVID pandemic when it was administered, it cannot be regarded as complete.

It has not been possible in this research to test whether these results will hold true for another location though, the PFR model developed for this research can allow for similar analysis to be carried out in another country.

Furthermore, the study only concentrated on three flood sources, which appear to be the most common and primary flood sources in the UK. However, there are other types of flood sources that are secondary in nature, such as a failed flood defence system or a poor drainage system. Future research could look into the effects of these types of flood sources on PFR.

CONCLUSION AND RECOMMENDATIONS

The main contribution of this research is in developing a predictive model that enables the flood resilience of a property to be quantified. It is recognised than the primary factors identified by the model are not new and are known to affect resilience. Hence, this study introduced the first ever quantification of the PFR measures at the individual property level. Employing a quantitative approach, this study has confirmed the contribution of various factors (such as the building characteristics; flood properties and flood insurance) that are responsible for understanding the PFR. The contribution of each factor influencing the PFR has been established using a questionnaire survey that elicited the homeowners' perspectives of the effectiveness of the PFR measures. Distinctive insight has been gained and this revealed that the most influencing factor of the building resilience is the flood risk level (the 'very low flood risk' category) [FRL] while the least is the flood experience (the 'no experience' category) [FE]. This is considered to be a meaningful contribution to the study of flood risk management and specifically to PFR and provides useful insights for property owners, local authorities, housing associations and property professionals.

However, this research cannot claim to have addressed in full all issues related to PFR measures. Therefore, further research is recommended in the following areas:

- The research should be expanded to include the perspectives of other PFR stakeholders, such as surveyors, engineers, insurers, and others, whose perspectives on the effectiveness of PFR measures would improve the PFR model.
- Findings from this study require a replica study applied to non-residential properties and public buildings such as commercial properties, retail buildings and schools which are also affected by floods, for comparison and validation of the universality of these findings. In conducting research on these non-residential properties and public buildings, it is necessary to devise a method to address the challenges of data accessibility, which is a unique issue with these types of properties.
- There exists the prospect of a user interface through the development of a mobile application for the implementation of model by potential users. A semi-automated template which is interactive, user friendly, and with more simulation options could be useful and enhance its acceptance. This application will help design a platform that makes the model accessible to stakeholders through mobile devices such as smartphones and tablets devices. With regard to adoption and usage in the future, further research intends to examine whether the findings obtained from this study are specific to the UK households or whether the model has the potential to be extended to flood resilience measurement at larger scale applications (at the community level, regional level and even national level).

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